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6-8 May 2021

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M. Schmid
Austria

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SP-0003 EMBRACE experience

Richard Pötter[1], Ina Jürgenliemk-Schulz[2]
Kari Tanderup, Christian Kirisits, Max Schmid, Alina Sturdza, Lars Fokdal, Kathrin Kirchheiner, Remi Nout, Stefan Ecker, Astrid de Leeuw,Umesh Mahantshetty, Li Tee Tan, Jacob Lindegaard - On Behalf Of The Embrace Study And Research Group
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Abstract Text

Objective:
To provide an overview on the multi-centre IntErnational studies on MRI-guided BRAchytherapy in locally advanced CErvical Cancer (EMBRACE): the retrospective RetroEMBRACE (RE), the prospective observational EMBRACE I (EI) and the interventional/observational EMBRACE II (EII).

Materials/Methods:
RE, EI and EII provide comprehensive data from 731, 1416 and 284 pts (620 12/2019), respectively, with locally advanced cervical cancer (LACC) stage IB-IVA and IVB (in paraaortic nodes (PAN)). Pts were treated before start of EMBRACE in 12 centres (RE), from 2008-2015 in 23 centres (EI) and from 2016-12/2018 in 14 centres. Treatment was definitive EBRT (3DCRT or IMRT/IGRT) and concurrent cisplatin followed by MR image guided adaptive brachytherapy (IGABT) with MRI available for at least one fraction. IGABT targets, OAR and dose volume parameters were reported following GEC-ESTRO recommendations (2005). In RE and EI dose prescription followed institutional guidelines. EBRT dose was 45-50Gy (1.5-2.0Gy/fraction). In EII a multiparametric dose prescription protocol is mandatory differentiating between soft and hard constraints for targets (GTV, CTV_{HR}, CTV_{IR}) and for OARs ($D2cm^3$ for bladder, rectum, sigmoid, bowel and rectovaginal point, bladder point (new vagina PIBS concept)). A new tumor and risk adapted LN target concept was introduced for IMRT in EII: CTV-T, CTV-E, ITV, PTV (45 Gy) and CTV-N, SIB (~60Gy); PA IMRT was prescribed for high risk N+ pts. A comprehensive QA programme was applied in EI and EII. Patient, tumor, treatment and outcome characteristics (crude rates, actuarial estimates) are reported. Toxicity was prospectively assessed in EI, EII (CTCAEv3.0).

Results:
Median age was 53, 56, 51 years and $FIGO_{2009}$ stage distribution was for RE, EI, EII: IB in 17,18,15%, IIB 50, 52, 57%, IIIB 20,14,18%, IVA 3,3,3%, IVB 6,7%; 40,52,58% were node-positive (N+); 85,82,81% had squamous Ca, 9, 14, 16% adeno, 6, 4, 3% adenosquamous.
Mean EBRT dose was 46±2.5, 46±2, 45±1 Gy in RE, EI, EII. 3D CRT and IMRT was in 91 and 9% in RE, 59 and 41% in EI and IMRT/IGRT in 100% in EII. Para-aortic RT was in 15, 17, 30% in RE, EI, EII. V43Gy was mean 2390/1418 cm3 in EI/EII for pelvis and 2895/1765 cm3 in EI/EII for pelvis+PAN (Berger). 77, 95, 95% received chemoth. IGABT technique was intracavitary alone (IC) in 77, 57, 27 % and IC/interstitial (IS) in 23, 43, 73% in RE, EI, EII. Mean CTV_{HR} volume was 37±24, 33±19, 30±16 cm^3 in RE, EI, EII: mean CTV_{HR} $D_{90\%}$ was overall 87±15, 89±9, 93±4 Gy_{10}: for stage IB 93±17, 90±8, 93±3 Gy_{10}; for stage IIB 88±14, 91±9, 93±4 Gy_{10}; for stage IIIB 83±13, 87±8, 93±4 Gy_{10}; for stage IVA 78±13, 83±10, 92±6 Gy_{10}. Isodose surface volumes were adapted to volume of CTV_{HR}: V85 Gy_{10} decreased overall by 23% compared to Pt A Standards. In RE, EI, EII, mean D_{2cm^3} for bladder was 81±22, 76±10, 75±9 Gy_3, rectum 64±9, 63±7, 59±6 Gy_3, sigmoid 66±10, 64±7, 62±7 Gy_3, bowel 64±9, 63±10, 59±9 Gy_3, rectovaginal point 66±9, 62±7 Gy_3. Median follow up was 43, 51 mths for 731, 1318 pats, resp. for RE, EI. Overall 30, 25% pts had recurrence (multiple events possible) in RE, EI: crude failure rates were local 9.4, 7.4%; overall pelvic 13.1, 12.5%, nodal pelvic 5.6, 6.7%; PAN 8.6, 8%. 21, 14% had recurrence beyond PAN. At the time of analysis, 35, 27% pts had died, 27, 21% from disease progression. In RE and EI at 5 years, actuarial LC was 89, 92%, PC 84, 87%, DC 70, 74%, OS 65, 74%, CSS 73, 79% (table 1). 5-year OS was 71,81% for N- pts and 57, 67% for N+ pts. In RE and EI crude G3-5 morbidity at 5 years was genito-urinary 5, 6.5%, gastro-intestinal 7, 7.6%, vagina 5, 6.1%.

Table 1: EMBRACE Studies: actuarial estimates at 3/5 years for local, pelvic and disease control, overall survival and disease-free survival according to $FIGO_{2009}$ stage and overall (Pötter et al. ESTRO 2020).

a. EMBRACE I: n=1318 (control), n=1337 (survival)

	IB1	IB2	IIB	IIIB	IVA	IVB	**overall**
Local Control LC	98%/98%	93%/92%	92%/91%	91%/91%	91%/91%	92%/89%	**92%/92%**
Pelvic Control PC	95%/95%	85%/84%	89%/87%	85%/85%	81%/81%	83%/81%	**88%/87%**
Disease Control DC	84%/83%	72%/69%	80%/78%	67%/66%	69%/69%	62%/56%	**76%/74%**
Overall Survival OS	88%/83%	76%/73%	86%/78%	70%/64%	62%/52%	73%/61%	**81%/74%**
Disease Free Survival DFS	81%/76%	70%/65%	77%/72%	60%/59%	58%/46%	59%/48%	**72%/68%**

b. Retro EMBRACE: n=731

(adapted from Sturdza et al. RadiothOncol 2016; 120:428-433)

	IB	IIB	IIIB	IVA	**overall**
Local Control	98%/98%	93%/91%	79%/75%	76%/76%	**91%/89%**
Pelvic Control	96%/96%	89%/87%	73%/67%	76%/76%	**87%/84%**
Overall Survival	88%/83%	78%/70%	56%/42%	43%/32%	**74%/65%**

Conclusion:
Age, local $FIGO_{2009}$ stage and histology are comparable within the EMBRACE studies. More nodal disease is diagnosed in EI and EII. EBRT technique changed from predominant 3DCRT in RE to 100% IMRT/IGRT in EII with markedly reduced volumes (V43 Gy) and increasing frequency of risk adapted PA RT. Concomitant chemotherapy is increased in EI and EII. IC/IS techniques have increased significantly during E1 and even more in EII which enables appropriate target coverage and OAR sparing. CTV_{HR} $D_{90\%}$ is overall increasing, in particular for large volumes. OAR D_{2cm3} are being reduced in EII. Dose homogeneity is much increasing for targets and OARs across patients.
From RE to EI overall local and pelvic control is excellent and even improving, based on systematic use of advanced MRI based IGABT including interstitial needles. Significant improvement is seen in stage IIIB and IVA. Para-aortic recurrence remains similar. Overall survival and Cancer specific survival are clearly improved.
Overall advanced MRI-based IGABT in combination with chemo-RT results in excellent and stable long-term local, pelvic and overall disease control and survival across all stages with limited severe morbidity. This EMBRACE experience should be used as benchmark for routine clinical practice as well as for design of any future clinical trials

SP-0004 Image guided Brachytherapy and Outcomes of Cervical Cancer:: Indian Experience

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Abstract Text

Cervical cancer in India accounts for 15% of all the cervical cancer deaths in the world. Majority of the patients present in locally advanced stages which require concurrent chemoradiation followed by brachytherapy (BT). In the presence of cultural diversities within the country, the implementation of BT in a systematic manner remains a challenge. I would present the journey of adaptation to image guided BT in cervical cancer. The outcomes of patients treated with two dimensional BT over 2 decades in women with cervical cancer were published. The transition from 2D to MRI based BT was

achieved with the involvement and participation by tertiary cancer centres in the multicentric EMBRACE trial. The results of MRI based BT in 2 cohorts from India have been published as separate reports with excellent local control rates. In one of the report, the outcomes were compared with the historical database in which patients were treated with 2D BT. In the limited resource setting, the use of MRI on a daily basis is a difficult task. Hence, the role of CT scan with the aid of ultrasound as a surrogate for MRI has been tested. Further research is ongoing in this regard. We have contributed to the IAEA trial which evaluated the difference in outcomes in 2 fractionation schedules of BT. Collaborative efforts with the Medical University of Vienna with data pooling of patients treated with advanced BT technique such as Vienna II applicator has resulted in the reporting of outcomes in this group with 5 year local rates of 72%. Guidelines for cervical cancer BT with an emphasis to the complex Indian settings have been published. These guidelines are more adaptable to our settings in comparison to the ICRU 89 Report. The results of image based BT for post surgical vault recurrences are encouraging with local control rates OF 84% at 5 years. The recruitment of patients for EMBRACE II trial is ongoing. The feasibility and safety of single application multifractionated BT has been tested in a phase II setting which awaits data maturity for outcome analysis. In addition, continuous audits and quality checks have been implemented regularly and reported.

SP-0005 Cervical Cancer Brachytherapy at Washington University: 1920-2020

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Abstract Text

The use of intracavitary Radium to treat cervical cancer began at Washington University in 1920. Then, as today, the treating physicians understood that there were two targets: *the primary cervix tumor and the lymph nodes.* Imaging of the implants was nonexistent. It was observed clinically that Radium could cure the primary cervix tumor but not the lymph node metastases. 2-D imaging of brachytherapy implants and the use of kilovoltage external irradiation to the lymph nodes was performed beginning in the 1930s. The hallmark of cervical cancer treatment at Washington University was to apply as much dose as possible to the cervix (within tolerance) with brachytherapy and to limit the use of 200-500 kVp external irradiation using small fields to the lymph nodes only. The results of this treatment were mixed. The primary cervix tumor was cured in a very high percentage of cases but control of lymph node metastases by kilovoltage and orthovoltage irradiation was dismal. In 1954 Washington University installed a 24 MeV Allis-Chalmers Betatron. The use of 24 MeV x-rays allowed the pelvic lymph nodes to be successfully treated and cured without the skin toxicity of lower energy x-rays. Two critical clinical decisions were made at that time. First, given that the primary cervix tumor control rates were high with the use of Radium, then, the cervix would continue to be treated with very high doses of Radium while the lymph nodes were targeted with 24 MeV x-rays and the primary central tumor would be blocked out of the 24 MeV external irradiation fields with a midline rectangular block. Secondly, brachytherapy and external irradiation would be given concurrently. This treatment paradigm of initiating treatment with brachytherapy, limiting external irradiation to the primary cervix tumor, and concurrent external irradiation and brachytherapy was continued. The only alteration was the replacement of the midline rectangular block with a midline stepwedge block whose steps conformed to the falloff of the intracavitary radioisotope application. Intracavitary applicator imaging was routinely performed with orthogonal 2-D radiographs. There was no imaging of the primary tumor.

Computerized 2-D brachytherapy dose distributions were developed at Washington University in 1964 and were then routinely used. Efforts at computerized tomography (CT) for 3-D brachytherapy imaging and dosimetry were begun in the mid- to late-1990's, however, the major limitation to routine adoption was the metallic artifact from the tungsten-shielded Fletcher-Suit intracavitary applicators. Our efforts toward 3-D image guided brachytherapy then focused on the use of FDG-PET imaging. Using the Fletcher-Suit applicators, we successfully imaged the applicator in the patient's tumor by using PET. The FDG isotope was placed in small tubes inside the applicator as a "dummy". The patient was then injected with FDG and subsequently imaged. This allowed us to visualize brachytherapy source positions within the metabolic tumor volume and calculate 3-D dose distributions. PET brachytherapy was continued with the goals of understanding 3-D dose distributions to OARs, tumor coverage, and metabolic response of the tumor to treatment. PET brachytherapy is a novel research tool but is not feasible for routine clinical use. During the period of the early 2000's, several other technological advances occurred. CT and MR compatible intracavitary applicators and 3-D brachytherapy treatment planning systems became available. LDR brachytherapy was replaced by HDR brachytherapy. IMRT and volumetric arc therapy are now routinely used for external irradiation. The challenges during this transition were then to re-think and understand OAR toxicity limits and appropriate tumor dose prescriptive criteria. Much data collected over the past 20 years have increased our understanding of these issues.

Today at Washington University, we administer external irradiation with IMRT and continue to limit the external irradiation dose to the primary cervix tumor while delivering high doses of brachytherapy given once weekly during external irradiation. We use MR-guided brachytherapy for six weekly fractions during the 6-week course of external irradiation. OARs and GTVs (as defined by DWI imaging) are contoured and doses calculated and summed with the external irradiation on each of the 6 brachytherapy fractions. A real-time DoseTracker® updates with each radiation fraction and predicts total cumulative doses as treatment progresses. D2cc OAR doses are used to limit toxicity and Dmean doses are used as the GTV prescriptive dose. Examples of treated cases and toxicity and tumor control rates will be presented.

SP-0006 Transition from 2D to MRI-based adaptive brachytherapy, Chulalongkorn University experience.

N. Amornwichet[1], C. Khorprasert[1], P. Alisanant[2], K. Shotelersuk[1]
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Abstract Text

3D-brachytherapy was adopted in Chulalongkorn University, Bangkok, Thailand from 2009. The number of patients who were treated with MRI-based brachytherapy were increasing since 1.5T MRI simulator installation in 2011.

The clinical outcome of 221 patients with stage IB2-IVA cervical cancer treated with curative radiation between July 2012 – December 2016 had been reviewed. The treatment protocol was the external beam radiation (EBRT) 45-50.4 Gy with or without concurrent platinum based chemotherapy, followed by high dose rate brachytherapy 8 Gy x 3 fractions or 7 Gy x 4 fractions.
As results, the median follow-up time was 39 months (range 7-61 months). FIGO 2019 stage was IB2: 2.8%, IB3: 0.5%, IIA1: 4.1%, IIA2: 1.4%, IIB: 41.4%, IIIA: 1.4%, IIIB: 6.3%, IIIC1: 26.0%: IIIC2: 9.0% and IVA: 6.8%. The mean maximal tumor width by clinical examination was 4.6 ± 1.5 cm which is slightly different from MRI, 4.9 ± 1.5 cm. 81% had squamous cell carcinoma. Interstitial technique combined with intracavitary brachytherapy was used in 173 patients (78.3%). Mean CTV_{HR} D90 ($EQD2_{10}$) was 89.4 ± 6.9 Gy and mean D2cc ($EQD2_3$) were 69.6 ± 8.1 Gy for rectum, 66.2 ± 7.2 Gy for sigmoid and 81.6 ± 9.3 Gy for bladder. The majority of patients received concurrent chemotherapy (90%). The mean overall treatment time was 48 ± 10 days Local control was 92.1 % at 5 years. The 5-year PFS and OS were 69% and 71.4%, respectively. More than grade 3 toxicity for rectum was 2.8%. And grade 3 toxicity for bladder was 4.5%.
Our outcomes were comparable to EMBRACE data and confirm that MRI-based adaptive 3D brachytherapy results excellent long-term local control with acceptable toxicities.

Symposium: Brachytherapy physics 2030 – Dosimetry for nuclides and radiation

SP-0007 Nuclides and dose delivery devices – An overview and Comparison

J. Perez Calatayud
Spain

Abstract Text

In this presentation, an overview of the available brachytherapy (BT) photon sealed sources and applicators is provided from a clinical practice perspective. In low energy (<50 keV) and low dose rate (LDR) modality the most used sources are based on I-125, Pd-103 and Cs-131. The main application is permanent implants in the prostate and the thoracic and abdominal cavities, and in temporary ophthalmic implants using plaques to a lesser extent. The pros and cons of each radionuclide are commented upon from physical, radiobiological and practical viewpoints. The most used radionuclide in BT is Ir-192, in high dose rate (HDR) or pulsed dose rate (PDR) mode. The main BT applications are post-surgery endometrium, prostate and cervix. The major developments in applicators are for the cervix case, with interstitial component compatible with magnetic resonance. In recent years there has been popular deployment of Co-60 due to its longer half-life advantage. Comparisons of HDR Ir-192 vs Co-60 are discussed considering different aspects as radiation protection, dose distribution, source change frequency, peripheral dose and treatment time. HDR electronic BT sources (x-rays 50-70 kV) are also utilized in BT within endocavitary with vaginal cylinders and in the breast with balloon applicators. Their advantages due to shielding for the patient and the treatment environment, ability to switch on and off, and lack of radioactivity waste and regulatory controls are discussed. Further, there has been a significant boost in the last decade with the use of BT to treat the skin and superficial targets. Electronic BT sources are well suited for these shallow lesions. Electronic BT has been strongly incorporated into this modality. Specific applicators using HDR Ir-192 sources include the Leipzig and Valencia for treatment of smaller lesions, i.e., diameters < 3 cm. The recent AAPM-ESTRO TG-253 Report produced specific recommendations for dosimetry and quality assurance for the treatment of superficial lesions. A brief summary is presented. As the assignment of radiation sources into the BT category (instead of being categorized as teletherapy sources) may be considered controversial, the ramifications of this decision are examined for some sources. Finally, innovative and unconventional BT sources, applicators, and delivery systems are examined as quickly advancing areas in the field of clinical BT. Current research and societal guidance reports including recommendations for clinical users are summarized, including the published and ongoing efforts of the joint AAPM+ESTRO TG-167, TG-292, and TG-337 Reports. These reports cover innovative BT devices and applications, robotic BT delivery systems, and intensity modulated BT sources and applicators using shielded BT sources or dynamic applicators, respectively.

SP-0008 Traceability of LDR and HDR source calibration.

T.Schneider
Germany

Abstract not available

SP-0009 Calibration at the clinical level for HDR and LDR brachytherapy sources

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Abstract Text

Source strength for high-dose-rate (HDR) and low-dose-rate (LDR) brachytherapy sources should be measured by the clinical medical physicist. In general, the manufacturer provides a calibration certificate documenting the reference air-kerma rate (RAKR) or air-kerma strength (S_K). This certificate will be at a specific time point and for individual sources or for the mean of a batch of sources. The physicist is responsibility for brachytherapy dose calculations, which require input of source strengths, so physicist-measured values are often used in the clinical process. Requirements for physicist-measured values vary based on local regulatory standards, but these measurements generally have lower uncertainties than manufacturer-reported values. This is because the manufacturer transfers the calibration of a traceably-calibrated instrument to the production instrument used for calibrating customer sources while the chamber used by the medical physicist is calibrated directly by the calibration laboratory.

The equipment needed to measure brachytherapy source strength has become more uniform over time, and includes a well-type air ionization chamber with an insert to reproducibly position the source at the center of the collecting volume, a radiation source to demonstrate system constancy, an electrometer and triaxial cabling, and a barometer/thermometer/hygrometer (often all part of a single instrument). The electrometer and triaxial cabling are typically shared with the dosimetry program for external-beam radiotherapy calibrations. The radiation source to demonstrate system constancy may be a long-lived radionuclide (e.g., ^{137}Cs, ^{90}Sr, or ^{241}Am) having similar radiation quality and source strength as the brachytherapy source to be measured. Other constancy sources could include another brachytherapy (such as demonstrating system constancy for a new HDR source by measuring an old HDR source preceding source exchange), or even a linac with the well chamber positioned on the floor. The well chamber and electrometer are sent for calibration every two years, or shown to have constancy if intercompared with other instruments that have been calibrated within two years. When mailing equipment for calibrations, the physicist should measure before and afterwards that the instruments have not changed over the course of shipment to demonstrate constancy of the calibration. All calibrations should be directly traceable to a primary standards laboratory and documented as such.
There are several guidance documents and national laws on how to interpret physicist-measured values of brachytherapy source strength in comparison to manufacturer-reported values. For a single HDR source such as ^{192}Ir or ^{60}Co, the measurement is compared and the physicist may use their value if the two agree within 3%. For LDR seeds (^{125}I, ^{103}Pd, ^{131}Cs), often there is more than a single source and guidance documents generally recommended that a subset be measured. When using stranded and sterile seeds to implant, additional loose and non-sterile seeds (5% or 5 seeds, whichever is fewer) from the same manufactured lot are ordered for the purpose of demonstrating agreement within 3%. When comparison of the manufacturer and physicist-measured values are not within the expected tolerance, the physicist must investigate the source of discrepancy and alert the manufacturer (Butler *et al*. MedPhys 2008). Sources with long half-lives (LDR ^{137}Cs tubes and HDR ^{90}Sr/^{90}Y ophthalmic applicators) are assayed at least annually to show predictable decay.
The formalism for deriving brachytherapy source strength is the product of the corrected reading, multiplied by the well chamber calibration coefficient for the particular source model, and decayed based on the source half-life to the reference day and time. The reading is averaged over at least three separate measurements, and corrections are made for ion recombination, atmospheric pressure and temperature, and shown to be within the acceptable range of relative humidity. Measurements are performed in a low-scatter environment to minimize increased signal due to radiation scatter from the room walls, floor, and ceiling (thus matching the chamber calibration conditions). Special calibration formalisms are available for combinations of brachytherapy sources and treatment applicators, electronic brachytherapy sources, LDR ophthalmic plaques containing ^{106}Ru/^{106}Rh, and ^{90}Y microspheres used for selective internal radiotherapy of hepatocellular carcinoma or liver metastases. Future brachytherapy calibration standards may employ the absorbed dose-rate to water at 1 cm as it may provide lower propagated uncertainties than the combination of RAKR (or S_K) and the dose-rate constant. However, such calibrations are not widely available for all sources, the gains realized by lower propagated uncertainties are minimal, and clinical brachytherapy treatment planning systems do not yet permit entry of this quantity.

SP-0010 Dosimetry beyond TG43 - Radiobiological models combined with model based and deep convolutional neural network algorithms

S. Enger
Canada

Abstract not available

Proffered papers: Breast and cervix

OC-0011 Automated multi-criteria treatment planning for adaptive HDR-BT for locally advanced cervical cancer

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Purpose or Objective
To develop and evaluate a fast, fully automated multi-criteria treatment planning strategy for adaptive HDR-BT for locally advanced cervical cancer. This automated strategy avoids suboptimal and slow manual treatment planning.

Materials and Methods
Our in-house developed TPS for automated multi-criteria treatment planning was extended with an option for combined intracavitary + interstitial (IC+IS) cervical cancer BT, and connected to the clinical treatment planning system for plan evaluation. The algorithm was configured using 22 single-fraction (SF) IC+IS training plans. Special attention was paid to establishing the clinically desired 'pear-shaped' dose distribution. Autoplanning was evaluated on 63 other SF IC+IS cases by blind clinician comparisons with corresponding clinical plans (SFclin). Subsequently, we developed an adaptive scheme for automatic planning of all IC+IS BT fractions of a patient, considering dose delivered in previous EBRT and BT fractions. The effect of adaptive autoplanning on total treatment (TT) plans (external beam + 3 BT fractions) was evaluated for 16 patients by simulating the clinically applied adaptive strategy to generate TTauto plans and compare them with the corresponding clinical treatments (TTclin).

Results
All automated SF (SFauto) IC+IS plans were clinically acceptable. The clinician"s plan comparisons pointed strongly at an overall preference for the automated plans: in 60/63 cases SFauto was preferred over SFclin, in 2/63 cases the overall quality of the plans was considered equal, and for 1/63 cases SFclin was preferred over SFauto. When comparing total adaptive treatments, the mean D90 CTVHR for the TTauto plans improved by + 3.6 Gy, (range +1.4 Gy - +6.0 Gy, $p<0.005$). The dose in the bladder and rectum was significantly reduced in the TTauto plans compared to TTclin with a mean

improvement in D2cc of -0.9 Gy (range -6.6 Gy - +1.8 Gy, p=0.05) and -1.4 Gy (range -6.3 Gy – +4.9 Gy, p=0.04), respectively. There were no significant differences in D2cc of the sigmoid and small bowel (p=0.3). The average optimization time for autoplanning was 19.7 seconds (range 4.4 - 106.0 s).

Conclusion
Fast automated multi-criteria treatment planning for adaptive IC+IS HDR-BT for patients with locally advanced cervical cancer is feasible. High-quality treatment plans could be automatically generated within a clinically acceptable time frame (~20 sec). The observed improvement in dosimetric parameters, mainly the improvement of the dose to the CTVHR, is clinically relevant. The algorithm will be extended with an approach for optimization of the needle configuration, which could allow real-time interactive intra-operative treatment planning.

OC-0012 Reading Between the Voxels: Radiomic Predictors of Progression-Free Survival in Cervical Cancer

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Purpose or Objective
We recently reported on a single axial T2 SPACE MR-based radiomic predictor for progression-free survival (PFS) in cervical cancer patients. This study aims to identify additional predictors for PFS in patients treated with definitive chemoradiation undergoing serial MR-based planning for every brachytherapy fraction.

Materials and Methods
In this retrospective review, 47 patients underwent definitive chemoradiation for stages IB-IV cervical cancer between 2012 and 2018, consisting of intracavitary brachytherapy following external beam radiation. Clinical factors with potential predictive power were analyzed. Sequential MRI scans were acquired on the same 3T scanner with acquisition of T2 SPACE sequences for every fraction (4-5) for each patient during their brachytherapy course. Radiomics feature extraction was performed with an in-house developed software to calculate histogram and Grey Level Co-occurrence Matrix texture features. The HR-CTV was contoured/segmented, the applicator was removed from the HR-CTV contour, and features relating to shape, image intensity, and texture were extracted from the T2 MR sequences from the first and last brachytherapy fractions. The difference between these fractions was calculated for each feature ("delta fraction"). Univariate Cox proportional hazards analysis (UVA) was performed on radiomics features and PFS. The receiver operating characteristic (ROC) analysis was performed to evaluate the performance of prediction model and radiomics nomogram. Kaplan-Meier (KM) survival curves were generated for each selected feature for correlation with PFS at 2 years (PFS2Y).

Results
Median patient age is 52 years (26-85). Progression occurred in 17% of patients (8/47), including 4% (2/47) with locoregional relapse, and 13% (6/47) with distant metastasis. PFS2Y was 77%. On UVA, 11 distinct features extracted from the first, last, or delta fraction T2 MR sequences demonstrated a statistically significant correlation with PFS ($p<0.05$, Table 1). Using the reported cutoff values per ROC analysis in Table 1, the calculated KM curves for each feature showed a statistically significant difference in PFS2Y. Improved PFS was associated with increased first fraction cluster prominence as well as decreased first or last fraction inverse variance, mean, sum average, and sum variance. Improved PFS correlated with increased delta mean, auto correlation, sum average, and sum variance as well as decreased delta skewness and inverse variance.

Table 1: Radiomic Features and Association with 2-Year PFS

Radiomic Feature	MRI for First, Last, or "Delta" Fractions	ROC Cutoff	PFS2Y for >Cutoff vs ≤Cutoff	P value
Cluster Prominence	First	21845	100 vs. 56%	0.007
Inverse Variance	First	0.3	51 vs. 91%	0.01
Mean	Last	12.9	32 vs. 89%	0.02
Sum Average	Last	24.7	32 vs. 89%	0.02
Sum Variance	Last	485.6	34 vs. 89%	0.03
Mean	Delta	-0.02	91 vs. 50%	0.02
Skewness	Delta	-0.05	65 vs. 81%	0.04
Auto Correlation	Delta	-89.8	88 vs. 40%	0.0004
Inverse Variance	Delta	0.06	40 vs. 88%	0.0002
Sum Average	Delta	-0.05	95 vs. 47%	0.003
Sum Variance	Delta	-289.4	88 vs. 40%	0.0004

Conclusion
T2 SPACE MR-based radiomic changes in homogeneity and texture may correlate with improved PFS in this series. These signatures may serve as a prognostic tool in predicting outcomes for patients with cervical cancer. Further research is needed for large scale validation, which may justify more aggressive and personalized treatment in patients identified with a high probability of recurrence.

OC-0013 Declining brachytherapy utilization for cervical cancer patients - have we reversed the trend?

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Purpose or Objective
Studies examining temporal trends in cervical brachytherapy use are conflicting and examined different health insurance populations. This study examined brachytherapy utilization over time by health insurance type and whether reported declines in brachytherapy have been reversed.

Materials and Methods
The National Cancer Database (NCDB) was queried for patients with FIGO IIB-IVA cervical cancer treated with definitive chemoradiotherapy between 2004-2014, identifying 17,442 patients. Brachytherapy utilization over time and by insurance type and other sociodemographic factors were compared using binary logistic regression. A secondary sensitivity analysis was done in a sub-cohort of patients using the boost modality variable in the NCDB.

Results
Brachytherapy utilization declined during 2008-10 (52.6%) compared to 2004-2007 (54.4%; Odds Ratio [OR] 0.93, 95% confidence interval [CI] 0.86-1.01) and declines were disproportionately larger for patients with government insurance (49.4% vs 52.3%, respectively) than privately-insured patients (57.6% vs 58.9%, respectively). However, rates of brachytherapy use subsequently recovered during 2011-14 (58.0%, OR 1.16, 95% CI 1.08-1.24, $p<0.001$) and was seen in all insurance groups including Medicare (OR 1.07, 95% CI 0.92-1.26), Medicaid (OR 1.25, 95% CI 1.09-1.44), and uninsured patients (OR 1.36, 95% CI 1.12-1.65). In patients with Medicare, rates of brachytherapy utilization in 2004-2007, 2008-2010, 2011-2014 were 50.0%, 47.6%, and 51.8%, respectively. A secondary analysis using the boost modality variable confirmed these trends.

Conclusion
In patients with FIGO IIB-IVA cervical cancer treated with definitive chemoradiotherapy from 2004-2014, brachytherapy utilization declined during the late 2000s and disproportionately affected patients with government insurance, but subsequently recovered in the early 2010s. Since government insurance covers vulnerable patients at-risk for future declines in brachytherapy use, proposed alternative payment models should incentivize cervical brachytherapy to solidify gains in brachytherapy utilization.

OC-0014 APBI versus very APBI in the elderly: a comparison analysis of oncological outcome and late toxicity

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Purpose or Objective
Accelerated partial breast irradiation (APBI) represents a validated technique for low-risk breast cancer. Recently, very APBI (vAPBI) based on a shorter regimen using less than 5 brachytherapy fractions was described in the literature. We analyzed clinical outcome and late toxicity after APBI or vAPBI in the elderly.

Materials and Methods
We compared data from two cohorts of elderly women with low-risk breast cancer treated with APBI based on multicatheter interstitial high-dose rate brachytherapy (MIB). From 2004 to 2012, APBI delivered a total dose of 34 Gy in 10 fractions. From 2013 to 2018, vAPBI delivered a single fraction of 16 Gy. All the patients were censored at 60 months. Five-year oncological outcome comparison was based on local (5y-LRFS), regional (5y-RRFS) and metastatic relapses (5y-MRFS), as well as specific (5y-SS) and overall survival (5y-OS). Late toxicity comparison was investigated. Statistical comparisons were performed using the x2 or Fisher's exact test for qualitative data, student test or non-parametric Wilcoxon test for quantitative data and log-rank test for censored data. All p values inferior to 0.05 (two-sided) were considered statistically significant.

Results
From 2004 to 2018, 157 pts were retrospectively analyzed (APBI:109pts vs. vAPBI:48pts). All the patients were enrolled in the APBI program according to the same selection criteria: elderly pts (>70) with low-risk breast cancer. Apart from MFU, no significant differences were noticed between APBI and vAPBI treatment groups: median age was 76 vs. 78y, median tumor size was 10 vs. 10mm, axillary status N0/N1mic was 92 vs. 96. With a MFU of 97 vs. 73 months (p=0.002) for APBI and vAPBI groups respectively, 1 local relapse was observed after APBI while no local relapses were detected after vAPBI. Regarding oncological outcome at 5 years, no significant differences were observed between APBI versus vAPBI groups for LRFS (99 vs. 100%), RRFS (98 vs. 98%), MFS (98 vs. 98%), SS (97 vs. 98%) and OS (91 vs. 90%). The rate of late toxicity (total number of complication) was 55 vs. 67% (p=0.173) for APBI versus vAPBI groups respectively with no G3.

Conclusion
According to our knowledge, this is the first study comparing APBI vs. vAPBI in a well-defined elderly cohort showing equivalent results in terms of oncological outcome and toxicity profile. vAPBI based on a single fraction of MIB represents an attractive option to reach an excellent local control in the elderly with low-risk breast cancer avoiding the burden of conventional/hypofractionnated external beam radiation therapy and the higher risk of local recurrence induced by the avoidance of adjuvant breast irradiation.

OC-0015 Dosimetric evaluation of OAR in APBI patients treated with multicatheter interstitial brachytherapy

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Purpose or Objective
Dosimetric evaluation of organs at risk (OARs) according to the recent GEC-ESTRO recommendations (1) in sixty-one APBI patients treated with multicatheter interstitial brachytherapy (MIBT) using a HDR Ir-192 source.

Materials and Methods
Between February 2017 and December 2019, 61 APBI patients (32 patients (52%) with left-sided and 29 (48%) with right-sided breast tumors) were treated with MIBT technique, with a prescription dose of 32Gy (4Gy/fraction in 5 days with a minimum interval between fractions of six hours). After lumpectomy, a post-operative multicatheter implant was performed. After catheter insertion, the patients underwent a CT scan (2mm slices), and treatment plans were obtained with TPS Oncentra MasterPlan v4.1. The target volumes and the OARs, including skin, lung ipsilateral, ipsilateral non-target breast and heart (in the cases of left-sided tumors) were delineated and the dose-volume histograms (DVH) were evaluated.

Results
Regarding the tumor location in breast, we did not find a relation between the quadrant and the dose received by OAR. Table 1 shows the analyzed dose-volume parameters and the recommended limits.

The mean values in all the parameters were below the limits of GEC-ESTRO recommendations, and doses to skin and ipsilateral non-target breast were low for all patients. However, some patient's heart, ribs and ipsilateral lung dose exceeded the constraints.

The minimum and maximum heart-to-PTV distance was 2mm and 46mm, respectively, and cardiac dose increased with decreased heart-to-PTV distance.

Regarding the ribs the average D0.1cm3 and D1cm3 values were 53.89% and 46.84%, respectively, but 5 patients exceeded dose-volume parameters because of PTV-ribs proximity.
Of the 61 patients, 9 exceeded the dose-volume parameter D0.1cm3 <60% to lung. Evaluating those cases, we detected that all of them had the 50% isodose curve reaching the lung, opposing the rest of the patients.

OAR	CONSTRAINTS	LEFT BREAST	RIGHT BREAST
IPSILATERAL LUNG	MLD <8%	2.14 (0.25-3.25)	2.31(0.56-3.06)
	D 0.1CM3<60%	41.61(21.84-76.99)	43.90(21.88-67.09)
	σ	0.26	0.27
RIBS	D 0.1CM3<90%	55.17 (33.73-105.88)	53.52 (23.72-114.53)
	D 1CM3<80%	47.39(29.38-87.82)	46.69 (25.58-74.40)
	σ	0.37	0.37
IPSILATERAL NON-TARGET BREAST	V90<10%	2.38(0.52-6.33)	2.61(0.59-4.53)
	V50<40%	12.49(5.44-25.04)	11.26 (3.63-19.35)
	σ	1.09	1.18
SKIN	D 1CM3<90%	57.15(26.54-88.54)	56.66 (26.12-74.92)
	D 0.2CM3<100%	62.73 (28.99-98.46)	62.04(28.63-80.85)
	σ	0.49	0.46
HEART	MLD <8%	1.53 (0.16-2.84)	
	D 0.1CM3<50%	30.09 (13.89-69.91)	
	σ	0.17	

Conclusion
The average of all dose-volume parameters was in conformity with guidelines, however there were patients (16.3%) that exceeded some recommendations because of PTV's location relative to OAR, mainly lung, ribs and heart. It is important to take it in consideration the follow-up of patients regarding toxicity.
APBI using multicatheter brachytherapy can reduce radiation exposure of organs-at-risk, nevertheless a anatomic tumor position study, such as distance from heart to lumpectomy bed, can help in individualized technique selection that ensure the lowest dose possible at OAR.

OC-0016 High dose rate brachytherapy versus electron boost for tumor bed after breast conserving therapy

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Purpose or Objective
To perform dosimetric comparison of interstitial high dose rate brachytherapy (HDRB) and electron boost to the tumor bed after breast conserving therapy.

Materials and Methods
In 62 patients with stage IA-IIIA breast cancer (pT1N0M0-pT2N2M0) HDRB was used to deliver a boost to the tumor bed. In all the cases preimplantation CT with markers on the scar and nipple was used for planning of the procedure. Tumor bed was determined by markers that were implanted during surgery with consideration of the tumor localization determined on pre-surgery staging CT. Insertion of the needles was performed under CT navigation. Postimplant CT was used for final planning with inverse and graphical optimization. Pre-implantation CT images were used for additional virtual planning of electron boost to the tumor bed. All brachytherapy and electron plans were compared according to the following dosimetric parameters: V90 (%) – percentage of PTV receiving 90% of prescribed dose;); Dmean – mean dose at organ at risk; Dmax – maximum dose in the organ at risk (heart, left main coronary artery and its descending branch, ipsilateral lung, breast, skin and subcutaneous tissue, liver).

Results
The use of HDRB it possible to more accurately irradiate the bed of a remote tumor than additional electron beam irradiation: the mean value of D90 using HDRB was 93.1% (69.1%-118%), while D90 was lower than 80% in only 8 patients; when using electrons, D90 was below 90% in 43.5% of cases, and in 10 patients below 70% with an average D90 value of 86.2% (47.6%-104%). The HDRB allows reducing the radiation load on the organs at risk: the myocardium and coronary vessels, especially during left-side localization of the process. Dmed for these structures is reduced from 3% when using electrons to 2.2% when using HDRB for myocardium, from 7.3% to 3.4% for the main trunk of the left coronary artery, from 12.1% to 6.9% for anterior descending branch of the left coronary artery; on the ipsilateral lung Dmax when using the electron beam was 69.8% (4.7%-104.5%), and when using VDB decreased to 26.8% (4.7%-76.7%), Dmed decreased from 6.5% (0.5%-19.3%) to 2.3% (0.8%-10.8%).

Conclusion
The use of brachytherapy, compared with the use of an electron beam, improves the accuracy of irradiation of the tumour bed and significantly reduce radiation dose to the organs at risk: main trunk of the left coronary artery, descending branch of the left coronary artery, ipsilateral lung, skin and subcutaneous tissue.

Proffered papers: Buccal mucosa and Skin

OC-0017 Long term outcomes of Carcinoma Buccal Mucosa treated with High Dose Rate Interstitial Brachytherapy

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Purpose or Objective
To analyze the long term local control, overall survival and toxicity in Carcinoma Buccal Mucosa patients treated with interstitial brachytherapy

Materials and Methods
This analysis included patients diagnosed as Carcinoma Buccal Mucosa on biopsy and treated with radical brachytherapy or External Beam Radiotherapy (EBRT) followed by brachytherapy boost. All patients received HDR Interstitial brachytherapy. The total dose was 35Gy in ten fractions for brachytherapy alone. Patients who received EBRT (50-54Gy) were boosted by brachytherapy to a dose of 18-24Gy in 6-8 fractions. All patients were treated using CT based planning

Results
Between 2007 to 2017, 24 patients of Carcinoma Buccal Mucosa received HDR interstitial brachytherapy either alone or as a boost. Majority of the patients were tobacco chewers (80%). 17(71%) patients were clinical stage T2N0M0 and 7(29%) were clinically T1N0M0. The five year overall survival rate was 80%. At a median follow up of 7 years (3-12 years), the local control rate was 100% in stage I and 88% in stage II. Two patients developed nodal recurrence and one patient developed distant metastasis within two years of treatment. Tumor size (<3 cm vs. ≥3 cm) and brachytherapy technique (radical vs boost) did not impact local control or overall survival ($p>0.05$). The incidence of Grade 1 or 2 late toxicity was 8%. None of the patients developed Grade 3 or more late toxicities except one patient who developed osteoradionecrosis of the mandible

Conclusion
Interstitial brachytherapy in early stage Buccal Mucosa cancer either alone or as a boost provides excellent local control and overall survival with acceptable toxicity

OC-0018 HDR 192-Ir surface brachytherapy in the treatment of basal cell skin cancer in elderly patients

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Purpose or Objective
Skin cancers are the most common malignancy in humans with increasing incidence. The likelihood of developing basal cell carcinoma increases with age. Patients 50 – 80 years of age are affected most often. Surgery remains the standard of care for BCC. However, brachytherapy provides an effective alternative for selected patients.

Materials and Methods
A retrospective analysis of 99 patients treated with HDR 192-Ir brachytherapy in years 2006 – 2018. All selected patients were ≥75 years old at the beginning of the treatment and diagnosed with basal cell skin cancer. A total of 142 tumours were treated. A single lesion was treated in 69 patients, in 24 patients – 2 lesions, in 4 patients – more than 3 lesions. In 81% of cases BT was a primary treatment, in 14.1% – a salvage treatment due to recurrence after surgery, in 4.9% – adjuvant treatment after non-radical surgery. In 74% of cases the tumour was in area "H", in 19% – area "M", and in 7% – area "L". Individual multi-catheter mould was used in 66.2% of cases and HAM applicator in 33.8%. Patients were treated with afterloader HDR brachytherapy system, with a total dose of 35 – 50 Gy (mean and median – 45 Gy) delivered in 7 – 10 fractions (mean and median – 9), fraction dose was 5 Gy in all cases. Overall treatment time (OTT) ranged from 18 to 45 days (mean and median – 28 days). Patients were followed for radiation toxicity and local failures. Kaplan-Meier estimator and log-rank test were used for statistical analysis.

Results
Median follow-up was 38 months (range 0 – 118 months). Recurrence was observed in 6.3% of cases, with the 5-year disease-free survival rate of 86.5%. DFS was poorer in more advanced lesions (p<0,0001). Local failure was observed in 3 cases. Acute toxicity was assessed in 97.2% of cases, late – in 96.5%. Acute toxicity grade 0 and 1 was observed in 71.1% of cases, in 16.2% grade 4 was reported. Late complications grade 0 and 1 were described in 76% of cases, grade 4 – only in 5.7%. A total dose of 45 Gy was most effective and provided the best DFS (p=0.027). Neither OTT nor treatment sequence had any impact on DFS (p=0.55 and p=0.91 respectively).

Toxicity grade	Acute	Late
G0	3.5%	4.1%
G1	67.6%	71.8%
G2	7.1%	12.7%
G3	0.7%	0.0%
G4	16.2%	5.7%
not assessed	2.8%	3.5%
tumour	2.1%	2.1%

Conclusion
HDR 192-Ir surface brachytherapy in the treatment of basal cell skin cancer in patients ≥75 years of age is an effective and safe treatment modality. With a very high disease-free survival and good tolerance, it is a valuable alternative to surgery.

OC-0019 Superficial HDR brachytherapy for skin lesions involving the finger - The Christie experience

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Purpose or Objective
The standard of care for treatment of skin cancer and refractory precancerous conditions located on the finger is largely surgical management. Surgery usually involves digits/finger amputation or wide local excision with reconstruction. Many patients are elderly and/or frail. Non-invasive methods of treatment are often the preferred option due to favourable cosmetic and/or functional outcomes and improved patient compliance.
External beam radiotherapy in finger location is challenging due to depth-dose characteristics in curved surfaces and close target location to joints and bones. HDR brachytherapy (BT) is a well-established non-invasive alternative treatment option delivering high radiation dose to the target with rapid dose fall-off in normal surrounding tissues. We report The Christie experience with HDT BT in the finger location over the past 6 years.

Materials and Methods
From Jan 2014 to Sept 2020, 13 patients (7 males and 5 females) underwent radical superficial HDR BT to the finger. There were 9 skin SCCs: 5 postoperative and 4 definitive. One patient had BCC and 3 patients had progressive refractory Bowen's disease. The median age at the time of BT was 71 years (range 52 – 95).
The patients were treated with a total dose of 30–34 Gy at 100% isodose in 8 fractions twice a day at least 6 hours apart. Target area was marked out by visual inspection, palpation and high frequency skin ultrasound. All patients were treated with The Christie mould technique: a flap mounted over an individually designed mould composed of a pre-calculated number of layers of thermoplastic material. Patients were followed for at least 2-3 years for treatment toxicity, cosmetic results, and local failures. Acute toxicity was graded using the CTC AE, v. 4.0 and cosmetic outcomes were classified using the RTOG cosmetic rating scale.

Results
Average follow-up from completion of the treatment was 23.5 months (2-36 months). All patients had an acute reaction to the BT: desquamation, crusting and erythema grade 1 or 2. One patient developed acute grade 3 wet desquamation. All acute toxicity was resolved within 2 months after treatment. Late toxicity was reported in 6 patients: slight/moderate atrophy, pigmentation change and grade 1 or 2 teleangiectasia. No cosmetic or functional results worse than good were observed. 11 patients had no evidence of recurrence in follow-up. 2 patients proceeded to salvage surgery due to either no response to BT or local recurrence at 4 months after BT. 2/11 patients passed away due to non-cancer related causes.

Conclusion
HDR mould BT is a valid non-invasive alternative to surgical management of skin cancer and refractory precancerous conditions located on the finger. It has its role particularly in elderly where PS and comorbidities may preclude surgery and short treatment duration can help with patient compliance. With appropriate patient selection skin HDR BT with customized surface moulds offers a good outcome and favourable cosmetic results with function preservation.

OC-0020 Freiburg Flap Surface Applicator Brachytherapy positional accuracy on MR-only PETRA images

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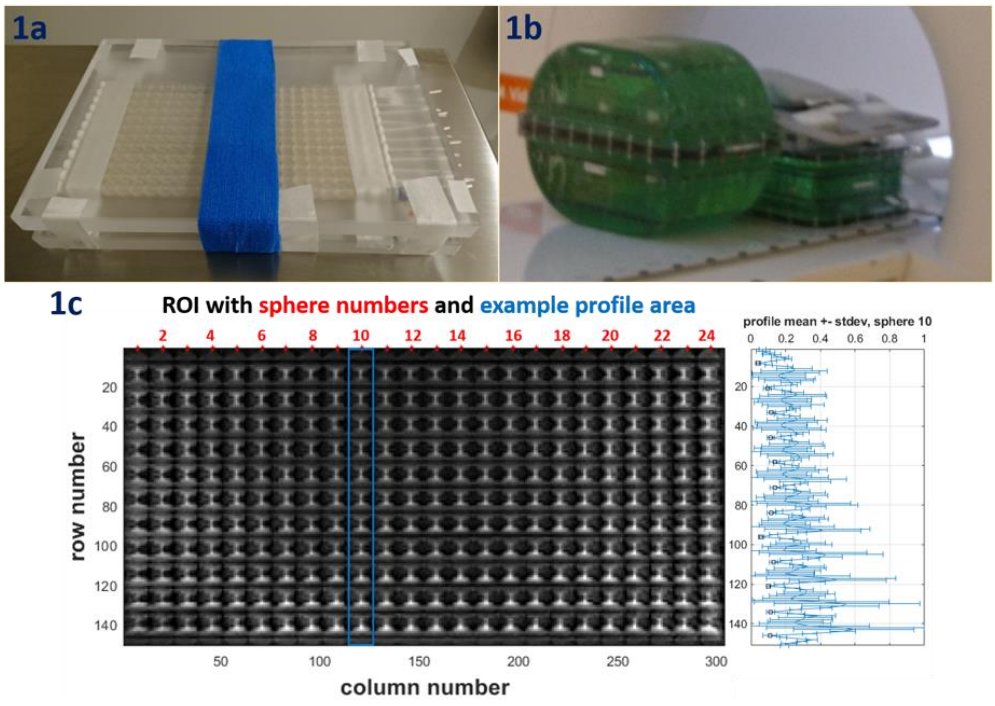
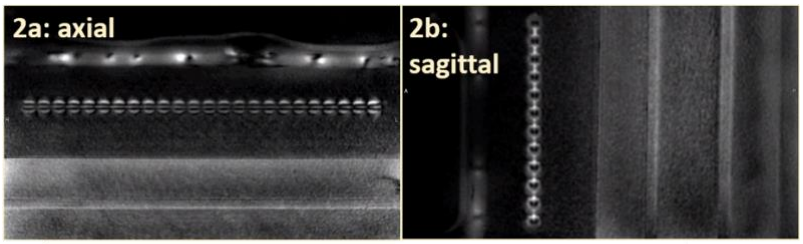
Purpose or Objective
For MR-only treatment planning in skin High Dose Rate (HDR) surface applicator brachytherapy (SABT) it is crucial to detect applicator channels on MRI with high spatial accuracy. An optimized PETRA (Pointwise Encoding Time Reduction with Radial Acquisition) MR sequence has shown the potential to visualize Freiburg Flap (FF) applicators for skin SABT. This study aimed to develop an algorithm to automatically detect FF applicator catheters on PETRA images and estimate their positional accuracy by comparing calculated distances between them to their known distances in a FF.

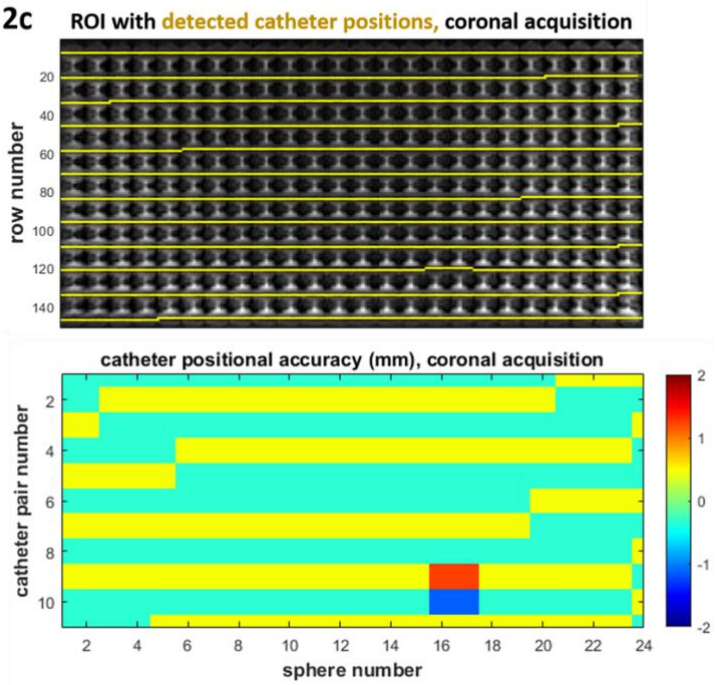
Materials and Methods
An FF applicator (12 catheters, each passing through the center of 24 spheres with 10mm diameter) was fixed between two plexiglass blocks with its sides parallel to the block edges and placed on a flat MagPhan TMR008 phantom in a 3T Siemens Vida scanner (Fig1 a, b). Coronal and axial 3D PETRA images (TR\TE\TI 3.3\0.07\100 ms, FOV 280x280 mm^2, 0.8 mm isotropic voxels, BW 406 Hz/px) were acquired using a top UltraFlex Large 18 and bottom Spine 32 coil.
A custom MATLAB code selected a ROI comprising the FF in the coronal plane. The central column of the top left sphere was manually selected, and the central column position of top row reference spheres (RSs) to its right was estimated using pixel size. Row profiles of 13 columns corresponding to each RS were extracted and normalized and their numerical gradient was computed. Profile mean and standard deviation and gradient mean over columns were calculated for each RS (Fig 1c). Catheter positions were defined as row numbers corresponding to minima of profile mean over rows, found within 2 pixels of minima of standard deviation and of gradient mean. The distance between adjacent catheters was calculated from their row difference. Catheter distance difference from the known 10 mm value yielded positional accuracy. Average absolute positional accuracy and its standard deviation were calculated for all adjacent catheter pairs of each RS in a ROI (Fig 2c).



Results
Catheters inside the FF were distinguished on PETRA images in all 3 orientations with higher signal intensity than air and lower signal intensity than silicone spheres (Fig 1 c; Fig 2 a, b). Automated catheter detection in the coronally placed

applicator was feasible using the proposed algorithm for originally acquired and for reconstructed coronal slices centered on the applicator. The positional accuracy obtained was 0.40 ± 0.11 and 0.52 ± 0.30 for two acquired, and 0.46 ± 0.23 and 0.53 ± 0.30 (average ± standard deviation) for two reconstructed coronal slices encompassing the catheters.





Conclusion
The catheters of an FF applicator with known dimensions were detected on PETRA MR images using a novel algorithm. Overall catheter positional accuracy was around half millimeter, indicating reliable detection of catheters along their length inside the applicator. These results suggest that PETRA provides adequate catheter detection accuracy for application in SABT MR-only treatment planning.

OC-0021 End-to-end verification of 3D printed applicators for HDR skin brachytherapy

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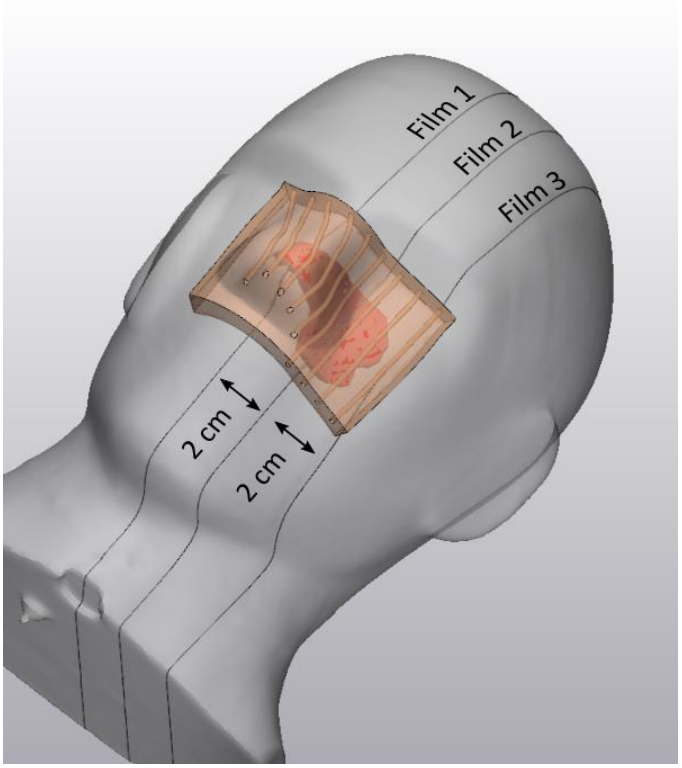
Purpose or Objective
3D printing allows for brachytherapy (BT) skin applicators adapted to challenging body contours like nose, ears, etc. Such patient specific applicators require proper verification. Therefore, a workflow for 2D dosimetric verification of these applicators was investigated. Here, we use EBT3 Gafchromic film measurements in an anthropomorphic head and neck (H&N) phantom (CIRS, USA) for an end-to-end verification of a high-dose-rate BT nose-skin treatment.

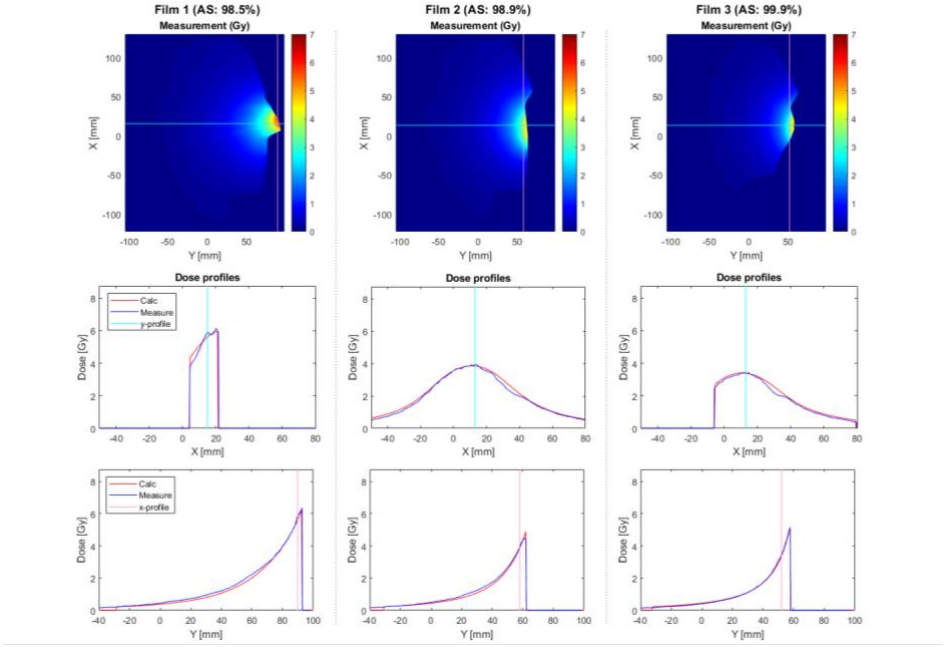
Materials and Methods
To generate the patient specific applicator, a CT scan (Somatom definition edge, Siemens Healthcare GmbH, Germany) was acquired of the H&N phantom in supine position. Delineation of a CTV in the region of the left nose wing and cheek was performed by a physician. Next, a 3D mesh of the body and CTV were exported from Eclipse (Varian, USA) using scripting. Subsequent design of the applicator was done in TriMatic (Materialise, Belgium). Within a 10 mm thick bolus, nine channels (2.2 mm diameter) were designed 5 mm from the patient surface and spaced 1 cm apart from each other. The direction, location and number of channels were manually optimized for target coverage and minimal local curvature to assure proper passage of the BT-source. The applicator was printed on a Raise3D N2+ 3D printer (Raise3D, Netherlands) using PLA (ICE filaments, Belgium) with 100% infill and 2 shells.
For treatment planning, a second CT was acquired of the applicator positioned on the phantom, with 5f BT catheters and radio-opaque markers in place. Next, the dosimetric planning was performed in Oncentra Brachy 4.5.2 (Elekta, Netherlands) with a 7 Gy prescription at 5 mm under the body surface.

The treatment was delivered with an Ir-192 Flexitron afterloader (Elekta, Netherlands) with laser cut EBT3 films positioned in the three sagittal planes of the phantom. The films were scanned and converted to dose using a calibration procedure for page-sized films and triple channel correction methodology[1].



Results

Dose comparison of the three films to the Oncentra dose calculation showed excellent agreement with an overall agreement score (AS) greater than 98% for gamma analysis[2] with a 5% dose difference, 2mm distance-to-agreement and 10% dose threshold criteria. For each analysis, a ROI was manually selected corresponding to the outline of the film. The figure below shows the good agreement between the measured (blue) and calculated (red) dose profiles trough the high dose region.



Conclusion

The presented E2E verification proves to be a useful verification methodology for customized 3D printed BT applicators. Here, it was applied to a relative complex surface geometry. The presented results showed excellent agreement between dose calculation and measurements using the 3D applicator. Future work is the investigation of more challenging situations

including cavities (e.g. nostrils) and interstitial BT. Although EBT3 film shows its usefulness, reusable OSL films can be explored as an instant alternative allowing for pre-treatment BT dosimetry.

OC-0022 MRI-guided Treatment Planning for Skin Brachytherapy with PETRA

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Purpose or Objective
Freiburg Flap (FF) is the most commonly used applicator in HDR surface brachytherapy. Treatment planning is performed on CT, as opposed to MRI that provides superior soft tissue contrast. An optimized MRI sequence - Pointwise Encoding Time Reduction with Radial Acquisition (PETRA) – presented in this study demonstrated a potential to make an MR-only treatment planning feasible. PETRA was used to digitize FF and create an MR-only treatment plan and compared to CT.

Materials and Methods
A FF (Elekta, Stockholm, Sweden) consisting of 12 catheters (24 spherical beads per catheter, 10 mm diameter) was sandwiched between 2 flat plexiglass plates (30 x 20 x 1.7 cm^3). An optimized coronal 3D PETRA sequence (TR\TE\TI 3.3\0.07\100 ms, FOV 306x306 mm^2, isotropic 0.8 mm-resolution, flip angle 4°, BW 407 Hz/px) was used to acquire MR images on a 3T SIEMENS Vida stimulator with a UltraFlex Large 18 and Spine 32 coil. The phantom was subsequently scanned on a helical CT (115 mA, 120 kV, 1.25 mm slice thickness). Applicators were localized and plans were created to the target defined as volume at 3 mm depth in the Oncentra Brachy (Elekta Brachytherapy, Netherlands) Treatment Planning System (TPS) for both CT and MRI. The TPS dwell points were calculated with step size of 10 mm from projected tip position in the TPS. MR images were registered onto CT images via rigid registration. Catheter difference (distance between the corresponding dwell positions between CT and MR-based digitization) were compared for each spatial dimension and for 3D. Relative percent dose from CT or MR-only treatment planning at a point 8, 10, 15, 20, and 25 mm beneath each dwell point (1380 points in total) were compared.

Results
The projected catheter trajectory between CT and MR showed good agreement (Hausdorff distance of 0.99 ± 0.36 mm for dwell points, Fig 1a). The catheter differences between the MR and CT-generated trajectories along each spatial dimension for all dwell points were 0.19 ± 0.42, 0.28 ± 0.11, 0.27 ± 0.66 mm for x-, y-, and z-dimension, respectively (Fig 1b-d). The catheter difference in 3D was 0.82 ± 0.37 mm (Fig 1e). The difference in the relative dose between CT and MR-only plans (Fig 2a) were not statistically significant (*paired t-test, a = 0.05*). Differences in the mean relative dose at each depth were all < 0.04% (Fig 2c).

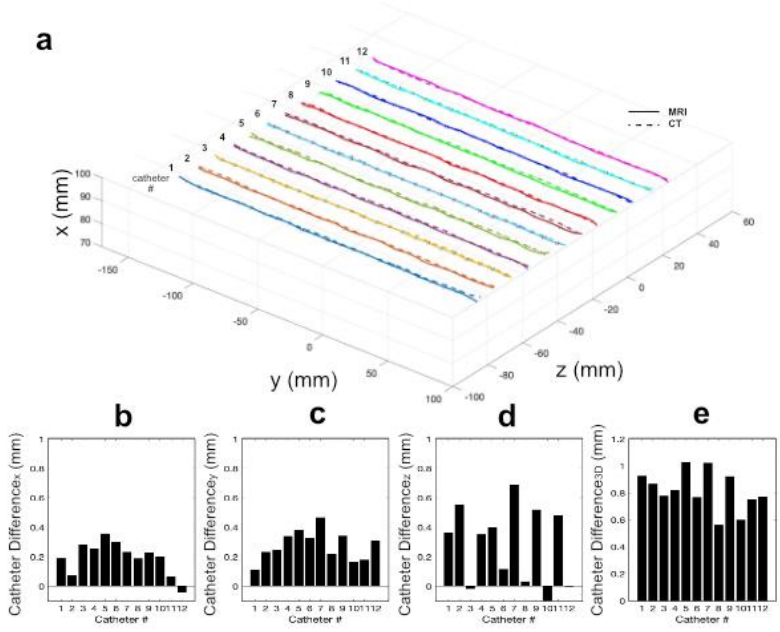

Fig. 1 a) Projected catheter trajectory in CT and MR, b-e) mean catheter differences in x, y, z, and 3D for individual catheters.

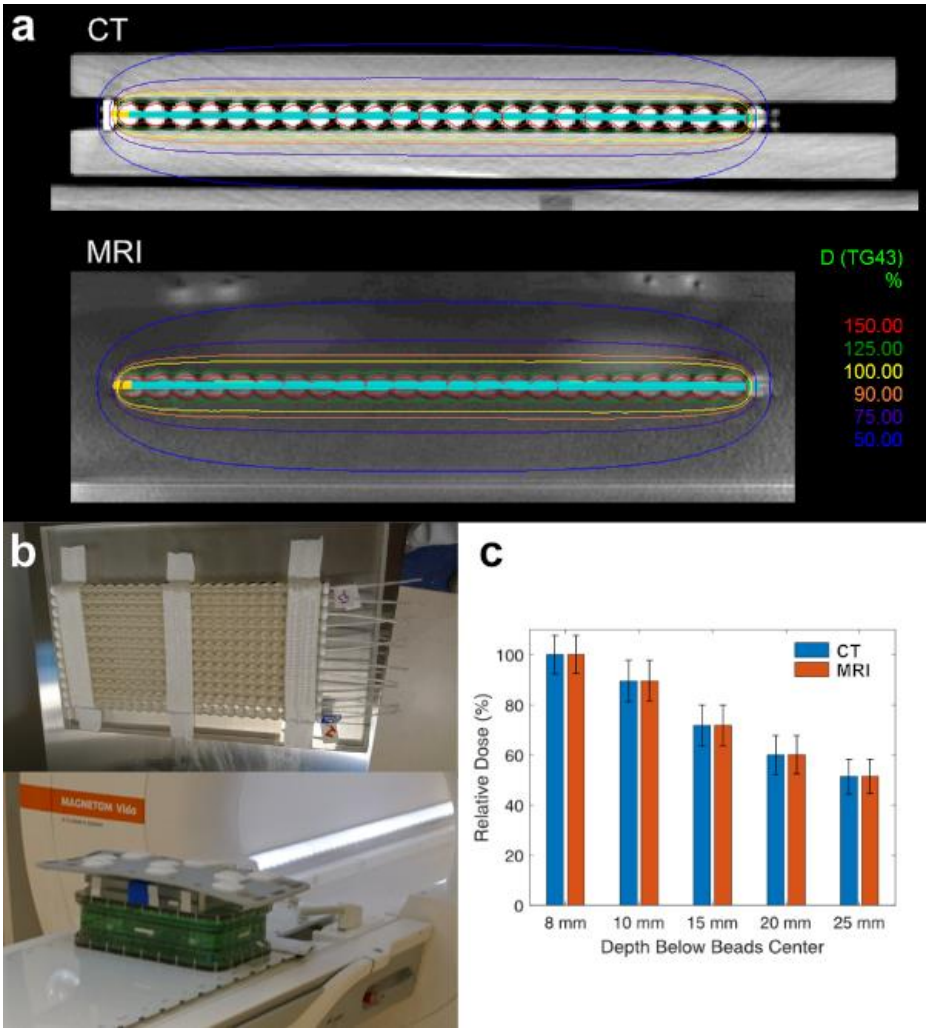

Fig. 2 a) Treatment plans generated with CT and MR, b) phantom setup, c) mean (± SD) relative dose at each depth.

Conclusion
The MR-only digitization of FF using PETRA sequence was shown to achieve < 1 mm accuracy compared to the CT. The optimized PETRA sequence created an MR-only plan that provides comparable dose profile to the plan generated via CT-based approach.

Proffered papers: 3 Best Moderated Abstracts

OC-0023 IMRT or Brachytherapy boost in oropharyngeal malignancies: A Randomized, open label study

Abstract withdrawn

OC-0025 Tumor regression of cervical cancer during chemoradiation evaluated by the T-score in EMBRACE I

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Purpose or Objective

A simple scoring system (T-score) for integrating diagnostic information from clinical examination and MRI has recently been shown to be a strong prognostic tool for local control (LC) and overall survival (OS) in patients with locally advanced cervical cancer (LACC) treated with chemoradiation and MRI guided brachytherapy (BT) in a single centre cohort[1]. The aim of the present work was to investigate the performance of the T-score in the prospective multicentre EMBRACE I study and to use the T-score for evaluating the prognostic implications of regression obtained during initial chemoradiation.

Materials and Methods

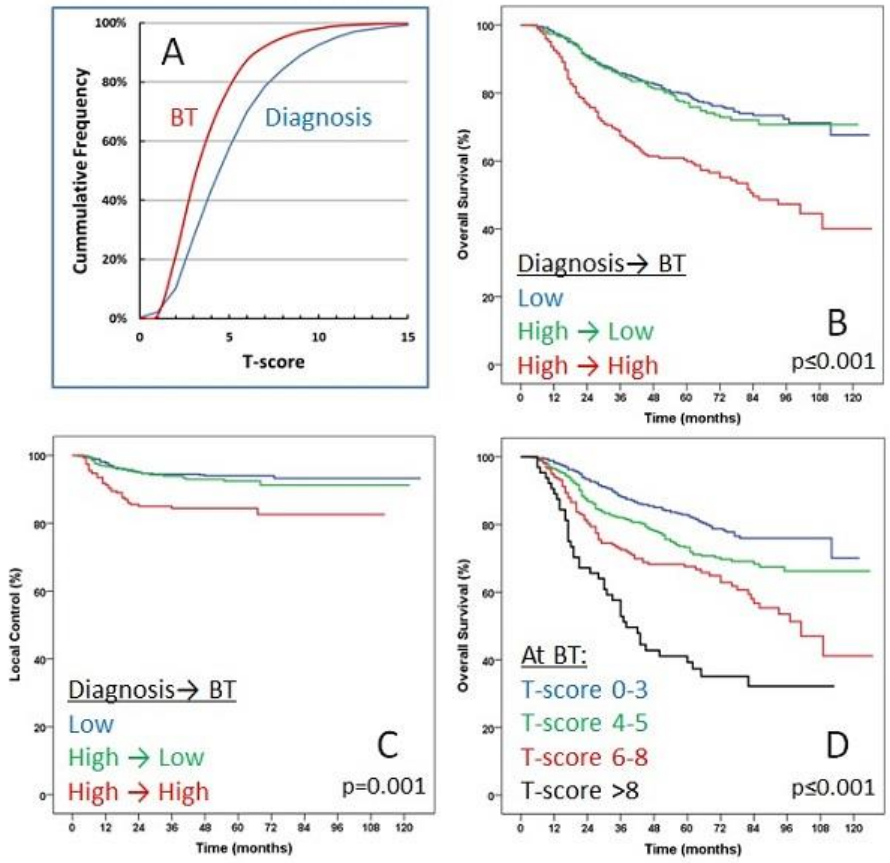
The EMBRACE I study recruited 1416 patients of which 1318 were available for analysis of both local control and survival. All patients were treated with external beam radiotherapy followed by MRI guided adaptive BT. Concomitant chemotherapy was given to 95%. A ranked ordinal scale of 0-3 points (Table 1) was used to assess the primary tumour regarding local involvement of 8 anatomic locations typical for spread of cervical cancer: cervix, left parametrium, right parametrium, corpus uteri, vagina, bladder, ureter, rectum. The 8 locations and the ranking were aligned with already established definitions used in e.g. staging systems. A 1-point increase per step was used. The T-score was calculated twice for each patient by adding the points obtained from each of the 8 locations (possible range of 0-23) at diagnosis and at BT, respectively.

Table 1:

Location	T-score points	Location	T-score points
1) Cervix	0: Not present 1: ≤ 20 mm 2: >20, ≤ 40 mm 3: > 40 mm	5) Corpus Uteri	0: Not present 1: Lower third 2: Middle third 3: Upper third
2) Left Parametrium	0: Not involved 1: Proximal 2: Distal 3: Pelvic wall	6) Bladder	0: Not involved 1: Bladder wall 2: Bullous edema 3: Mucosa
3) Right Parametrium	0: Not involved 1: Proximal 2: Distal 3: Pelvic wall	7) Ureter	0: Not involved 1: Unilateral 2: Bilateral
4) Vagina	0: Not involved 1: Upper third 2: Middle third 3: Lower third	8) Rectum	0: Not involved 1: Mesorectum 2: Rectal wall 3: Mucosa

Results

The median T-score at diagnosis was 5 with a mean value of 5.6. The cumulative frequency distribution of the T-score showed a left shift when re-scored at BT (Figure 1A) with a significant decrease of the mean to 4.2 (p≤0.001). Overall survival of 697 patients with a low initial T-score (≤5) or 351 patients with an initial high (>5) but low T-score at BT (≤5) was similar (Fig. 1B). In contrast, survival in the 270 patients with a T-score remaining high at BT (>5) was significantly reduced (p≤0.001). A similar pattern (Fig. 1C) was observed for local control (p=0.001). By dividing the patients into four groups according to T-score (0-3/4-5/6-8/>8) a significant and gradual decrease in survival with increasing T-score (p≤0.001) could be demonstrated both at diagnosis (not shown) and at BT (Fig. 1D), but with a better discrimination and a larger difference between the T-score groups using the latter. Cox regression showed that the T-score was a significant predictor of both OS and LC when analysed in the context of traditional prognostic parameters for LACC.



Conclusion
The T-score concept is applicable to the Embrace I study cohort and provides substantial information concerning impact of initial regression during chemoradiation on the probability for obtaining local control and survival. The T-score is a potential selection tool for treatment modifications.
[1]*Lindegaard et al, Int J Radiat Oncol Biol Phys. 2020 Mar 15;106(4):754-763.*

OC-0027 Intensity modulated HDR ocular brachytherapy using Yb-169 and Se-75

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Purpose or Objective
Ocular melanomas currently are treated using brachytherapy plaques containing I-125 or Pd-103 seeds. Because the geometry of these seeds are fixed, it is difficult to achieve an optimal dose distribution, which contributes to a significant number of radiation associated ocular complications. This treatment also requires two minor surgeries- the first to suture the plaque onto the sclera and the second to remove the plaque after 5-12 days. Because of this, the surgeon receives a significant dose to the hands of about 2-6 mSv per procedure.
We propose an alternative approach for treating ocular melanomas by using middle energy HDR brachytherapy sources such as Yb-169 and Se-75, along with a gold shielded applicator that is designed to permit the use of an afterloader device with a treatment time of 10 minutes. Because this device uses middle energy photons, it is possible to modulate the dose distributions to optimize dose to the tumor while minimizing the absorbed dose to healthy tissues. In addition, using an afterloader will eliminate dose to the surgeon's hands during applicator placement.

Materials and Methods
The proposed ring source is an assembly of discrete sources that are delivered together into an applicator that forms a circular ring configuration. This array of sources is contained in a spring-like structure, which maintains containment and provides flexibility. The gold applicator has a conical collimator opening, tangent to the outside of the source tube, which will act to alter and focus the dose distribution. Figure 1 shows the design of the applicator and the collimation. The prescribed dose rate for HDR eye plaque brachytherapy is 3 Gy/min for 10 minutes at a depth of 5 mm. Using MCNP6, we simulated the ring source containing Yb-169 and Se-75 with different diameter applicators and varying collimator angles to reach various depths within the tumor.

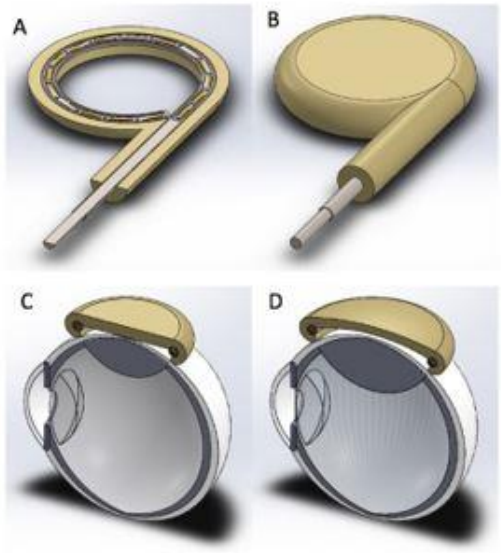

Figure 1: A) is the inside cross section of a 12 mm applicator containing 16 individual seeds. B) is the outside of the applicator containing 1.3 mm thick gold to reduce dose outside of the target. C) is of a 12 mm applicator and D) is of a 16 mm applicator. The gold shielding tangent to the outside of the source tube, which aligns with the outer edge of the tumor, collimates the dose to treat different sized tumors.

Results
The MCNP6 simulation results show that a Yb-169 or Se-75 HDR source array placed in the proposed gold applicator can reduce the absorbed dose to healthy tissue while simultaneously delivering the prescription dose to the target. The dose to critical structures in the eye is about 30% higher when using Se-75 compared to Yb-169 however it is still within acceptable limits. Figure 2 shows the dose distributions of a 12 and 16 mm applicator delivering the prescription dose to a 5 mm depth in the eye for Yb-169 and Se-75 compared to an I-125 COMS plaque. Simulations were also performed using different collimators to deliver the dose to 3.5-8.0 mm depths in the eye to cover tumors 10-15 mm in diameter.

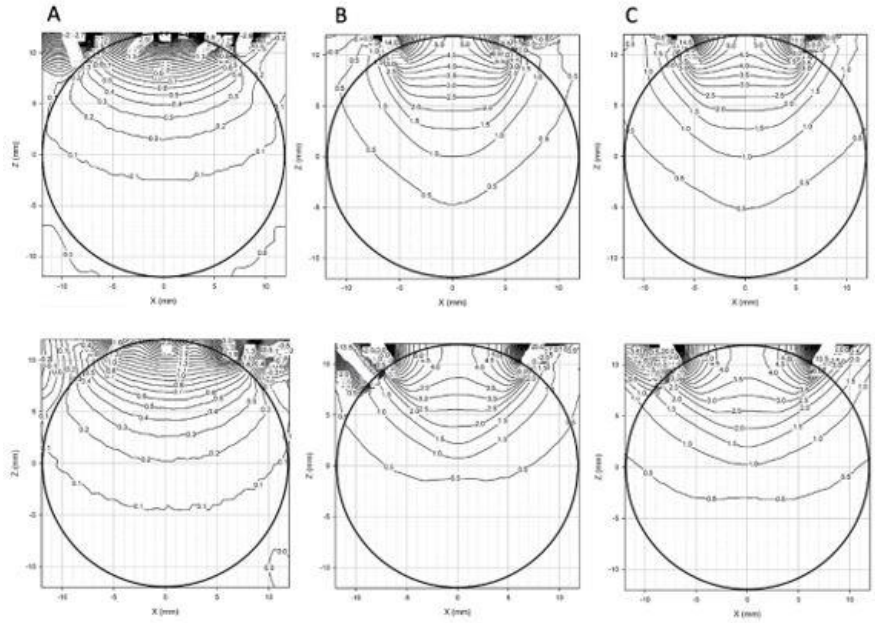

Figure 2: Dose distributions of the X-Z plane representing the dose rate in Gy/hr. The top row contains the distributions of a 12 mm applicator and the bottom row is of a 16 mm applicator delivering the prescription dose to a depth of 5 mm in the eye. Column A) is of an I-125 COMS plaque. B) is of Yb-169 and C) is of Se-75 both with our shielded ring applicator.

Conclusion
A novel eye plaque design is proposed using middle energy HDR brachytherapy sources with gold shielding. This source assembly is able to deliver a dose of 3 Gy/min to a depth of 5 mm in the eye in 10 minutes. More conformal dose distributions can be achieved from the conical opening and gold shielding. This design also permits the use of an automated afterloader, which eliminates dose to the surgeon's hands.

Debate: This house believes that combination therapy for intermediate and high-risk prostate cancer represents best standard of care

SP-0029 This house believes: Combination therapy for intermediate and high-risk pCa represents the best standard of care

M. Keyes[1]
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Abstract Text

Combination of brachytherapy boost and external beam radiation with or without androgen deprivation therapy (ADT) has been an excellent treatment option for men with high intermediate risk and favorable high risk patients. The treatment outcomes with brachytherapy including long term PSA control, metastatic free survival, cause specific survival and ultimately cure rates with any form of brachytherapy are very high. The superior disease outcomes are confirmed in numerous institutional reports, large US database queries, systemic overviews, and 3 randomized controlled trials (RCT) comparing EBRT with or without PB boost. From all levels of evidence, the congruence of results is remarkably high. The American Society of Clinical Oncology (ASCO), Cancer Care Ontario (CCO), American Brachytherapy Society (ABS), NCCN and ASTRO all endorse EBRT and PB boost as a standard management for high-tier intermediate and high-risk PCa. The ongoing RCT are in progress to determine the role of ADT, duration of ADT, the role of pelvic radiation.

However, dose escalation with brachytherapy boost has not been shown to increase the overall survival. There is an ongoing debate on most appropriate end points when considering PCa treatment outcomes. While OS is the most robust in many disease sites, it fails to address numerous issues including; long natural history of Pca, advanced age at diagnosis, effects of commodities on outcomes, availability of new and more effective systemic treatment for metastatic disease, poorly researched and documented cost to the health care system of additional morbidity and detrimental quality of life outcomes associated with local and systemic salvage treatments.

Increased toxicity of brachytherapy boost has been a concern used as a reason to consider alternative, less effective treatments for high risk disease, including EBRT or radical prostatectomy. One must keep in mind that the reported brachytherapy boost Gr 3 toxicity prevalence rate is markedly less than the late grade 3 toxicity, after radical prostatectomy, as reported in published RCTs. Addition of EBRT in adjuvant or salvage setting further contributes to long term toxicity. New radiation fractionation schemes and SBRT lack long term disease and toxicity outcomes in high risk disease.

Brachytherapy is the most effective radiation treatment for localized PC. Brachytherapy boost significantly increase PSA recurrence free survival, obviating the need for expensive investigation for PSA recurrence, toxic local salvage treatments, and expensive and toxic lifelong systemic treatments. Brachytherapy boost should be only offered to younger patents with good urinary function and good life expectancy, where the trade-off between of up front higher toxicity vs. lifelong toxic systemic treatment for failure to cure, is favorable.

SP-0030 Against the motion: Data, data, data

D. Spratt
USA

Abstract not available

SP-0031 For the motion rebuttal

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[1]Cruces University Hospital, Biocruces Bizkaia Health Research Institute, Radiation Oncology, Barakaldo, Spain

Abstract Text

The use of brachytherapy in combination with EBRT, based on data from randomized controlled trials, is considered a standard of care in published guidelines. As most trials on dose escalation, combo BT-EBRT has also shown an increase in toxicity. Most of the recent prospective studies evaluating toxicity after BT-EBRT have demonstrated extremely low rates of grade 3 toxicity. On the other hand, this treatment has demonstrated to get the best outcomes to date in terms of biochemical and local control, when radiation is the primary treatment for localized prostate cancer. Although in last years the value of biochemical and local control after radical treatment for localized prostate cancer has been challenge, lately, it has been shown in different publications that these outcomes may be appropriate surrogates of more important outcomes such as metastases free survival.

Although trade-offs must be accepted, the optimal approach to treatment may not necessarily be the one that is associated with the least morbidity, but instead the one that is most effective in preventing the need for subsequent treatment. Patients with a biochemical and local failure face the anxiety, costs, and adverse effects of salvage treatments, and all these could be diminished if combo BT-EBRT is used. The efforts should be focused towards decreasing the toxicity of the BT-EBRT while maintaining its efficacy. To relegate brachytherapy just to the salvage setting is a mistake that will not help our patients.

SP-0032 Against the motion rebuttal: Brachytherapy Boost for Prostate Cancer - A Diminishing Solution

J. Martin[1], M. Sidhom[2], D. Pryor[3], C. Tang[4], A. Hayden[5], A. Miller[6], S. Sridaran[7], Y. Trada[7], A. Capp[8], P. Greer[9], P. Keall[10], S. Siva[11], J. Tomaszewski[12]
[1]Calvary Mater Newcastle, Department of Radiation Oncology, Newcastle, Australia; [2]Liverpool Hospital, Department of Radiation Oncology, Sydney, Australia; [3]Princess Alexandra Hospital, Radiation Oncology, Brisbane, Australia; [4]5D Clinics, Radiation Oncology, Perth, Australia; [5]Westmead Hospital, Radiation Oncology, Sydney, Australia; [6]Illawarra Cancer Care Centre, Radiation Oncology, Wollongong, Australia; [7]Calvary Mater Newcastle, Radiation Oncology, Newcastle, Australia; [8]GenesisCare Gateshead, Radiation Oncology, Newcastle, Australia; [9]University of Newcastle, Medical Physics, Newcastle, Australia; [10]University of Sydney, Image X Institute, Sydney, Australia; [11]Peter MacCallum Cancer Centre, Radiation Oncology, Melbourne, Australia; [12]Ballarat Austin Radiation Oncology Centre, Radiation Oncology, Ballarat, Australia

Abstract Text

Prostate cancer dose escalation was pioneered in the 1980s and 90s with brachytherapy. As external beam approaches have become more sophisticated alongside better functional staging investigations and integration of systemic therapies, the use of brachytherapy has been declining world wide. Although we recognize the valuable lessons learnt from the brachytherapy literature, the field is evolving in different directions which we will explore in this debate.

Symposium: Eye/orbital brachytherapy: from organ sparing to function sparing

SP-0034 Brachytherapy Choice of the best approach for eye melanoma

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Abstract Text
Melanoma of the eye can be intraocular (uveal), ocular surface, in the orbit or on the eyelid. There is a range of possible treatments for uveal melanoma. These include laser (thermotherapy or photodynamic therapy), radiotherapy (brachytherapy, proton beam radiotherapy, stereotactic radiosurgery) and surgery (tumour resection or enucleation).
Plaque brachytherapy is designed to deliver radiotherapy to uveal melanoma in a controlled way. The aim is to treat the tumour, and to minimise risks of vision or eye loss. The Collaborative Ocular Melanoma Study (COMS) described the standard for brachytherapy using 125-I, defined the size of melanomas and importantly showed equivalent survival in a randomised controlled trial between brachytherapy versus plaque radiotherapy for medium sized melanomas.
The American Brachytherapy Society's consensus guidelines for the treatment of intraocular tumours suggest certain parameters. For uveal melanoma the dose prescribed is 70 to 100 Gy to the tumour apex. The prescription isodose line should encompass the entire tumour. Dose rates should not be less than the COMS historical standard of 0.60 Gy/hour. Isotope choice is limited by the size of tumour, with 106-Ru plaques for tumours less than 6mm height. 125-I or 103-Pd can treat larger tumours, but tumours greater than 12 mm in apical height or 20 mm in base carry guarded prognosis for retaining useful vision. Alternatives to brachytherapy for unsuitable cases where the plaque cannot be placed easily or the tumour is too large, include proton beam radiotherapy, stereotactic radiosurgery or enucleation of the eye. Failure of brachytherapy can be managed by further radiotherapy (brachytherapy or proton beam), laser (usually thermotherapy) or enucleation of the eye.
Plaque radiotherapy is an established technique for the treatment of uveal melanoma. Many eyes that would otherwise be lost are treated with this method. The challenge remains to minimise complications and to save more lives.

SP-0035 The role of interstitial radiotherapy in orbital tumors or extrascleral uveal melanoma

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Abstract Text

introduction
Radiation therapy continues to play an essential role in the management of benign and malignant orbital tumors of children and adults.

Material and methods
Multidisciplinary perioperative and interstitial interventional radiotherapy (IRT) after extensive but visual acuity preserving tumor resection is reported as safe and well tolerated treatment of advanced/recurrent malignancies involving the intraorbital space and of the skull base. If comparing modern EBRT and IRT technologies, the advantage of IRT was stated also in the adjuvant setting.

Results
Interstitial IRT can be applied as monotherapy or complementary to external beam radiation as a local dose escalation at the external radiation field margins or functionally important sites with micro-, and/or macroscopic residual tumor masses. Nowadays, stepping source techniques with personalized dose planning dominate the field. Visual acuity preservation become possible due to multidisciplinary teamwork in IRT excellence centers of specialized orbita groups. Especially in children intraorbital tumors, surgery combined with intraorbital interventional radiotherapy was proven by several groups as an optimal visual acuity preservation treatment method.
Furthermore, regardless of the invasive character of the treatment, it can be used as adjuvant local treatment following enucleation in cases of extraocular infiltrating melanomas, since the toxicity profile is more advantageous compared to any other modern external beam technique. Additionally, by avoiding exenteration, better cosmetic rehabilitation becomes possible. Although, adjuvant postenucleation EBRT with modern technology has low toxicity rates, review works in the literature advise the use of IRT because of improvements in toxicity results.

Conclusion
Interstitial, multidisciplinary IRT plays an important role in visual acuity preservation treatments of intraorbital tumors and offers the lowest toxicity profile in the adjuvant radiotherapy of enucleated extrascleral uveal melanomas.

SP-0036 Brachytherapy toxicity: diagnosis, therapies and preventive strategies

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Abstract Text

Purpose: to illustrate diagnostic methods, therapies and preventive strategies for radiation-induced side effects, after brachytherapy. The benefits of saving the eye with brachytherapy may be reduced by visual function impairment, secondary

to radiation-induced toxicity. Radiation retinopathy and maculopathy appear to be the most common complications, and remain devastating causes of visual morbidity. Methods: radiation injury to the posterior segment involves microangiopathy of the small retinal vessels secondary to endothelial cell loss and capillary closure. This vascular injury leads to predictable cascade of events that ultimately leads to macular edema (radiation maculopathy, and macular edema involving the fovea is a major source of visual morbidity in patients with radiation retinopathy), optic neuropathy, and neovascularization. Diagnostic tools for early detection and for monitoring treatment are used in the treated patients. Results: several effective therapy approaches for the prevention and treatment of this diseases are available and will be discuss. Treatments have been directed towards reduction of macular edema and neovascular events. Laser therapy had varying efficacies, but newer treatments with anti-VEGF therapies and steroid-based therapies may have remarkable results on retinal thickness and visual acuity. Conclusion: radiation-induced maculopathy predictive model could be a useful tool in order to identify the patients that could take more advantage from preventive strategies. 1.) U.O.C. Oncologia Oculare, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy; 2.) Sezione di Oftalmologia, Università Cattolica del Sacro Cuore, Rome, Italy 3.) U.O.C. Radioterapia Oncologica, Dipartimento di Diagnostica per immagini, Radioterapia Oncologica ed Ematologia, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy;

Proffered papers: Prostate Outcome and Treatment Plans

OC-0037 Updated results of focal salvage high-dose-rate brachytherapy for radiorecurrent prostate cancer.

M. Peters[1], M. van Son[2], M. Moerland[2], J. Lagendijk[2], W. Eppinga[2], T. Shah[3], H. Ahmed[3], J. van der Voort van Zyp[2]
[1]University Medical Center Utrecht, Radiation Oncology, Utrecht, The Netherlands; [2]UMC Utrecht, Department of Radiation Oncology, Utrecht, The Netherlands; [3]Imperial College, Department of Urology, London, United Kingdom

Purpose or Objective
Most patients with post-radiation prostate cancer recurrence undergo palliative androgen deprivation therapy (ADT), since whole-gland salvage treatments have a high risk of severe toxicity. Focal treatment of the recurrence reduces this risk while offering a second chance at cure. The objective of this study is to evaluate updated clinical outcomes of ultrafocal salvage high-dose-rate brachytherapy (HDR-BT) and to explore potential risk factors for treatment failure.

Materials and Methods
We analyzed prospectively collected data from the first 50 treated patients with locally recurrent prostate cancer (treated between July 2013 and April 2017). Disease status was assessed by 3T multiparametric MRI, 18F-Choline or 68Ga-PSMA PET/CT and systematic or tumor-targeted biopsies. Ultrafocal salvage HDR-BT (1x19 Gy) was performed by implanting the clinical target volume (CTV: gross tumor volume + 5mm margin) under fused TRUS/MRI guidance. Follow-up included toxicity grading (using CTCAE 4.0), quality of life (QoL) assessment and PSA-testing. Potential risk factors for biochemical failure (nadir PSA+2) were assessed.

Results
T-stage was T2 (62%), T3 (34%) and T4 (4%), Gleason ≥4+3=7 in 42%, PSA>10 ng/ml in 6% and PSADT<12 months in 16%. Median CTV D95% was 18.8 Gy. Median follow-up was 31 months. We observed 2% grade 3 genitourinary toxicity, no grade 3 gastro-intestinal toxicity and 22% grade 3 erectile dysfunction; 5/13 (38%) with pre-treatment potency (IIEF>17) remained potent. Relevant but non-significant QoL deterioration was reported for social functioning, mental health, tiredness, cognitive functioning and sexual functioning and activity (6/31 items). Biochemical failure (BF) occurred in 26 at median 20 months. Among intraprostatic recurrences, 73% was in-field. After 2.5 years, biochemical disease-free survival (BDFS) was 51% (95% CI 37-69%), metastases-free survival 75% (64-89%), ADT-free survival 90% (82-99%) and overall survival 98% (94-100%) (Figure 1). "Higher-risk" disease (≥T3, PSA ≥10, or PSADT ≤9 months) had 25% BDFS at 2.5 years, against 71% for patients without (Figure 2).

Conclusion
MRI-guided ultrafocal HDR-BT is a safe salvage treatment option, with a very low toxicity profile and stable patient-reported QoL. It has acceptable biochemical control in a well-selected group of patients and it can be an effective way to postpone ADT (90% free after 2.5 years).

Figure 1:

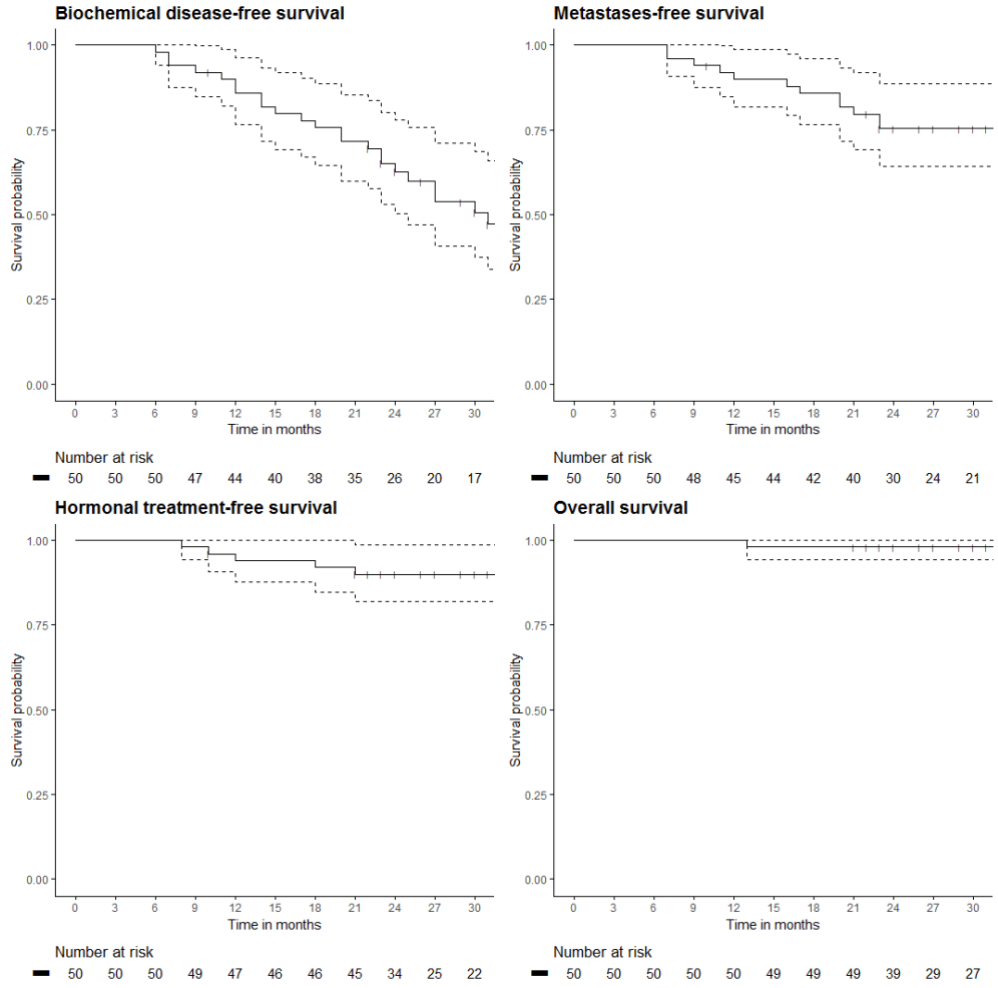
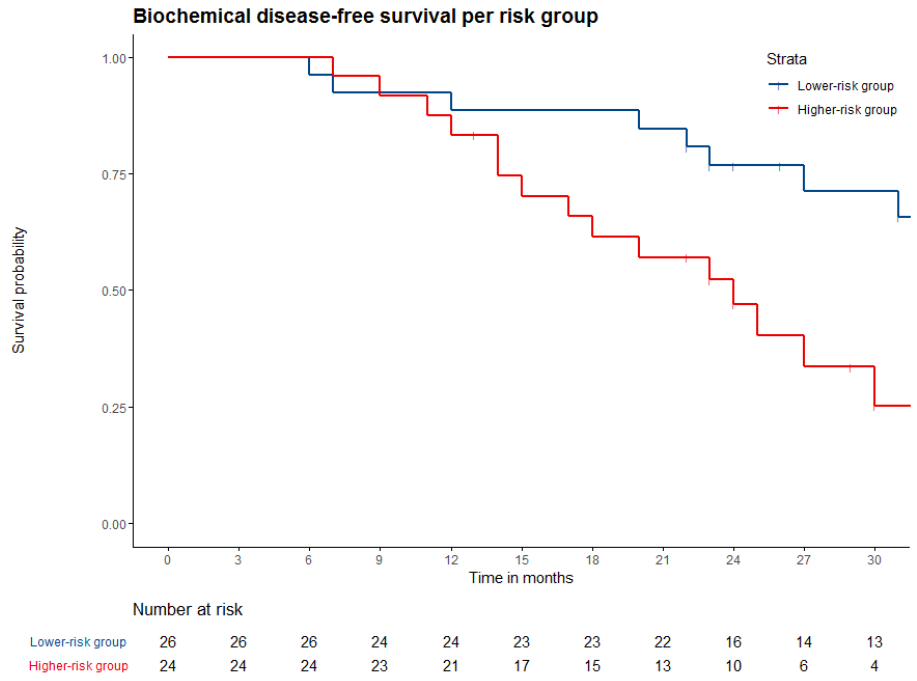


Figure 2:



OC-0038 Outcomes in focal vs. dose-painted salvage HDR brachytherapy for locally recurrent prostate cancer

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Purpose or Objective
To report toxicity and cancer control outcomes in a combined cohort of patients with locally recurrent prostate cancer treated with MRI-guided focal or dose-painted salvage high dose rate (HDR) brachytherapy (BT).

Materials and Methods
Between 2009-2020, 79 patients with pathologically confirmed and MRI visible local recurrence after previous EBRT and/or BT received salvage brachytherapy at 1 of 2 academic cancer centres. BT was delivered in 2 fractions over a median 7 days (range, 5-14), differentiated into two cohorts: dose-painted whole gland (dpBT) to a dose of 16-22 Gy with tumour boost of 22-26 Gy (n=15), and focal BT (fBT) to a dose of 26Gy (n=64). Failure free survival (FFS) was defined as the time from salvage brachytherapy to biochemical failure, local or regional recurrence, distant metastasis, or death from any cause. Fisher's exact test was used to compare toxicity, and Kaplan-Meier method was used for FFS.

Results
The median age at salvage treatment was 71 years (56-85). At initial diagnosis, 22% presented with low, 66% intermediate, and 13% high risk localized disease (NCCN). The median time between initial and salvage treatment was 7 years (3-17). Median PSA prior to salvage PSA BT was 4.6 (1.2-24), with median PSA doubling time of 15 months (5-51). Gleason grade group at initial failure was 4 or 5 in 34%, and short course adjuvant ADT was used in 33%.
At a median follow up of 38 months (6-134), the 3 and 5 year FFS (95% CI) rates were 67.8% (56.7-80.9) and 49.1% (35.8 - 67.4) respectively, with a median time to progression of 59.3 months (42.4-not reached). The 3 and 5 year cumulative incidence of local failure (LF) was 13.9% (95% CI, 4.1-23.7) and 30.1% (14.6-45.7), respectively. LF occurred earlier in the fBT cohort (Figure 1), but no statistically significant difference was found (fBT vs. dpBT, 19% vs. 0% p=0.32 at 3 years, and 27.8% vs. 23.3% at 5 years). The 3 and 5-year cumulative incidence of DM was 2.9% (0-6.9) and 12.6% (1.2-24), respectively. There were no G3 toxicity events attributable to salvage brachytherapy. Overall, grade 2 genitourinary (GU) and gastrointestinal (GI) toxicity events were reported in 24% and 4% of patients, respectively. The fBT approach resulted in substantially fewer grade 2 GU and GI toxicity events compared with the dpBT approach (p<0.001, Table1).

Figure1. Local failure in dpBT and fBT cohorts.

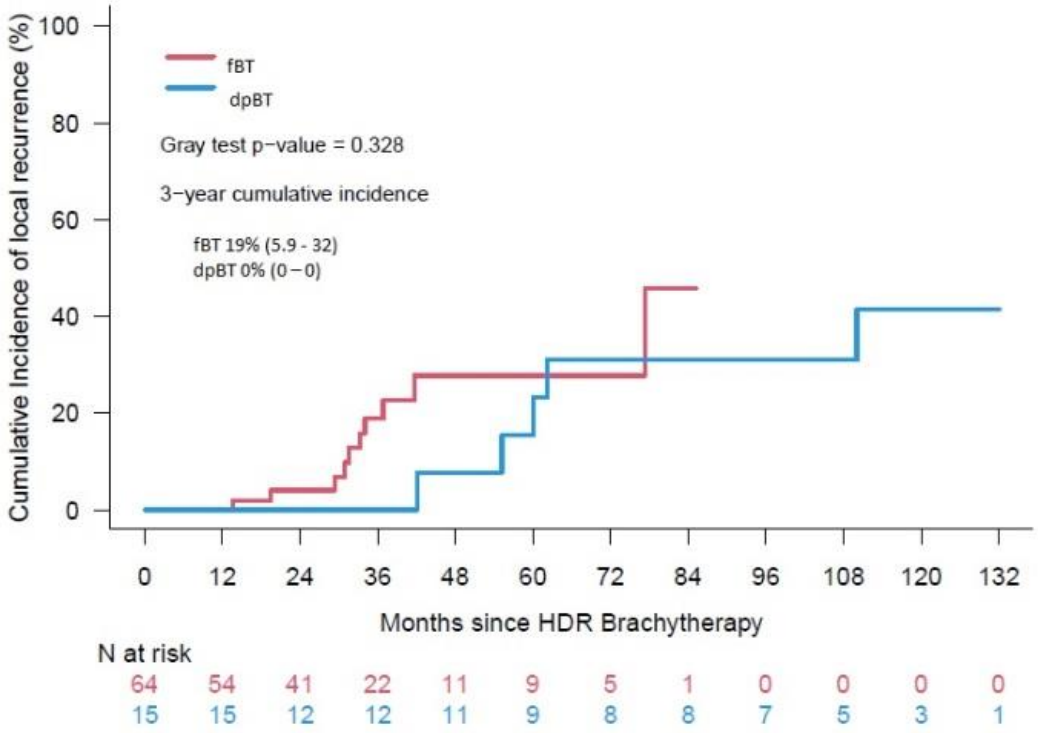

Table1. Toxicity by Type of Therapy

Toxicity	Focal (n=64)	Dose Painted (n=15)	p-value
GU CTCAE Grade			**<0.001**
0	36 (56)	1 (7)	
1	18 (28)	5 (33)	
2	10 (16)	9 (60)	
GI CTCAE Grade			**<0.001**
0	61 (95)	8 (53)	
1	3 (5)	4 (27)	
2	0 (0)	3 (20)	

Conclusion
Focal and dose-painted salvage HDR brachytherapy is associated with minimal toxicity, particularly in those treated with fBT. However, suboptimal local control with local failures occurring earlier in the fBT approach remain an issue. Dose escalation may be feasible and justified in order to improve local control outcomes. Further analysis will seek to identify those patients destined for early failure after fBT.

OC-0039 Predicting biochemical failure after MR-guided focal HDR brachytherapy for recurrent prostate cancer

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Purpose or Objective
Magnetic resonance (MR)-guided focal salvage high-dose-rate brachytherapy (FS-HDR-BT) for localized radiorecurrent prostate cancer (PCa) is associated with low toxicity rates. However, biochemical failure (BF) remains common. We developed two prediction models for BF to (1) enhance patient selection for FS-HDR-BT at baseline and (2) to identify patients at high-risk of BF during follow-up.

Materials and Methods
The models were based on a prospective cohort of 150 patients with localized radiorecurrent PCa, treated with FS-HDR-BT between 2013 and 2020 at the University Medical Center Utrecht. For model 1, the following pre-salvage characteristics were selected for multivariable analysis: age, gross tumour volume (GTV), PSA-level, PSA-doubling time (PSADT), and seminal vesicle involvement. For model 2, clinical target volume (CTV) D95% (dose to 95% of the CTV), post-salvage time to PSA nadir, and PSA reduction (ratio between pre-salvage PSA and post-salvage PSA nadir, in %) were added. Restricted cubic splines with 3 knots were used for non-linear continuous variables. Pre-salvage PSA-level was log-transformed. Predictors of BF (Phoenix-definition) were identified by multivariable Cox proportional hazards regression using backward elimination (based on lowest AIC). Internal validation was performed with 2000 bootstrap resamples and the C-statistics and hazard ratios (HR) were adjusted accordingly. Nomograms were constructed, and three risk groups were identified based on the 25th and 75th percentile of the linear predictor (total score).

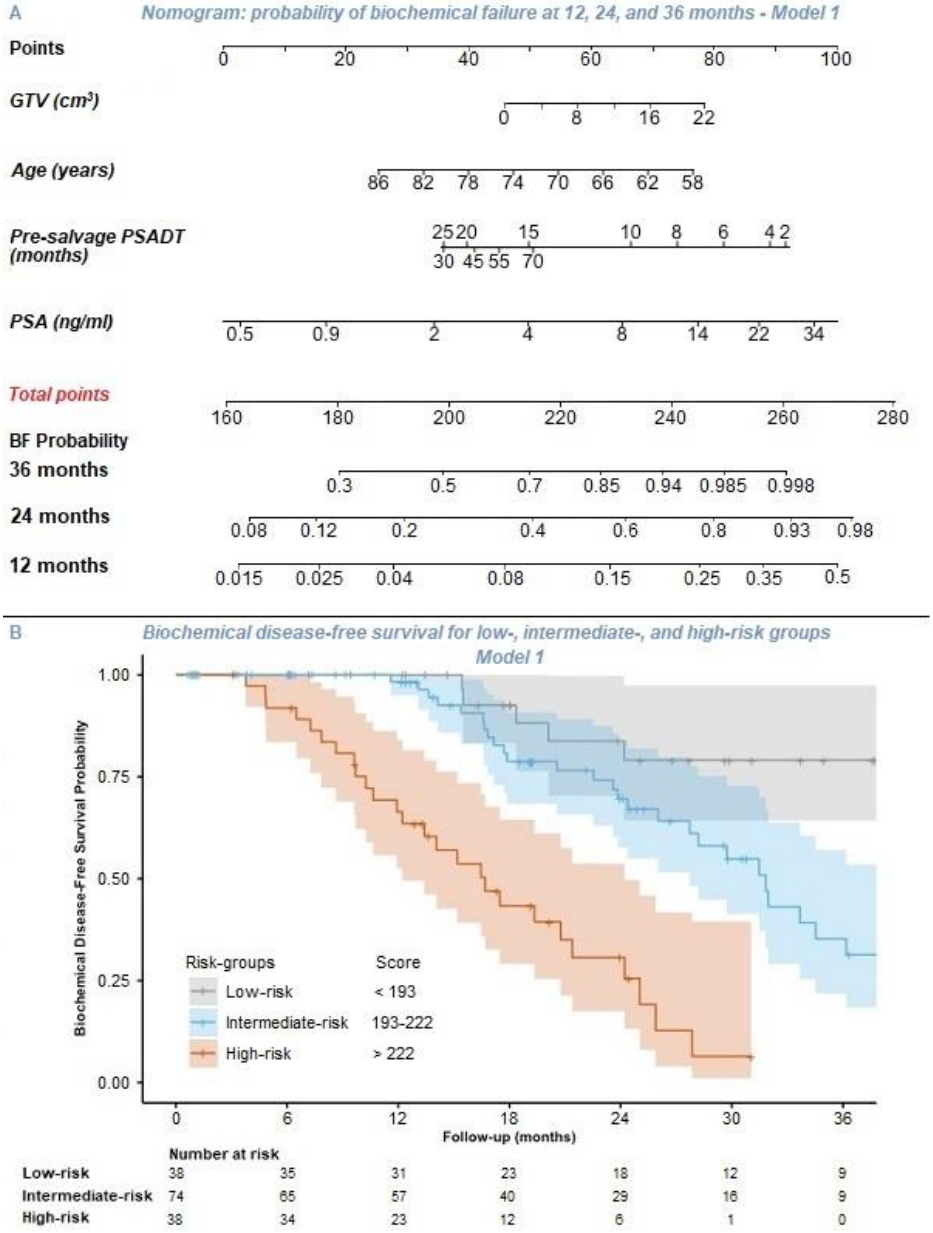
Results
Median follow-up was 25.1 months (IQR 13.5-38.1). Sixty-one patients (41%) experienced BF after a median of 29.7 months (IQR 23.5-43.6). At baseline (model 1), age, GTV, pre-salvage PSA, and pre-salvage PSADT were predictive of BF (Table 1). For model 2, age, pre-salvage PSA, seminal vesicle involvement, time to PSA nadir, and percentage PSA reduction were predictive of BF (Table 1). The adjusted C-statistics were 0.73 and 0.84 and calibration was acceptable. The nomogram belonging to model 1 is shown in Figure 1A. Estimated 2-year biochemical disease-free survival was 84%, 70%, and 31% for model 1 (Figure 1B), and 100%, 71%, and 5% (model 2) for the low-, intermediate-, and high-risk group, respectively.

Table 1 *Multivariable Cox proportional hazard models*

	Model 1		Model 2	
Candidate predictor	**HR (95% CI)**	**p-value**	**HR (95% CI)**	**p-value**
Age (years)	0.94 (0.90-0.98)	0.002	0.92 (0.87-0.96)	0.0005
Pre-salvage PSADT (months) (rcs)	0.87 (0.83-0.92)	<0.0001	0.89 (0.83-0.94)	0.0001
Pre-salvage PSADT' (months) (rcs)	1.18 (1.09-1.27)	<0.0001	1.16 (1.07-1.26)	0.0004
Pre-salvage PSA (ng/ml) (log)	2.19 (1.51-3.176)	0.0001	4.47 (2.94-6.80)	<0.0001
Seminal vesicle involvement	X	X	1.49 (0.87-2.55)	0.14
GTV (cm^3)	1.054 (1.003-1.107)	0.036	X	X
D95% CTV (Gy)	*NA*	*NA*	X	X
Post-salvage Time to PSA nadir (months)	*NA*	*NA*	0.82 (0.76-0.88)	<0.0001
Post-salvage PSA reduction (%)	*NA*	*NA*	0.98 (0.97-0.99)	0.0003

X = eliminated after backward selection based on lowest AIC. NA = not applicable. Log = log-transformed. rcs = modelled with restricted cubic splines, 3 knots at the 10^{th}, 50^{th} and 90^{th} percentile.

Figure 1 *Nomogram (A) belonging to Model 1 and corresponding Kaplan-Meier survival curves (B) for the risk groups based on the total score.*



Conclusion
This study provides two models for prediction of BF in patients with localized radiorecurrent PCa treated with FS-HDR-BT. Our findings support that both pre- and post-salvage PSA characteristics are important predictors of BF in patients treated with focal therapy for radiorecurrent PCa. Model 1 could be used for patient selection for FS-HDR-BT. During follow-up, an updated risk prediction can be obtained with model 2, which can support patient guidance. Potentially, these models can also be used for other salvage techniques, for which external validation remains necessary.

OC-0040 Ultrafractionated radiotherapy(RT) in localised prostate cancer:HDR brachytherapy vs stereotactic RT

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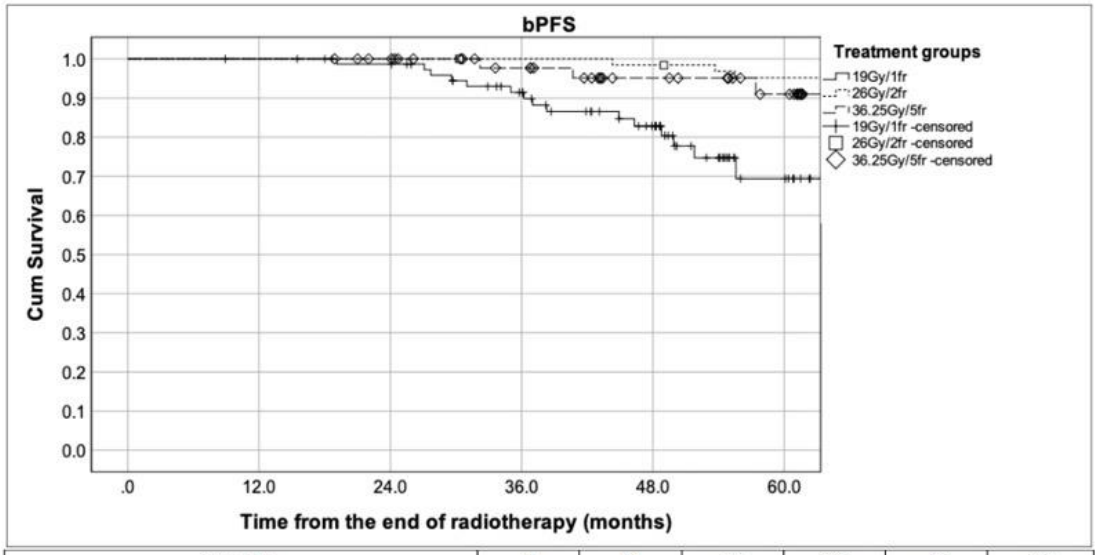
Purpose or Objective
To compare the biochemical progression-free survival (bPFS), late gastrointestinal (GI) and genitourinary (GU) toxicities in patients with low- and intermediate risk prostate cancer (PCa) treated with high-dose-rate brachytherapy (HDR BT) of 19Gy/1 fraction, 26Gy/2 fractions, or stereotactic ablative radiotherapy (SABR) of 36.25Gy/5 fractions.

Materials and Methods
Between August 2008 and December 2017, patients with low- and intermediate risk PCa who received single dose or 2-fraction HDR BT, or 5-fraction SABR at a single institution were included. bPFS rates for the whole population and the individual treatment groups were calculated using the Phoenix definition. Post treatment GI and GU toxicities were evaluated according to the CTCAE v4.0 guidelines.

Results
195 patients with low- and intermediate risk PCa were included in this study with a median follow up of 60.5 months. bPFS at 5 years was 86% for all patients, and 69%, 95% and 91% for the 19Gy/1 fraction, 26Gy/2 fractions and 36.25Gy/5 fractions groups respectively (Fig 1). The cumulative 5-year incidence rates of ≥grade 2 GI events in the 19Gy/1fr, 26Gy/2fr and 36.25Gy/5fr groups were 0%, 2% and 5%, respectively. Incidence rates in those treated in the 5-fraction SABR arm were significantly higher($p<0.05$) than those treated in both HDR BT arms where no statistically significant difference between the two HDR BT groups was seen($p=0.15$). The cumulative 5-year incidence rates of ≥grade 2 GU events in the 19Gy/1fr, 26Gy/2fr and 36.25Gy/5fr groups were 30%, 5% and 7%, respectively. No statistically significant difference was found between the 26Gy/2fr and 36.25Gy/5fr($p=0.29$) treatment arms but incidence rates in these groups were significantly lower than those seen after 19Gy/1fr($p<0.05$)



Months		0	12	24	36	48	60
19Gy/1fraction	No of cumulative events	0	0	1	6	11	15
	No of remaining cases	78	77	72	58	40	11
26Gy/2fractions	No of cumulative events	0	0	0	0	1	3
	No of remaining cases	64	64	64	63	62	59
36.25Gy/5fractions	No of cumulative events	0	0	0	1	2	3
	No of remaining cases	53	53	50	41	30	21

Figure 1: Kaplan-Meier biochemical progression-free survival (bPFS) curves for all patients treated with 19Gy/1fraction HDR BT, 26Gy/2fractions HDR BT and 36.25Gy/5fractions SABR.

Conclusion
26Gy/2 fractions HDR BT provided equivalent bPFS with lower toxicity compared to 36.25Gy/5 fractions SABR. Both 2-fraction HBR BT and 5-fraction SABR achieved better bPFS than single dose 19Gy HDR BT. The two-fraction HDR BT schedule should be considered as an important comparator in future clinical trials.

OC-0041 Dosimetric comparison of SBRT and HDR brachytherapy in patients from randomized study.

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Purpose or Objective
Background: There has been an increasing interest in stereotactic body therapy (SBRT) and high dose rate brachytherapy (HDRB) in treatment of low-intermediate risk prostate cancer. In order to compare efficacy and safety of both methods in 2018 we initiated single center prospective randomized trial.
The aim of this study was to compare dosimetric plans of patients that received HDRB with those that were randomized to SBRT.

Materials and Methods
Between 01.06.2018 and 01.07.2019, 139 men with low-intermediate risk prostate cancer were randomized between HDRB or SBRT. Sixty-nine patients received TRUS guided HDRB in 2 fractions of 13 Gy (BED-251.3; α/ß-1.5), among them 10 men received HDRB with the low dose tunnel for urethra (D10 ur<90%). Another 70 men were treated by SBRT in 5 fractions of 7.25Gy (BED-211.5; α/ß-1.5). For comparison of dosimetric plans we used the following parameters: V100 pr – the percentage of prostate that received 100% of prescription does and D90 pr – minimum dose that covers 90% of prostate; D2cc rec - the maximum dose for 2cc of the rectal wall; D10 ur – the dose that covered 10% of the urethra volume.

Results
All plans were characterized by excellent coverage of the target (prostate). V100 and D90 for prostate were as follows: for SBRT - 91% (87.3-94.7%) and 100.1% (99.9-100.3%); for HDRB – 94.3% (92.1-96.5%) and 104.7% (102.3-107.1%). SBRT demonstrated uniform dose distribution with nearly equivalent dose to the prostate and urethra (D10ur- 101%; 100.3-101.7%) and high dose to the rectum (D2cc – 91%; 86.7-95.3%) and bladder (D2cc 100.9%; 99.6-102.2%). HDRB give the opportunity for significant reduction of the dose to the anterior rectal wall (D2cc - 55.3%; 48.4-62.2%) with moderate dose to the bladder (D2cc – 69%; 61.6-76.4%) and urethra (D10 – 108.3%; 105.5-111.1%). HDRB with "tunnel for urethra" was performed only in low risk patients with negative periurethral biopsy cores. This technique gives the opportunity to reduce dose to the urethra (D10 – 89.4%; 86.5-92.3%) and to the bladder (D2cc - 56%; 49.1-62.94%) with moderate underdose of the prostate (central and transitional zones).

Conclusion
Our data indicate that both HDRB and SBRT characterized by excellent target (prostate) coverage. Important advantage of HDRB against SBRT is significant (from 91% to 55.3%) reduction of the dose to the rectum. HDRBT with "tunnel to urethra" reduce the dose to the urethra and bladder neck with underdose of the central and transitional zones of prostate.

OC-0042 Applying column generation to the intensity-modulated high-dose-rate brachytherapy inverse planning

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Purpose or Objective
Intensity modulated high dose rate brachytherapy (IMBT) is a rapidly developing application of brachytherapy where anisotropic dose distributions can be produced at each source dwell position. This technique is made possible by placing rotating metallic shields inside brachytherapy needles or catheters. By dynamically directing the radiation towards the tumours and away from the healthy tissues a more conformal dose distribution is created at the expense of increasing complexity of the treatment planning process. In this study column generation method is investigated for IMBT treatment plan optimization.

Materials and Methods
A column generation optimization algorithm is developed to optimize the dwell times and shield angles. At every iteration, the plan is optimized with the chosen dwell position and shield angle (DPSA) combinations and the DPSA that would best improve the cost function at every iteration is added to the plan. The optimization process can be stopped when the clinical plan evaluation criteria have been met to limit the plan complexity. In this work the optimization was stopped when no more DPSAs is expected to add value to the current plan.

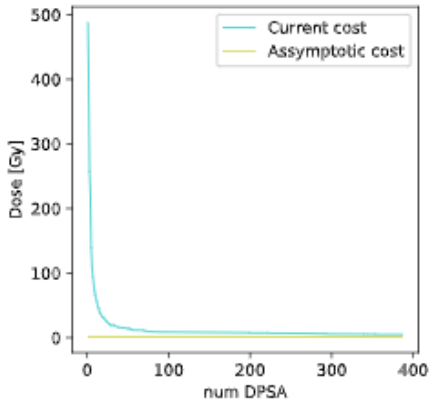

Figure 1. Final cost function value as a function of number of DPSAs included in the treatment plan. The asymptotic cost is the final cost function value when all possible DPSAs are optimized at once.

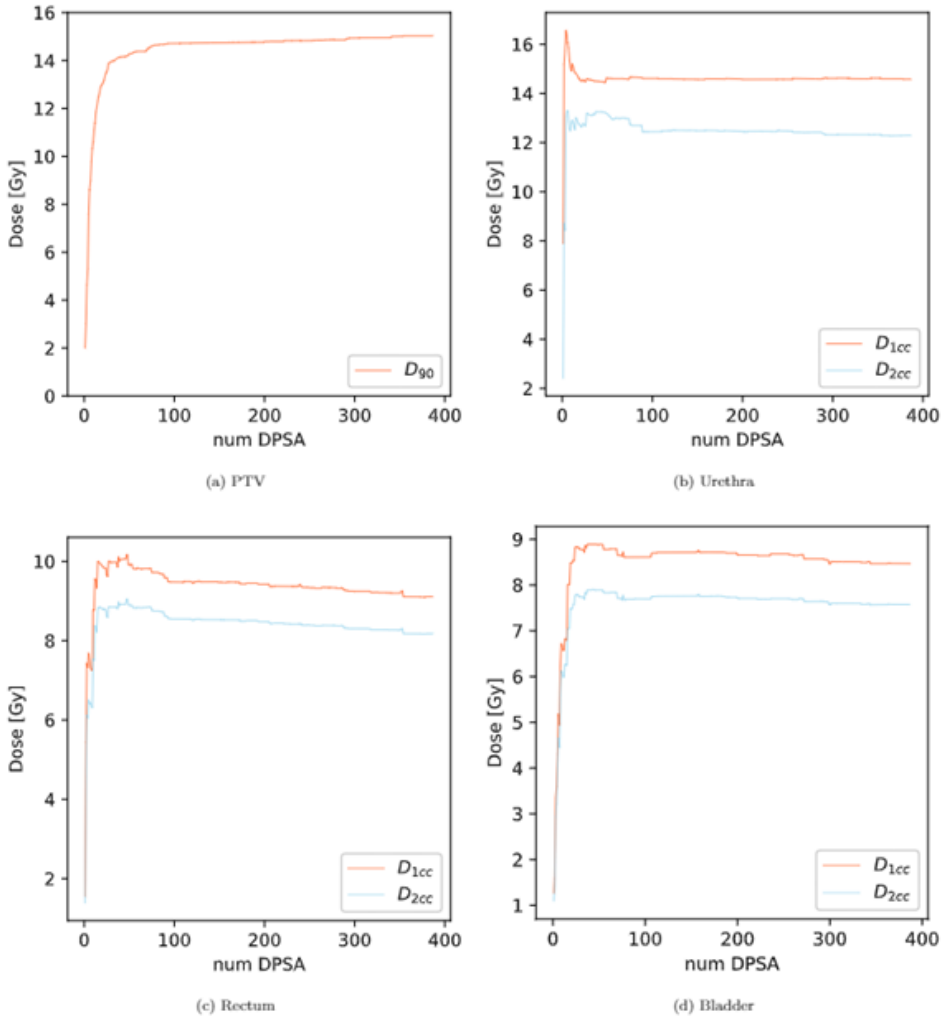

Figure 2. Dove-volume histogram parameters as a function of number of DPSAs included in the treatment plan for the planning target volume (PTV), urethra, rectum and bladder. In (a), the minimum dose received by 90% of the volume (D_{90}) is shown while the figures corresponding to organs at risk (b, c, d), only the maximum doses to 1cc and 2cc of the volumes are plotted.

Results

The column generation approach yielded a near-optimal treatment plan with 387 DPSAs from 2080 possible DPSAs for a prostate case. The final iteration contained a plan with a complexity five times smaller than the original one. Figure 1 shows that the cost function converges to the asymptotic cost, which is the cost when all DPSAs are included in the optimization. Figure 2 illustrates the dosimetric indices of interest at each iteration. After some fluctuations D1cc and D2cc of the organs at risk (OAR) reach their maxima during the first 50 iterations, then decrease to stabilize after 100 iterations. With the D2cc of both the bladder and the rectum being below 10 Gy, and the D1cc of the urethra below 15 Gy, the dosimetric requirement for the OAR are satisfied while still having V100 > 15 Gy in the planning target volume.

Conclusion

The column generation method produced a high-quality deliverable prostate IMBT plan. The treatment plan quality eventually reached a plateau where adding more DPSAs had a minimal effect on dose volume histogram parameters. The iterative nature of the column generation method allows early termination of the treatment plan creation process as soon as dose volume histogram parameters satisfy their clinical requirements or if they have stabilized.

Proffered papers: Optimising treatment

OC-0043 Feasibility Study of Quantitative Silicone Oxygen Sensors in HDR Cervical Cancer Brachytherapy

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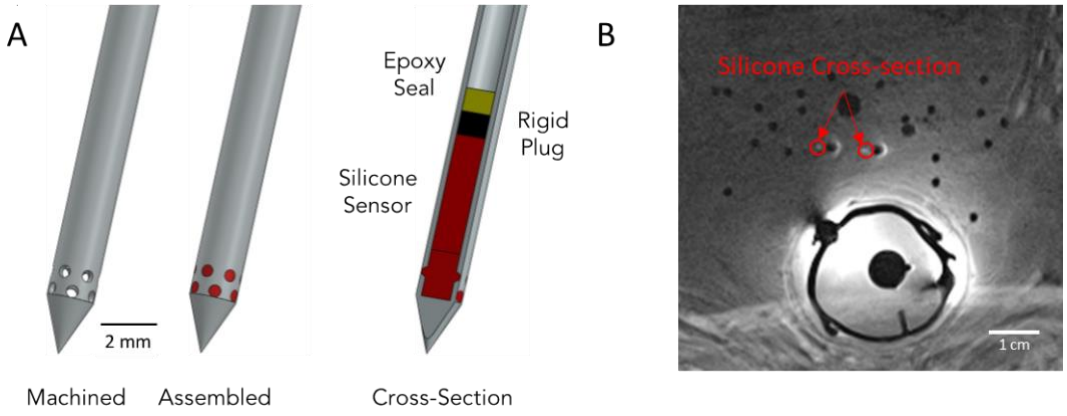
Purpose or Objective
Tumor hypoxia is a well-known adverse prognostic marker for poor clinical outcome, including radiation and chemotherapy resistance and development of distant metastases. In cervical cancer, patients with hypoxic tumors based on oxygen electrode measurement have higher local failure rates and worse disease-free survival. [1] Currently available clinical techniques for measuring hypoxia are qualitative and limited by poor sensitivity. As hypoxia-related radiation resistance may be overcome by higher radiation dose, HDR brachytherapy is uniquiely suited for localized dose escalation to hypoxic tumor subvolumes. Given the emerging importance of MRI in brachytherapy, an MRI-compatible quantitative oxygen sensor would be a valuable tool for tumor oxygen measurement during radiation treatment.

Materials and Methods
The primary objective of this pilot study is to evaluate the feasibility of obtaining tumor oxygen measurements at the time of MR-guided interstitial brachytherapy with the temporary placement of a modified brachytherapy catheter that contains an oxygen sensitive polymer in the inner lumen. Study eligibility required: diagnosis of cervical cancer for which interstitial brachytherapy was planned and ECOG performance status ≤2. Patients with a contraindication to MRI or uncontrolled intercurrent illness were ineligible. At the time of MR-guided brachytherapy, 2 oxygen sensor catheters are placed through a perineal template into cervical tumor. Longitudinal relaxation times are captured using a single slice turbo spin echo sequence with 10 inversions. Target accrual is 10 patients with a 2-stage design and safety lead-in of 4 patients. Feasibility is defined as acquisition of data from at least 1 oxygen sensor with an overall success rate of 90%.

Results
The pandemic response cause the study to be closed before full accrual. In 7 patients, the oxygen sensing catheters (Figure 1A) were allowed to reach thermal and oxygen equilibrium while the brachytherapy treatment catheters were placed and adjusted under MR-guidance. The silicone portion of the oxygen sensor catheters were captured in a single 2-mm slice (Figure 1B) and intensity values fit to extract the longitudinal relaxation time as a function of tissue oxygenation



Conclusion
Initial clinical experience in a pilot study shows that silicone-based polymeric oxygen sensors may be used to measure tumor oxygen content using a clinical MRI with available parameters and pulse sequences. Sensor insertion and measurements integrated well into the clinical workflow of MR-guided brachytherapy. Future iterations of this device may allow for accurate estimation of hypoxic tumor regions and permit modulation of HDR brachytherapy dose.
This effort was supported by a Bridge Project Expansion Grant, the Image Guided Therapy Center (NIH P41EB015898), the Koch Institute Quinquennial Cancer Research Fellowship and the Kavanaugh Translational Innovation Fellowship.
Reference: [1]Knocke, T.H., et al., Radiother Oncol, 1999. **53**(2):99-104

OC-0044 Clinical evaluation of an interactive multi-criteria optimisation workflow for HDR brachytherapy

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Purpose or Objective
Recently, our graphics processing unit (GPU)-based multi-criteria optimisation (gMCO) algorithm was integrated in a novel graphical user interface (gMCO-GUI) that allows real-time plan navigation through a gMCO-generated set of Pareto-optimal plans for high-dose-rate (HDR) brachytherapy. This work reports on the integration of the gMCO algorithm into the workflow of an active brachytherapy program.

Materials and Methods
10 HDR brachytherapy prostate cancer patients were retrospectively re-planned. A range of prostate volumes was chosen (26 to 100 cc) to test robustness to prostate size. The target, bladder, rectum and urethra structures were delineated from ultrasound images. The original plans were each generated by experienced physicists using IPSA followed by graphical

optimization as implemented in Oncentra Prostate v4.2.2 (OcP) (Elekta, Veenendaal, The Netherlands), and approved by a Radiation oncologist (RO). Each case was re-planned with gMCO algorithm by generating 1000 Pareto-optimal plans. The computations were executed on an Intel(R) Core(TM) i9-10920X CPU and a NVIDIA GeForce RTX 2080-Ti GPU. A single treatment plan was chosen by two physicists (without the RO) from the generated set of gMCO plans using the gMCO-GUI plan navigation tools. To compare with the plan dosimetry of the original clinical plan, the optimized dwell times were exported via DICOM RTPLAN files to OcP where the final dosimetry was calculated. A RO blindly compared the gMCO plan with the clinical plan for each case. Paired two-sided Wilcoxon signed-rank tests were used to evaluate the statistical significance of the null hypothesis.

Results

gMCO plans and clinical plans were all considered clinically acceptable by the RO. The RO preferred 7 gMCO plans out of the 10 cases. From these 7 plans, 3 plans would have required local dose adjustments to cover specific regions of the target. 3 clinical plans were preferred to gMCO plans. Fig. 1 illustrates a gMCO plan that was preferred to the clinical plan because of its better urethra sparing.

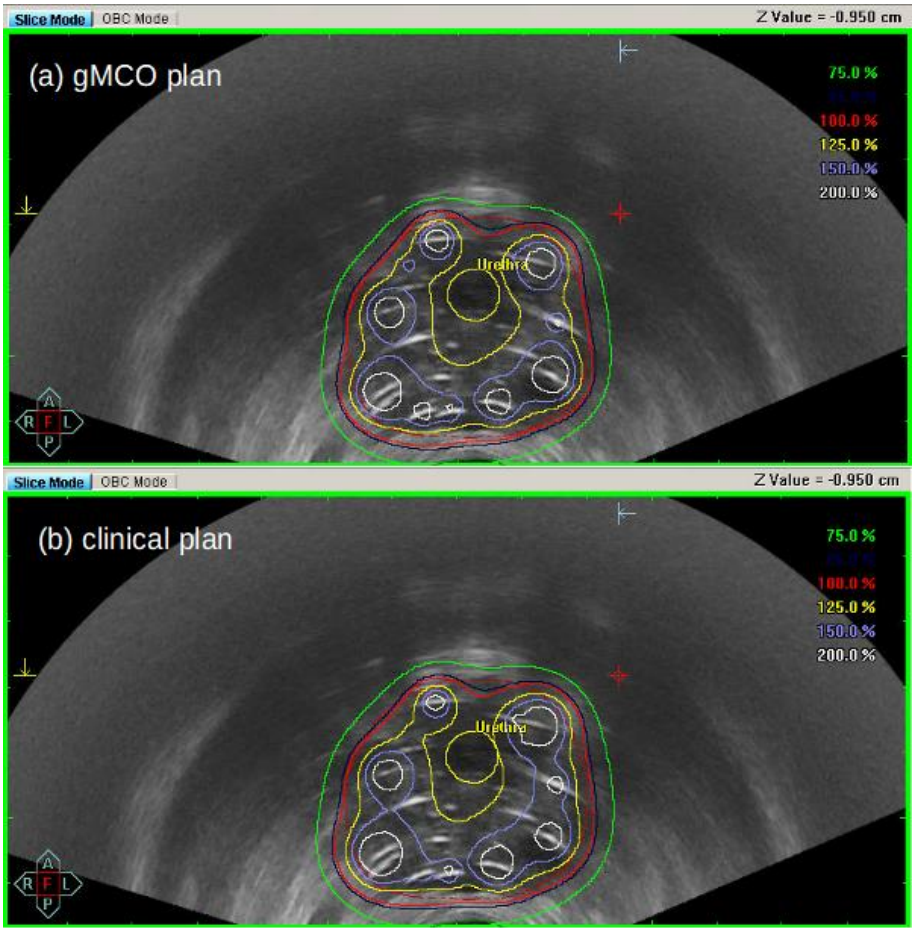

Fig 1. Illustration of the isodose lines of a (a) gMCO plan that was preferred to the (b) clinical plan.

The dosimetric results are summarized in Table 1. Overall, gMCO plans were more conformal, and the urethra sparing was superior compared to clinical plans (Table 1). The mean calculation time with gMCO was 5.7 s. While the planning time was not recorded, the physicists mentioned that the planning seemed to be faster with gMCO.

Table 1: Dosimetric results (median values) of gMCO plans and clinical plans

	gMCO	Clinic	p value
Target V_{100}	97.1%	98.0%	0.08
Target COIN	64.4%	62.2%	0.02
Bladder V75	0.70 cc	0.61 cc	0.23
Rectum V75	0.37 cc	0.27 cc	0.51
Urethra D_{10}	112.2%	117.1%	0.01

Conclusion

The gMCO algorithm was implemented into the clinical workflow. Plan quality was evaluated and compared favorably to clinical plans. Optimization time was trivial, but a bottleneck was identified when plans needed to be transferred to the

clinical planning system for final dose evaluation. This would be remedied if the algorithm was integrated directly into the clinical planning system.

OC-0045 Extracting anatomical information from Iridium-192 gamma images using artificial intelligence

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Purpose or Objective
Brachytherapy is a treatment option for different cancer types with an excellent treatment outcome. However, options for treatment verification are currently lacking. A solution to this problem is currently explored by using an imaging panel (IP) to intercept Iridium-192 photons from the radioactive source, and extract information like dwell positions and dwell times, which would allow for real-time treatment verification. Ideally, anatomical information from the patient would be used as a reference to determine dwell positions, however due to the high amount of scattered photons created during the treatment this proves to be challenging. In this project the use of a convolutional neural network (CNN) is explored to remove scatter from the IP images, highlighting anatomical structures. Detection of these structures will help determining the source position and thus allow for improved real-time treatment verification for brachytherapy.

Materials and Methods
A Monte Carlo model of the patient based on a CT images was created to simulate the IP acquisitions for liver, gynaecological and prostate brachytherapy cases. Tissue segmentation was performed on the CT using HU thresholding and by provided contours for certain organs. The panel was simulated in several positions around the patient at a distance of approximately

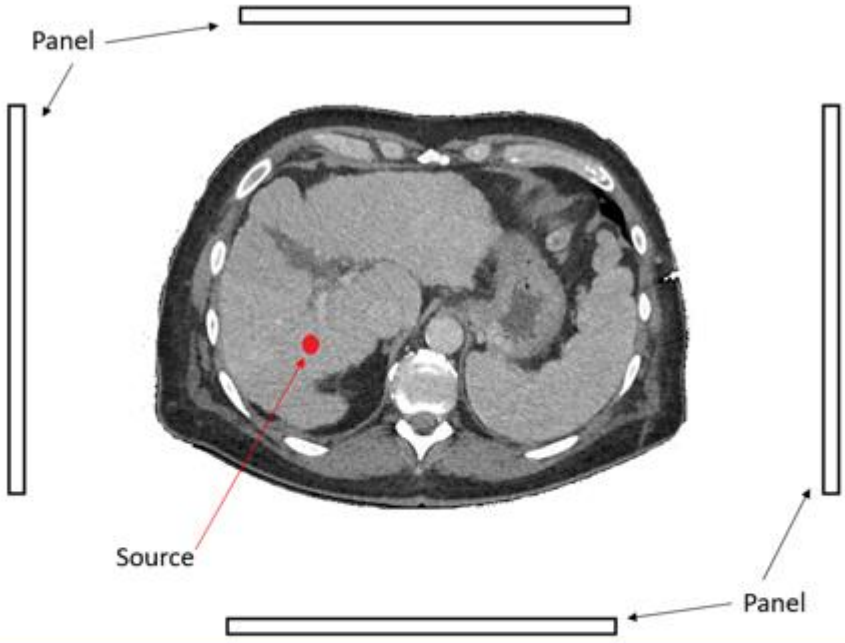

Figure 1: Overview of a Monte Carlo simulation used to acquire the training data, with the patient in the middle, the source position (red) and 4 different panel positions where the signal of the primary and secondary photons is simulated.

10 cm (see figure 1), so multiple images could be obtained for a single source position, creating a dataset of approximately 2000 different acquisitions. Only a select number of dwell positions were picked from the treatment plan for every patient, to avoid having very similar images in the dataset.
The detector response of the primary and secondary photons was simulated separately, allowing the primary image to be used as the ground truth, and the combination of all photons as a realistic simulation of a real panel acquisition. A convolutional neural network based on a U-net architecture used to reduce scatter for cone-beam CT acquisitions was adapted to this application.

Results
Applying the trained network on validation data shows that it can greatly reduce the amount of scattered photons in the panel acquisitions, allowing bone-like structures like vertebrae and ribs to become visible in the images (see figure 2). A comparison of the normalized intensity line profiles supports this claim, as bony structures create more noticeable dips after scatter correction, similarly to the ground truth.

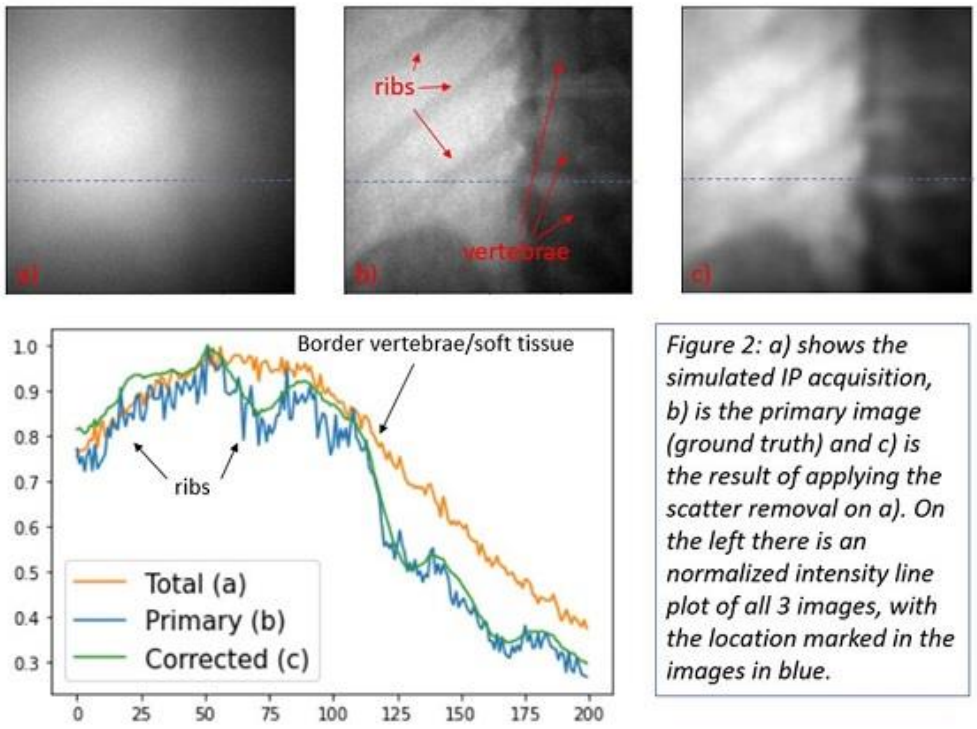

Figure 2: a) shows the simulated IP acquisition, b) is the primary image (ground truth) and c) is the result of applying the scatter removal on a). On the left there is an normalized intensity line plot of all 3 images, with the location marked in the images in blue.

Conclusion
With a neural network based approach, the amount of scatter in panel acquisitions of the Iridium-192 source during brachytherapy can be greatly reduced, allowing for detection of anatomical landmarks and indirectly the source position. With the enhanced images from the neural network it will be possible to verify the position of the radioactive source inside the patient, and allow for real-time treatment verification for brachytherapy.

OC-0046 Robust optimization to mitigate rotational uncertainty effects in intensity modulated brachytherapy

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Purpose or Objective
Intensity modulated brachytherapy is an emerging technology for cancer treatment, in which shielded sources are used to shape the dose distribution. We study the effects of rotational errors in the shields with respect to planning criteria. A robust optimization model is proposed to take several scenarios into account, where each scenario corresponds to a specified rotational and positional placement error.

Materials and Methods
We consider the prototype for prostate 169Yb-based intensity modulated brachytherapy, described by Famulari et. al (2020, Medical Physics, vol 47:3). The retrospective patient dataset comes from two clinics. Monte Carlo simulations are used to generate the dose-rate contributions, to take the shields of a high-Z material into account. The robust optimization model puts a penalty on a combination of the averaged outcome and the worst outcome. In our computational experiments we consider systematic rotational shield errors of the size of ten degrees, that is, the rotational errors are the same for all dwell positions in each scenario. Three scenarios are included in the model, the nominal scenario and two scenarios with errors of plus and minus ten degrees, respectively. We compare results from a model in which only the nominal scenario is included (the standard model) with the robust model. For both models we evaluate the obtained dose distributions for all scenarios.

Results
The urethra is the structure that is most affected from the rotational errors, and the received dose is significantly increased in the worst scenario, with dwell times obtained from the standard model. With dwell times obtained from the robust optimization model the highest dose to the urethra is more stable for all scenarios. In particular, we show that the dose to urethra, for example measured by D0.1cc, is reduced in the worst scenario with the robust model compared to the standard model; see Figures 1 and 2 for an illustration of dose-volume histograms for one patient.

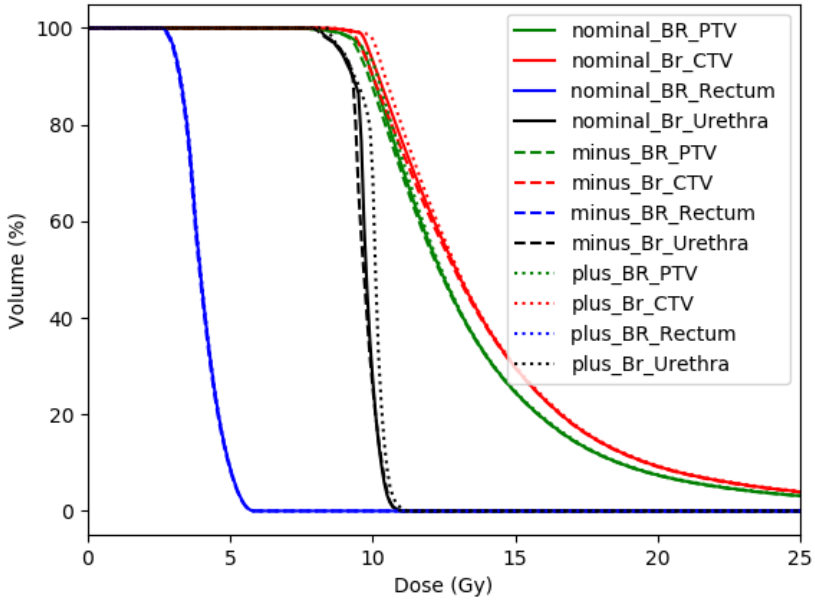

Figure 1: Dose-volume histograms for the standard model and three scenarios are shown. These are marked with solid, dashed, and dotted lines, respectively.

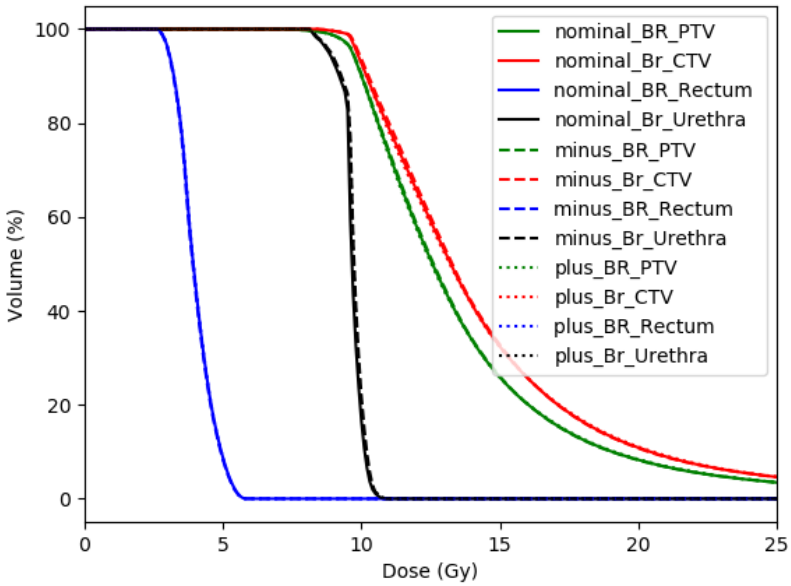

Figure 2: Dose-volume histograms for the robust model and three scenarios are shown. These are marked with solid, dashed, and dotted lines, respectively.

Conclusion
With the robust optimization approach we were able to mitigate the effects from the rotational uncertainty in the shield placement, without worsening target coverage. Hence, robust optimization can be used to ensure the expected treatment plan quality.

OC-0047 Multi-criteria optimization integrating catheter optimization for prostate HDR brachytherapy

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Purpose or Objective
High dose rate (HDR) prostate brachytherapy is an efficient method for the treatment of prostate cancer. Currently, the number of catheters is predetermined and they are manually inserted with a template by the radiation oncologist. It has

been shown that using too many catheters would increase toxicity while too few would not cover the target adequately while damaging healthy organs. In this work, a catheter optimization (number and position) layer is added to a fast GPU-based multi-criteria optimization (gMCO) algorithm to determine the optimal number of catheters.

Materials and Methods

A centroidal Voronoi tessellations (CVT) algorithm, that uniformly distributes any number of catheters over a region (here prostate minus urethra), was added to our gMCO algorithm. As published by Cédric et al, it is a quasi-Newton Algorithm on GPU, gL-BFGS (Limited-memory-Broyden-Fletcher-Goldfab-Shanno) that calculate thousand Pareto optimal plans in seconds (NVIDIA Titan X - Pascal). 108 ultrasound HDR prostate brachytherapy cases were used in this study (volume range: 20-100 cc). The positions of the catheters were first calculated by the CVT algorithm (E5-2620 v3 Intel Xeon CPU @ 2.40 GHz), which takes into account the point of insertion to mimic clinical limitations. The range of catheters explored was 8 to 18 catheters. Two types of position optimization were used, the first one is called freehand (CVT_{FH} - no template used) while the second is limited to a standard 5 mm template (CVT_T). The two methods were compared with the clinical plans and with the clinically reconstructed catheters but with the dwell times optimized with the gMCO algorithm. The protocols used for plan evaluation are based on RTOG criteria (RTOGp with target V100 > 95%). Plans with errors were also generated to validate robustness. For each scenario (number of catheters, type of insertion, robustness) 1000 plans/scenario were generated.

Results

For the clinically reconstructed catheter optimized with gMCO, RTOG (RTOGp) criteria were met 99% (94%) of the time. For comparison, 62% (59%) of the clinically delivered plans met the criteria. Adding CVT_T catheter optimization and using 14 catheters, the criteria are met 100% (94%) for RTOG (RTOGp). However, for the CVT_{FH} optimization approach, 100% of the plans pass RTOGp criteria (Figure 1). An analysis of the robustness of insertion deviation (with random error and fewer patients) (Figure 2) and catheter reconstruction deviation (with systematic error) is also present. Plan generation time is about 36s/11000 plans: 9s for the CVT algorithms, 2s for MCO optimization, 25s dose grid initialization, dose, and DVH computation.

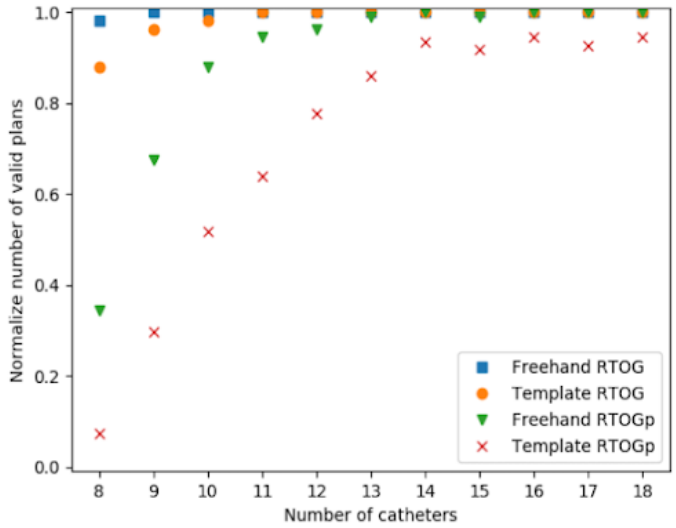

Figure 1: Results of the optimization for CVT_{FH} and CVT_T both with gMCO.

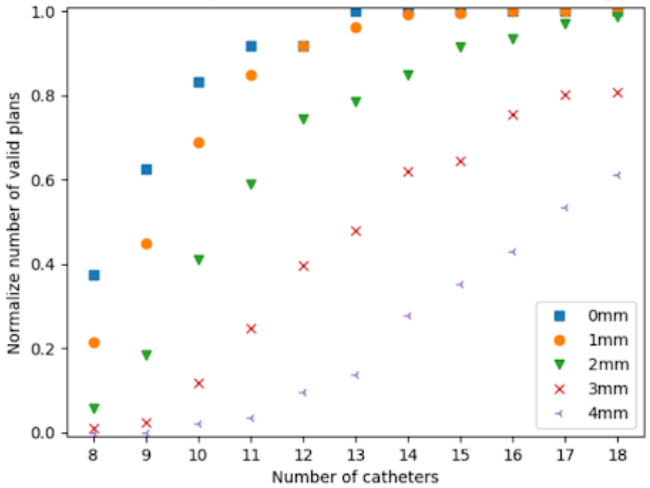

Figure 2: The number of valid plan with RTOGp criterias with CVT_{FH} on a subset of 24 patients for error in the plan of insertion with a random angle (20 different simulations) for all catheters.

s.

Conclusion
Going from standard inverse planning to MCO provides the largest gain in dosimetric plan quality. Adding catheter position optimization is a second-order gain with freehand optimization being better than template-based optimization. Robust plans (2 mm of deviation) with 14 catheters in CVT_T and even less with CVT_{FH} are achievable.

OC-0048 Correlation between radiation-induced foci from 192Ir brachytherapy and tumor nuclei Size

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Purpose or Objective
The response of tumors to radiation varies widely between different tumor types and among different patients. Main target for radiotherapy is nuclear DNA. However, there is a variation in nuclei size and DNA content for the same cell type and between healthy and cancerous cells. Cell cycle is another factor which influences the nuclei size. Identification of the correlation between the dose response and the size of the cell nuclei may have important implications for radiotherapy. DNA double strand break (DSB) is one of the most toxic lesions and could induce apoptosis in tumor cells following radiation. Phosphorylation of the Ser-139 residue of the histone variant H2AX, forming γ-H2AX, is an early cellular response to the induction of DNA DSB after a few minutes following the irradiation. Hence, γ-H2AX foci can be used as a biomarker for detection of DSBs. The aim of this study was to evaluate the induction of DSBs based on nuclei size distribution in different cancer cell lines irradiated with ^{192}Ir brachytherapy source.

Materials and Methods
Prior to radiation, prostate PC-3 and cervix HeLa adenocarcinoma cells were seeded in 4-well chamber slides or 60 mm petri dishes. The cell lines were incubated at 37 °C with 5% CO_2 until 80% confluency. Prior to irradiation, the cells were synchronized overnight in G0/G1 by serum starvation, since cells during division have a high γ-H2AX background. The cells were irradiated by using MicroSelectronV2 (ElektaBrachytherapy, Veenendaal, TheNetherlands) ^{192}Ir high dose rate brachytherapy source to doses of 1 Gy and 4 Gy planned with Oncentra®Brachy treatment planning system. The radiation setup was validated using EBT3 Gafchromic™ films and is presented in Figure 1a. Following radiation, the cells were incubated in similar incubation condition as above for 30 minutes or 1 hour to maximize the γ-H2AX intensity. The nuclei region and expression of γ-H2AX were evaluated by immunofluorescence staining. Fluorescent labeled cell lines were quantified with confocal microscopy and imaging flow cytometry.

Results
Figure 1b shows the dosimetric validation of the irradiation setup using EBT3 Gafchromic™ film. Dose homogeneity within the 4-well chamber slides was found to be ±2% from planned values using Oncentra®Brachy. The relationship between radiation-induced foci and the size of the nuclei for HeLa cells following ^{192}Ir irradiation is shown in Figure 2a. The number of foci increases with nuclei size. Table 1 in Figure 2b presents the mean and median for the nuclei size and the number of radiation-induced foci following different radiation doses; 1 and 4 Gy for PC-3 and 4 Gy for HeLa cells. The number of γ-H2AX foci increases as a function of dose.

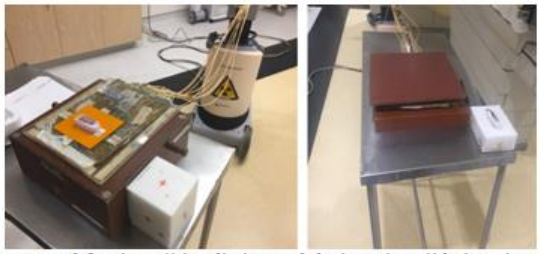

Figure 1a. The setup used for the cell irradiation and dosimetric validation. 4-well chamber slides were placed on an applicator made of two layers of molten bolus superflab with 18 catheters placed between the layers, 0.5 cm from the surface of applicator and 1.0 cm apart. Full TG-43 scatter condition was achieved by using a 5 cm backscatter and 1 cm front-scatter water slabs. Oncentra® Brachy was used for planning of 1 Gy and 4 Gy absorbed doses.

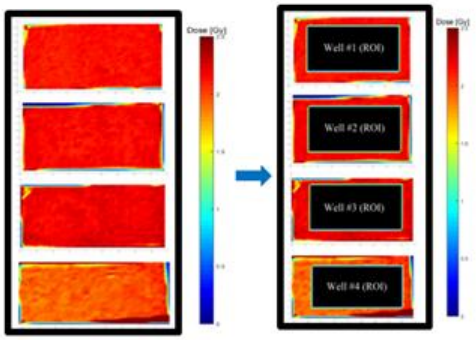

Figure 1b. EBT3 Gafchromic™ film cut to fit the bottom of the 4-well chamber slides. Dose map obtained by multichannel analysis showed dose homogeneity ±2% over the irradiated area. The film was calibrated using an orthovoltage beam according to AAPM TG-61 protocol.

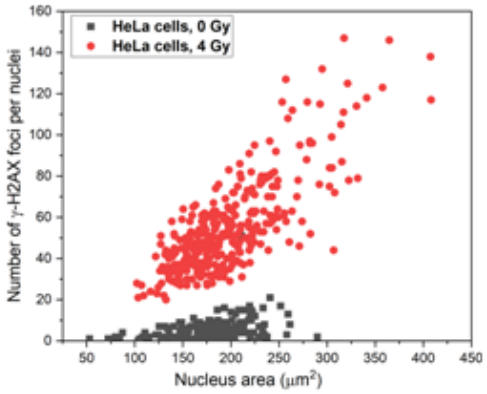

Figure 2a. Number of γ-H2AX foci per nucleus as a function of nucleus size in HeLa cells, 30 minutes following ^{192}Ir irradiation with a dose of 4 Gy (red) and non-irradiated cells (black). Analysis was performed with ImageJ software after confocal microscopy image acquisition.

Cell Lines	Dose (Gy)	Nuclei Area (μm²)		γ-H2AX Foci	
		Mean	Median	Mean	Median
PC-3	1	175	175	15	13
	4	186	175	36	33
HeLa	4	195	186	52	50

Figure 2b. Table 1: Mean and median for nuclei size and radiation-induced foci, 30 minutes following ^{192}Ir high dose rate brachytherapy irradiation for PC-3 and HeLa cell lines.

Conclusion
These preliminary results show that there is a correlation between nucleus size and the number of radiation induced DSBs, which increases with increasing size of the nuclei. Further investigations are required to compare the radiosensitivity based on nuclei size for cancer and healthy cell lines.

Teaching lecture: Using health economics to make the case for brachytherapy – HALYS, QALYS and DALYS

SP-0049 Using health economics to make the case for brachytherapy – HALYS, QALYS and DALYS

M. Milosevic[1], D. Rodin[2]
[1]Princess Margaret Cancer Centre , University of Toronto, Toronto, Canada; [2]Princess Margaret Cancer Centre , University of Toronto, Toronto, Canada

Abstract Text

Brachytherapy is essential in the definitive management of many gynecological cancers, including locally advanced cervical or vaginal cancers. However, brachytherapy is underutilized in many parts of the world despite clear dosimetric and survival advantages compared to even the most conformal EBRT techniques. Many factors may be contributing to this, including the costs associated with investing in new technology, training personnel and maintaining competency. In many low and middle income countries where gynecologic cancers are among the most common and most debilitating diseases, brachytherapy is not available at all and the investment needed to address this disparity is often perceived to be high and without economic payback. In more developed parts of the world, economic concerns about higher infrastructure and personnel costs often constrain the transition from 'one-size-fits-all' 2D brachytherapy to more conformal, image-guided techniques with the potential for improved tumor control and fewer side effects.
Investment in healthcare technology reflects a priority-setting process in which governments and payers decide how to allocate scarce healthcare resources. Economic evaluation provides decision-makers with common metrics to determine the value for money of investment in one healthcare tool over another.

M. Milosevic, Princess Margaret Cancer Centre and University of Toronto, Toronto, Canada
This presentation will review the economic evidence to support investing in image-guided brachytherapy for gynecological cancer from the perspective of patients, individual cancer treatment programs and the healthcare payer, with a focus on the cost-effectiveness of MR-guided brachytherapy for cervical cancer. The case will be made that best-practice MR-guided brachytherapy can be economically attractive compared to CT-guided brachytherapy or 2D brachytherapy by improving clinical outcomes and saving money. The path to scale-up of MR-guided brachytherapy in Ontario, Canada by assisting

policy-makers with future infrastructure and human resource planning will be outlined as a model that can be adapted to other jurisdictions and practice settings.

D. Rodin, Princess Margaret Cancer Centre and University of Toronto, Toronto, Canada
This presentation will provide an overview of the different forms of economic evaluation and health technology assessment tools and will apply these concepts to brachytherapy. Drawing from the cervical cancer literature, it will use a macroeconomic approach to healthcare investment and will review how cost-benefit analyses can demonstrate the health and economic benefits of radiotherapy in different resource settings. By viewing women with cancer as productive members of the labour force and of their community, a strong investment case for making brachytherapy available can be demonstrated to decision-makers.

Symposium: Single dose vs fractionated HDR monotherapy for prostate cancer

SP-0050 Single dose HDR brachytherapy is safe for low-risk prostate cancer

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Abstract Text

HDR brachytherapy is a well-established technique in prostate cancer most commonly used as a single dose boost with external beam treatment. It has also been explored as sole radiation modality in schedules delivering a radical dose over 2 to 4 or more fractions. Evidence from this experience has identified a dose of 36Gy in 4 fractions, 30-32Gy in 3 fractions and 26-27Gy in 2 fractions to all achieve high biochemical relapse free survival rates with low rates of genitourinary and gastrointestinal toxicity. Following on from this experience several groups have investigated the possibility of using a single dose of HDR brachytherapy for localised prostate cancer. Using a simple linear quadratic model the equivalent dose to the previous fractionated schedules using an alpha beta value of 1.5 is around 19-20Gy. There are now several cohorts of patients with low risk prostate cancer treated with monotherapy schedules of 19Gy with several years follow up. Safety, in terms of both acute and late toxicity is good with low rates of gastrointestinal and genitourinary toxicity and preserved erectile function. However there is uncertainty around efficacy with early (2 to 3 years) biochemical progression free survival rates of 60-94%. A phase II randomised trial of 19Gy vs 27Gy confirms a lower bPFS after 19Gy with relapses seen predominantly in the dominant nodule region at presentation. Two questions emerge from this: (1) is there a subpopulation for whom single dose 19Gy HDR monotherapy offers safe effective treatment (2) is fractionation essential in prostate cancer to achieve maximal cell kill or will higher single doses be the answer.

SP-0051 Single dose HDR prostate brachytherapy and residual disease

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[1]*University of Toronto, Radiation Oncology, Toronto, Canada*

Abstract Text

Single fraction HDR brachytherapy offers the potential to effectively treat prostate cancer in a single outpatient treatment, with significant cost savings, efficient use of resources, and great patient convenience. Based on radiobiological considerations, and assuming a low alpha/beta ratio for prostate cancer, it was hypothesised that 19 Gy in a single fraction would have similar biological efficacy to fractionated treatments such as 27 Gy/2, 34.5 Gy/ 3, 39 Gy/4, or 45 Gy/6. Several investigators reported outcome following single 19 Gy. Treatment was universally well tolerated with a virtual absence of late gastro-intestinal toxicity, late grade 3 urinary toxicity rates typically under 5%, and high preservation of patient quality of life(1). Although early reports with median follow-up in the range of 18-36 months reported high disease control rates (2), longer follow-up was invariably associated with an unacceptably high recurrence rate, with failure-free survival rates typically of 66-75% in a mostly favourable risk population (3). A randomized trial of 19 Gy x 1 or 13.5 Gy x 2 in low and intermediate risk patients has reported a local failure rate of 29% and 3%, respectively, with a median follow-up of 5 years (4). It is uncertain whether increasing the prescription dose to 20.5 Gy leads to better results – failure free survival was still only 62% for patients with Gleason 7 disease at a median follow-up of just over 4 years (5).

Recurrence following single HDR predominantly occurs in the area of initial disease (6). This led investigators to explore further dose escalation to the initial dominant intraprostatic lesion using an MRI-guided focal boosting technique (7). Unfortunately, despite focal escalation of dose to over 27 Gy, local disease persistence was still common, with a local relapse rate of 32% in a series of low and intermediate risk patients(8). Focal boosting at time of single fraction HDR did not improve local control rates. This observation calls into question the underlying radiobiological assumptions, suggesting that factors such as hypoxia and tumour heterogeneity may limit the efficacy of single fraction treatments, even when given to extremely high dose.

Disease persistence or recurrence following single fraction HDR, however, is usually amenable to local salvage. Of 34 patients in our clinical trial who experienced local failure, 21 have undergone local salvage treatment – 13 (62%) with focal HDR, 6 (28%) with salvage prostatectomy and the others (10%) with focal ablative therapies (1).

In conclusion, single fraction HDR, even with focal dose escalation is associated with an unacceptably high local recurrence rate. This most often occurs at the site of initial bulk disease and is usually amenable to further local salvage treatment.

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SP-0052 HDR prostate brachytherapy and fractionation; does it matter?

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Abstract Text

Analyses of prostate cancer radiation-response have suggested a high sensitivity to increased fractional doses; in other words, a low alpha-beta ratio in the linear-quadratic model. Assuming this "LQ" model, higher effective doses to the cancer ("Biologically-equivalent dose", or BED)—with a higher therapeutic ratio—would be achieved by increasing the fraction size, and decreasing the total dose.

High Dose-Rate (HDR) brachytherapy ("brachy")—as "boost" to external beam radiotherapy (EBRT)—has been a widely-employed standard of care for some groups of men in some centres since the late 1990s. Consequent to the insight on prostate cancer radio-sensitivity, there have been multiple reports of large numbers of men treated with increasingly high HDR brachy doses per fraction, and fewer numbers of fractions. Most of these reports have been single-arm series reporting increasing doses, but at least two randomised trials comparing brachy combined with external beam, with "equivalent" doses of EBRT alone, have favoured the brachy "boosts". Typical reported doses given in combination with EBRT increased from ranges such as four-times 5 Gy, or three-times 6 Gy, to two-times 9.5–15 Gy. Single fractions of 12.5–15 Gy in combination with EBRT have become the standard HDR boost dose in randomised trials (RTOG 0924 and 1115).

Increasingly, the EBRT component of the the "EBRT and HDR boost" has been dropped in favour of higher fractional doses given as HDR brachy "monotherapy". Recently this has been taken to the logical extreme of administering prostate HDR brachytherapy in single fractions of 19–21.5 Gy.

The cancer control in series reporting the outcomes from the large numbers of men treated in the non-comparative series of HDR-and-EBRT combinations—with long term followup (up to ten years)—has been encouraging: around 95% for low-risk men, 90% for intermediate risk and 80% for high-risk. Non-randomised comparative data also supports the conclusion that disease-control with HDR boosts might provide better control rates than EBRT alone, or even surgery, in at least men with high-grade disease.

Similarly, non-comparative reports of fractionated HDR monotherapy for prostate cancer have also suggested high rates of biochemical control for dose fractionated schemes such as eight-times 6 Gy, six-times 7 Gy, four-times 8.5–9.5 Gy, three-times 10.5–15 Gy, and two-times 12–13.5 Gy. In contrast a well-conducted *randomised* Canadian study reported on the comparison of a single fraction of 19 Gy (that would be expected—on the basis of linear-quadratic modelling—to be an iso-effective dose) to the other trial arm of 27 Gy in two fractions. This study showed inferior disease control results for the 19 Gy arm. Retrospective series from the United States and from Spain have also reported biochemical-control results at three- and six-years for low- and intermediate-risk groups of men treated with 19 Gy as a single fraction were lower than would be anticipated from reports of other HDR fractionation schemes.

HDR brachytherapy with decreased fraction numbers (and without external beam) is convenient for men, especially at the limit of single fractions. In short term follow-up of many prostate HDR-brachytherapy series, the treatments seem to be well-tolerated with low rates of acute complications. Late rectal and urethral injuries continue to occur more than a decade after treatment, and can be hard to accurately discern without disciplined and standardised followup. Some series report higher rates of late complications such as urethral strictures with long-term followup of HDR fractionation schemes with lower doses per fraction in series longer followup. Late complications from higher dose-per-fraction schedules and few or single fractions might become manifest in the next decade as they evolve and are reported.

Dose-fractionation fundamentally affects prostate cancer control rates and the likelihood of side-effects. HDR

brachytherapy treatments with doses such as 15 Gy in one fraction in combination with external beam seems effective and well tolerated. Fractionated HDR brachy monotherapy seems promising on relatively short-term followup, but the clinical outcomes from single fraction HDR monotherapy suggest doses higher than 19 Gy are required and seem discordant from what would be expected from simple LQ models. Better understanding of optimal HDR fractionation schedules, of the underlying radiobiological mechanisms, and their place in relation to other radiation or surgical treatments will rely on long-term followup of well-designed randomised comparative trials.

In a wider sense, the continued benefit of brachy for patients with prostate cancer relies on clinicians being able to give at least *one* fraction.This fraction matters.

SP-0053 LDR prostate brachytherapy is safe and effective for all localized prostate cancer risk groups

B. Davis[1]
[1]*Mayo Clinic and Foundation, Radiation Oncology, Rochester, USA*

LDR Brachytherapy is a safe and effective treatment for all risk groups of localized prostate cancer The presentation will address:

I. LDR brachytherapy: brief history, rationale and techniques
II. Permanent brachytherapy guidelines and management: risk groups, external radiotherapy and androgen deprivation
III. Long term outcomes of LDR brachytherapy: efficacy and toxicity

Symposium: Brachytherapy physics 2030 – Enhanced application and in-vivo treatment verification

SP-0054 Increasing the degrees of freedom with applicators

A. Damato.[1]
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Abstract Text

Brachytherapy has been successful in targeting the tumor while sparing surrounding normal tissues thanks to the basic principle of introducing the source of radiation directly into the tumor. Proper applicator/catheter placement is essential to optimal brachytherapy delivery. HDR dwell time optimization has permitted further customization of the treatment plan, but its impact is limited to what can be achieved with a given implant geometry and patient anatomy. Recently, new approaches have been attempted to further the customization of brachytherapy treatment plans, through (i) customization of applicators; (ii) enhanced customization of dose distribution; (iii) manipulation of the underlying anatomy. The status of the art for 3D printing of applicators will be covered, with a focus on future opportunities in the design of patient-specific applicators and an assessment of logistical and regulatory issues surrounding the medical use of this technology. Examples (e.g., custom applicator for intra-operative radiation treatments) will be discussed. A second novel approach to treatment plan customization is to maintain the basic implant geometry but utilize “modulated” brachytherapy optimization to permit preferential irradiation of the tissue on one side of the source instead of other. While this approach has historically been used in shielded applicator with little or no “modulation” of the shield during treatment, recent advances in rotating shield brachytherapy and other technological solutions have the potential of expanding the scope of shielded brachytherapy. Potential applications in prostate and gynecologic brachytherapy will be presented. Finally, custom modification of anatomy using spacer gels has been used to permit escalation of dose to the tumor while limiting the complication probability to the displaces organ. Examples in prostate and gynecologic brachytherapy will be presented.

SP-0055 Update by the ESTRO task group on in vivo dosimetry in brachytherapy

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Abstract Text

The steep dose gradient is one of the benefits of brachytherapy as it enables delivery of high doses to the target while sparing healthy tissues leading to excellent clinical outcome. At the same time, it also puts high constraints on the treatment accuracy. This, together with the several manual steps involved in brachytherapy, makes it important to perform treatment delivery verification. The most direct way to verify the dose delivery is through *in vivo* dosimetry, where the dose is measured during delivery. The steep dose gradient puts high constraints on both the internal and positional accuracy of any *in vivo* dosimetry system. Currently, there are no commercially available system that has the sufficient accuracy and treatment delivery verification is not routinely available in brachytherapy. This has led, in some cases, to systematic errors going unnoticed for years.
In 2017, an ESTRO task group was established to investigate how to enhance the clinical implementation of *in vivo* dosimetry in both external beam radiotherapy and brachytherapy. This presentation will report on the findings of the brachytherapy part of this task investigation.
it was found that the likelihood of detecting deviations from the treatment plan increases significantly with time-resolved methods. Time–resolved methods could interrupt a treatment avoiding gross errors which is not possible with time-

integrated dosimetry. In addition, lower experimental uncertainties can be achieved by using more advanced techniques such as source-tracking instead of direct dose measurements, fig. 1. However, the detector position in relation to the patient anatomy remains a main source of uncertainty.
Several time-resolved systems have been developed and tested in laboratories, but only few are used clinically. The development was found to be driven by research groups and small start-up companies. These new systems use different techniques such as point detectors, flat panels and pin-hole detectors. All with their own pros and cons. It is of utmost importance that the sensitivity to different types of errors is well understood for each system as this will enable the end-users to select the most suitable method for their needs.
The many new developments within dosimetry systems for brachytherapy bodes well for the future use of *in vivo* dosimetry. The next steps towards clinical implementation of *in vivo* dosimetry will require clinical trials and systematic reporting of errors and near-misses.

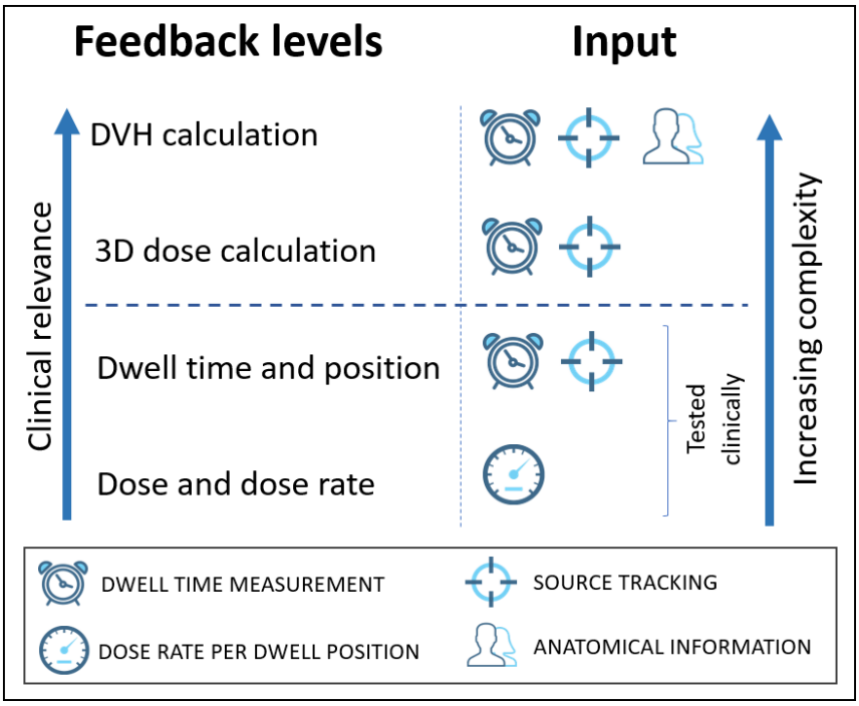

Figure 1: Feedback levels and corresponding necessary measurement inputs.

SP-0056 In vivo HDR brachytherapy source tracking with point dosimeters: current status and future directions

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Abstract Text

Brachytherapy has been proven to be an effective radiotherapy modality for a number of treatment sites including the breast, prostate and cervix. However, it is also recognized that amongst patients who have received brachytherapy as part of their treatment that up to 15% of such procedures may result in sub-optimal dose distributions.
There has therefore been an increased focus within the brachytherapy community in recent years towards more comprehensive treatment validation. One form of treatment validation that is beginning to be utilized is in-vivo source tracking, through the use of either two-dimensional detector arrays or single point detectors.
A review of the literature reveals that in-vivo source tracking techniques using two-dimensional arrays placed beneath a patient have been shown to have the ability to track the brachytherapy source to within 2 mm relative to the patient anatomy, whilst detector arrays integrated into transrectal ultrasound imaging devices can measure a dwell position with sub-millimetre accuracy, and point detectors placed within a catheter or on an applicator have measured shifts in dwell positions (relative to the detector) on the order of 0.5 mm.
In this talk I will discuss the potential advantages of in-vivo source tracking using point dosimeter arrays as compared to performing in-vivo dosimetry, particularly in the context of the steep dose gradients experienced in brachytherapy. Desirable detector properties for performing in-vivo source tracking will be outlined, with particular reference to the angular dependence and detector sensitivity.
I will also give an overview of the evolution and current status of novel detector systems developed at the Centre for Medical Radiation Physics that have been applied to in-vivo source tracking in HDR brachytherapy at St George Cancer Care Centre, Sydney and the Fondazione IRCCS Istituto Nazionale Tumori, Milan.
Finally, beyond the suitability of the detector type selected for in-vivo source tracking, there are several additional practical and philosophical challenges that must be overcome when implementing a successful in-vivo source tracking system. For example, the question of what is an appropriate in-vivo source tracking error threshold. I'll conclude this talk

by presenting the current status of in-vivo source tracking in overcoming these challenges and discuss the outlook of in-vivo source tracking for HDR brachytherapy as the community moves towards more comprehensive treatment validation.

SP-0057 In vivo source tracking with imaging panels and fluoroscopy

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Abstract Text

Purpose: Reported brachytherapy incidents affecting a large number of patients raise relevant concerns about safety and treatment verification. The clinical acceptance of the methods currently available for estimating the delivered dose in BT is limited due to the absence of adequate commercial systems, large uncertainties, and laborious methods. Time-resolved measurements using imaging panels (IPs) can overcome several of the current technical limitations. However, considerable efforts are necessary to implement such technology in clinical practice. This talk will provide an overview of current developments, main challenges, uncertainties and clinical trials using source tracking. In addition, we will present results obtained using an IP for source tracking aiming to evaluate the sensitivity of the panel and the possibility to combine source tracking with anatomical information.
Materials/Methods: A 3D printed pelvic phantom (Figure 1), based on a brachytherapy prostate patient, was made with 4 holes for the insertion of tissue-mimicking inserts, a "rectum" (cavity for the insertion of an ultrasound probe), and a template for needle insertion allowing several implant configurations. Two radiopaque markers (spheres with d ≈ 1mm) were placed at the back of the phantom to register CT coordinates and IP measurements. Different arrangements were tested with 4 tissue-mimicking inserts (cortical bone, inner bone, muscle, solid water, and adipose tissue). Different needle arrangements (4 – 9 needles) dwell times (0.3 – 1s) and interdwell distances (1 – 5 mm) were used to verify the IP sensitivity. In addition, IP acquisitions were performed using 0.139 and 0.278 mm spatial resolution and acquisition rates up to 33 fps.
Results: source movements <1mm are detected comparing consecutive frames whilst dwell positions are identified when the source dwells for at least 2 consecutive frames. Therefore, the acquisition rate should be at least 2 to 3 times higher than the desired measurement uncertainty. All dwell positions were identified (figure 2) with acquisition rates ≥ 20 fps with and standard deviation (k=1) around 0.02 s. Higher acquisition rates (> 9 fps) require a lower spatial resolution, which didn't affect source tracking capabilities. Radiopaque markers were clearly visible in both planning CT and IP measurements. Results obtained with different tissue-mimicking inserts showed differences in imaging intensity >10%. In addition, the ultrasound probe is visible in the IP images providing another geometric reference related to the patient anatomy.
Conclusion: The evaluated IP has submillimeter accuracy and acquisition rates (≥20 fps) allowing dwell time measurements with an accuracy superior to 0.1s. IP acquisitions include geometric information (e.g. ultrasound sound probes) that can be related to the patient anatomy. In addition, the evaluated IP is sensitive to the material composition and could allow the use of patient anatomy as a reference.

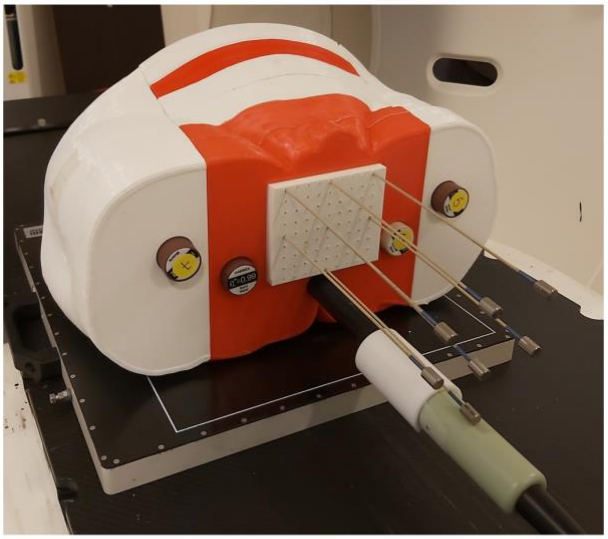

Figure 1. 3D printed phantom based on a HDR prostate patient including tissue mimicking inserts, an ultrasound probe and 7 needles.

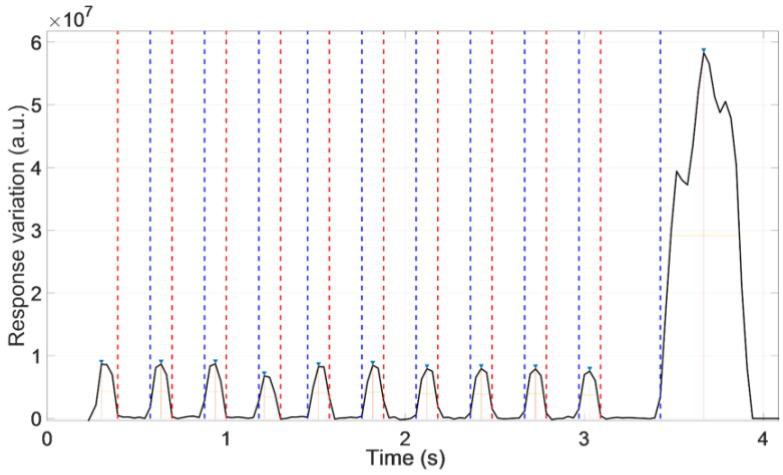

Figure 2. panel response variation used to identify dwell positions showing the worst-case scenario with 1 mm interdwell distance and 0.3s dwell time. Results acquired with 33 fps. The vertical dashed lines indicate dwell positions.

Proffered papers: Treatment outcomes cervix

OC-0058 Does dose to the ureter predict for ureteral stenosis? - Analysis of 3D MRI-based brachytherapy

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Purpose or Objective
Image-guided brachytherapy (IGBT) allows for accurate delineation of target/organs at risk and treatment planning optimization based on a dose-volume histogram. Ureteral stenosis (US) is a known complication from IGBT; however, no dosimetric parameter has been associated with ureteral toxicity. The present study was undertaken to see if dose to the ureter predicts risk for US.

Materials and Methods
All cervical cancer patients treated with MRI-based IGBT between 2007-2017 were identified. Patients who developed late grade ≥3 US, including those with hydronephrosis at diagnosis who had persistent hydronephrosis (chronic nephroureteral stents/nephrostomy tubes required due to unresolved US), were identified (n=18). Late grade ≥3 US was defined according to CTCAE 4.03 as symptomatic with altered organ function requiring elective intervention (radiologic, endoscopic, or operative), occurring in the absence of tumor progression at 3 months or later after brachytherapy. A control group of 36 patients (72 ureters) without late grade ≥3 US, and who had no evidence of tumor recurrence or disease progression at last follow-up, was also analyzed. For each patient, both ureters were retrospectively contoured on the planning MRI for every brachytherapy fraction. The dose to 0.1 cm3 of ureter (D0.1cm3) was extracted from dose-volume histograms. All doses were converted to the biologically equivalent dose in 2-Gy per fraction (EQD2), applying the linear-quadratic model (α/β = 3). Mean D0.1cc values for affected (late grade ≥3 US) and unaffected ureters were compared with the Student's t-test and Mann-Whitney U test, wherever applicable. The dose-effect correlations were tested using the logistic regression analysis with the Probit model.

Results
A total of 18 patients developed late grade ≥3 US, of which 7 had pre-existing hydronephrosis. Among these patients, 36 ureters were retrospectively contoured (24 affected and 12 unaffected). A total of 108 ureters were analyzed. The mean cumulative D0.1cm3 for affected and unaffected ureters was 90.7 ± 16.9 Gy and 76.1 ± 11.8 Gy, respectively (p<0.01). Among patients without pre-existing hydronephrosis (11 patients who developed US and 33 controls, with n=88 ureters for analysis), the mean difference in D0.1cm3 between affected (n=14) and unaffected (n=74) ureters was 8.1 Gy (affected ureters mean D0.1cm3 = 82.2 Gy ± 12.3 Gy; unaffected ureters mean D0.1cm3 = 74.1 ± 10.6 Gy; p=0.02). Among patients with pre-existing hydronephrosis (7 patients who developed US and 3 controls, with n=20 ureters for analysis), the mean difference between affected (n=10) and unaffected ureters (n=10) was 11.6 Gy (affected ureters mean D0.1cm3 = 102.5 ± 15.6 Gy; unaffected ureters mean D0.1cm3 = 90.9 ± 9.3 Gy; p=0.06). Ureters with D0.1cm3 ≥77 Gy had a 28.6% incidence of late grade ≥3 US compared to 7.5% in those with D0.1cm3 <77 Gy (OR 2.39; 95% CI 1.23-4.65; p=0.01).

Conclusion
This is the first study to report a dose-effect relationship for US. Ureteral dose ≥77 Gy to D0.1cm3 correlates with development of late grade ≥3 US. Future studies should look at ureter as avoidance structure to decrease risk of US.

OC-0059 Clinical characteristics and risk factors for local failure in cervix cancer patients after MR IGABT

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Purpose or Objective
To report clinical and treatment characteristics and risk factors for local failure (LF) from the prospective observational multi-centre IntErnational study on MRI-guided BRAchytherapy in locally advanced CErvical Cancer (EMBRACE)

Materials and Methods
Data from 1416 patients with locally advanced cervical cancer treated from 2008-2015 in 24 centres was prospectively collected. Treatment consisted of external beam radiotherapy (EBRT) with 45-50Gy (1.8-2.0 Gy per fraction), concomitant chemotherapy (CHT) and MRI based image-guided adaptive brachytherapy (IGABT). Patient, tumor (clinical and MRI features at diagnosis & BT) and treatment related parameters (EBRT, CHT and BT details, dose volume parameters, total doses and overall treatment time (OTT)) were compiled and analysed. A LF was defined as progressive or recurrent disease in the cervix, uterus, parametria or vagina. Kaplan-Meier method was used to estimate survival and Cox proportional regression models were used for multivariable analysis (MVA). HR are estimated with significance level as $p< 0.05$

Results
1318 patients (local FIGO stages: IB1: 127, IB2: 122, IIA1:37, IIA2: 34, IIB: 731, IIIA: 16, IIIB: 211, IVA: 39) with a median follow-up time of 51 months were available for this analysis. In total, 98 LFs were observed. The 5yr local control rate was 92% (FIGO IB1: 97% IB2: 92% IIA1: 91%, IIA2:90%, IIB: 91%, IIIA: 92%, IIIB: 91%, IVA: 89%). 48% of LF had simultaneous nodal or systemic disease. Median survival after LF was 10 months (1yr/3yr overall survival: 48%/13%).
In MVA, histology, D90 of CTV_{HR}, CTV_{HR} volume >45cm^3, OTT, presence of tumor necrosis on MRI at diagnosis, uterine corpus infiltration at diagnosis and at BT and mesorectal infiltration at BT had significant impact on LF. FIGO stage, nodal status, age and vaginal/parametrial/bladder infiltration at diagnosis and at BT, hemoglobin level, WHO performance score, menopausal status, smoking history and number of chemotherapy cycles were not significant.

Conclusion
MRI-based IGABT overcomes the impact of FIGO stage on local tumor control and leads to excellent local tumor control across all stages. Patients with LF have poor outcome. The cumulative dose (D90 for CTV_{HR}) and the OTT are the crucial treatment-related factors for local tumor control in MRI based IGABT of cervical cancer.

OC-0060 Prediction of treatment response in patients with cervical cancer using midtreatment PET/MRI

Abstract withdrawn

OC-0061 Phase III randomized trial of trans-abdominal ultrasound in intra-cavitary brachytherapy in Cervix

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Purpose or Objective
Intra-cavitary brachytherapy (ICB) remains an integral part of radiotherapy treatment in cervical cancer. Two-dimensional X ray point-based planning remains common and blind insertion leads to uterine perforations and higher toxicity. We conducted a randomised controlled trial of using trans-abdominal ultrasound in performing ICB to reduce perforation and organ at risk doses.

Materials and Methods
The present study is a phase III open label randomised controlled trial of ultrasound guided ICB conducted on invasive cervical cancer patients. Patients were randomized by a simple computer-generated randomization chart into Arm A (No Ultrasound guidance) and Arm B (ICB with ultrasound guidance). The uterine perforation rates, tandem length change rates, bladder doses, rectal dose and procedure times were compared. Fischer exact test was used to compare the arms and p value < 0.05 considered significant.

Results
A total of 160 patients were randomised. With US assistance, the uterine perforation

rate was 1.25% (n =1). In the non-US assistance arm the perforation rate was 12.5% (n = 10) (p = 0.005). Mean time to complete the entire procedure was significantly shortened from 26 minutes to 19 minutes favouring the US arm (p = 0.001). Dosimetric assessment between the two groups showed significant decrease in dose received by the various organs at risk with US assistance.

Conclusion
The present study confirms significant improvement in application quality as well as dosimetry with reduction in procedure time. Trans-abdominal US should be routinely used for ICB procedures, particularly in resource limited settings

OC-0062 Comparision Of Two Hdr Intracavitary Brachytherapy Regimens In Treatment Of Cervical Cancer

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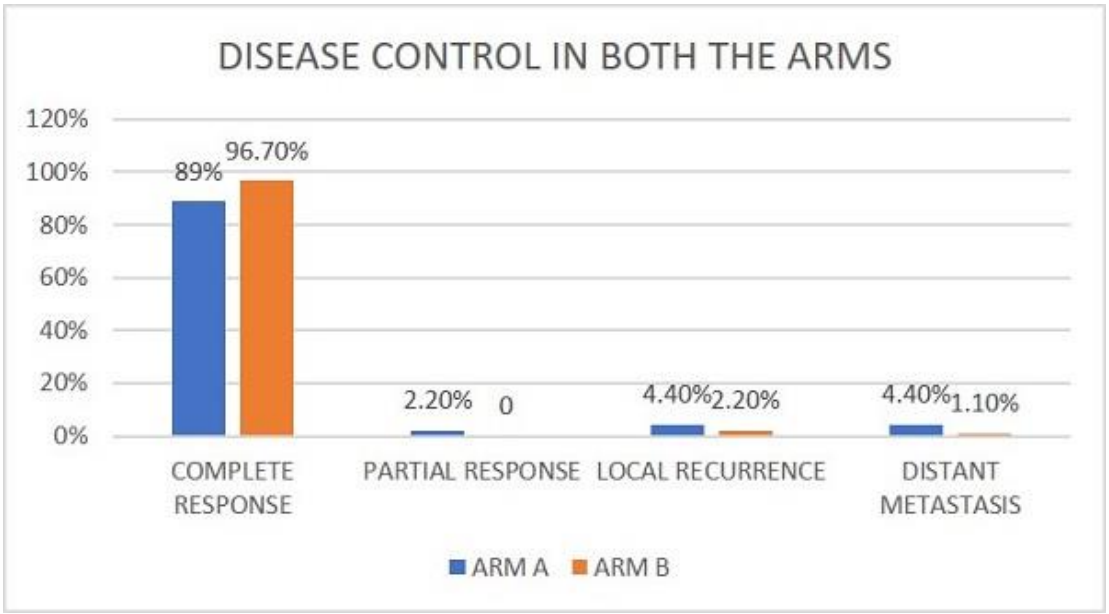
Purpose or Objective
Carcinoma of the uterine cervix is one of the common malignancies among Indian women. Radiation therapy including external beam radiotherapy(EBRT) and intracavitary brachytherapy (ICBT) plays a pivotal role in patients with locally advanced disease. HDR ICBT for carcinoma of the cervix is now well established because of its various advantages. Although there are three decades of published literature on the efficacy of HDR brachytherapy, optimum time, dose, and fractionation is not very well defined. Two fractions of high-dose-rate brachytherapy are convenient for patients, but most radiation oncologists fear that they could lead to excessive rectal or bladder toxicity.
The objective of this study was to assess and compare the local control and toxicities between HDR Intracavitary Brachytherapy with 7.5 Gy per fraction in three fractions (Arm A) and 9 Gy per fraction in two fractions (Arm B) post EBRT in treatment of carcinoma cervix.

Materials and Methods
A total of 180 patients meeting the inclusion criteria were included in the study and randomly assigned to 2 arms of 90 patients each. All patients received concurrent chemoradiation to a dose of 50 Gy in 25 fractions along with weekly cisplatin. Post chemoradiation, arm A received HDR ICBT with a dose of 7.5 Gy per fraction, 1 fraction per week for 3 fractions and arm B received HDR ICBT 9 Gy per fraction , 1 fraction per week for 2 fractions. Patients were evaluated monthly for assessment of local control and toxicities. Statistical evaluation was done with mean, percentage and frequency using Chi Square , Student T test.

Results
180 patients were included in the study with 90 patients in each arm. The total duration of treatment was significant less in Arm B compared to Arm A (59 days vs 68 days, p<0.0001). 80 (89%) patients in arm A, had complete response at 6 months. 2(2.2%) patients had partial response and 4(4.4%) patients had local recurrence. In Arm B, 87 (96.7%) of the patients had complete response and was statistically significant (p=0.040). 2(2.2%) patient had local recurrence in the cervix.
Grade 2 and above diarrhea was seen in 4.4% of the patients in arm A and in 7.7% of patients in arm B. Grade 2 and above proctitis was seen in 3.3 % of the patient in arm A and in 6.6 % of the patients in arm B. One patient in arm B had Grade 4 proctitis. Grade 2 urinary tract pain was seen in 10 (11.1%) patients in arm A and in 6 (6.7%) patients in arm B. One patient each in arm A and arm B had grade 1 hematuria.



Conclusion
This study, with intracavitary brachytherapy with 9 Gy in 2 fractions showed a better local control of tumour compared to 7.5 Gy in 3 fractions. Although there was no statistical significance, our study showed a slightly higher rate of rectal toxicities in the 9 Gy arm which could be managed medically. The study also highlighted the need for completion of total treatment of EBRT and brachytherapy within 60 days to reduce the recurrence rates.

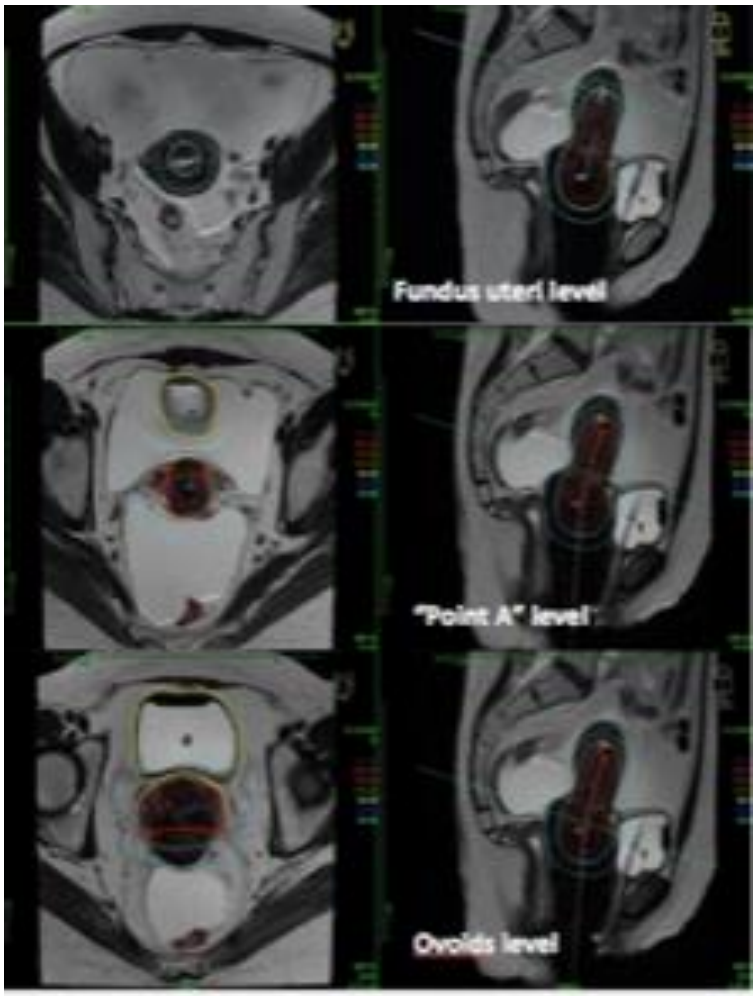


Fig.1 Example of a patient with 2000 cc of peritoneal saline.

OC-0063 Peritoneal spacing reduce OAR dose in cervical cancer BT. Preliminary results of a pilot study

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Purpose or Objective
We present the early dosimetric results of a peritoneal spacing technique for GYN brachytherapy

Materials and Methods
300 pts with cervical cancer consecutively treated between 2013-20 were included. All had 45 Gy EBRT/CDDP40mg/m^2 plus MRbased HDR IGABT (Utrecht applicator 92.3% with parametrial needles). Pts received 4BT fx of 7Gy in 2 applications within 7-10 days. Implantation was under anaesthesia and US guidance. In April 2019 we started a prospective pilot study to explore benefit and limitations of *peritoneal spacing* to reduce dose to OAR. Since then 82 pts were treated. 70 were included in the study; 12 were excluded (age, physic conditions or refusal). Different amounts (100-2500cc) of saline (progressively increasing over time) were introduced in peritoneal space through vaginal fornix under US guidance Fig1. At the beginning the peritoneal filling was realized in one application (1st implant) and after taking some confidence with the technique, at 1st and 2nd implant. After implant pts underwent simulation imaging (1.5T MR and CT). Applicator was reconstructed on MR images and OAR/HRCTV delineated (GEC recommendations). Dose was optimized upon a system of *hard and soft* constraints (EBRT+BT). *Hard constraints* were: HRCTV D90 >86 Gy_{EQD2} Bladder D2cc<90 Gy_{EQD2} RectumD2cc<70

Gy_{EQD2} Sigmoid D2cc<75Gy_{EQD2}. *Soft constraints* were: Bladder D2cc<80Gy_{EQD2} RectumD2cc<60 Gy_{EQD2} Sigmoid D2cc<65Gy_{EQD2}. Following day, after simulation and dose re-planning the 2ndBT fx was delivered and implant removed under sedation. After blood tests pts leave the hospital in the evening or the morning after.

Results
230 pts received 460 applications before April 2019. In this group, dosimetric results (APL1 fraction 1 and APL2 fraction 3) were the following: HRCTV D90 10.7±1.6Gy EQD2; Bladder D2cc 8.8±4.2Gy EQD2; Rectum D2cc 4.7±2.3Gy EQD2; Sigmoid D2cc 5.3±1.8Gy EQD2.
Pts included in peritoneal filling protocol received overall 140 BT fx. In 125 of these, variable amounts of buffer saline were introduced in the peritoneal space. Dosimetric results (APL1 fraction 1 and APL2 fraction 3) were the following: HRCTV D90 10.6±0.7Gy EQD2; Bladder D2cc 7.1±2.4Gy EQD2; Rectum D2cc 3.6±1.9Gy EQD2; Sigmoid D2cc 3.6±1.5Gy EQD2. With the exception of HRCTV D90, the dose difference for OAR with or without peritoneal filling was statistically significant. On average the dose de-escalation to OAR due to peritoneal spacing was 19.3% for bladder, 23.7% for rectum and 31.3% for sigmoid

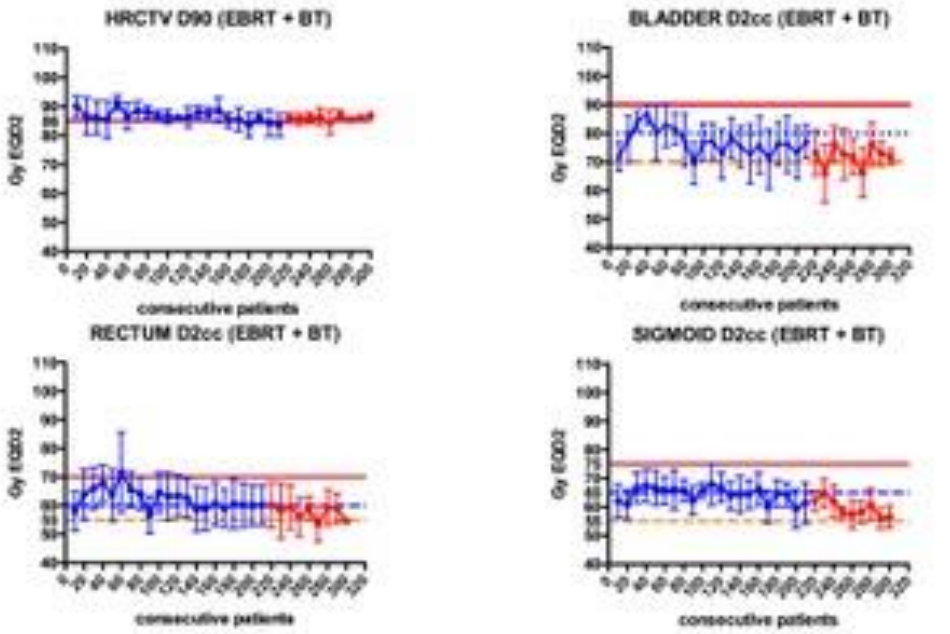

Fig 2. Dosimetric results without (blue dots) and with (red dots) peritoneal spacing. Each point represent the average value (with SD) of 10 consecutive patients. Red continued lines represents "hard constraints". Blue dotted lines represents actual "soft constraints". Orange dotted lines represents a new set of "soft constraints" possibly achievable with peritoneal spacing technique

Conclusion
In our preliminary experience peritoneal filling is safe, well tolerated, inexpensive and do not prolong patient's hospitalization. After introducing peritoneal filling in our routine, we are foreseeing to reduce our OAR "soft constraints" according the following values: Bladder D2cc<70 Gy_{EQD2}, RectumD2cc<55 Gy_{EQD2}, Sigmoid D2cc<55Gy_{EQD2} (Fig2).

Proffered papers: Treatment verification

OC-0064 First clinical results of integrated EM tracking for pre-treatment verification in prostate BT

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Purpose or Objective
Accurate dose delivery is paramount in hypofractionated prostate HDR brachytherapy (BT) due to tight dosimetric constraints and high dose gradients. To achieve this, pre-treatment verification of the implant location and geometry is necessary. Electromagnetic tracking (EMT) has been proposed for this challenging task. A prototype of an integrated EMT/BT system is currently available, which consists of a Flexitron afterloader with an EMT sensor (Elekta, Veenendaal). Using this sytem, we have demonstrated in phantom experiments an accuracy of less than a millimeter for a prostate workflow in typical clinical environments (OR, CT, and irradiation room). The purpose of this study is to analyze prospectively the clinical feasibility of using this system for pre-treatment verification in prostate HDR BT patients. In particular, the impact of motion correction using reference sensors was quantified.

Materials and Methods
Twenty prostate patients with up to 26 needles, treated with 2 fractions of US/CT guided HDR-BT, were included in a prospective study. EMT measurements, in which the EMT sensor was automatically moved by the afterloader through the

implant according to the predefined treatment plan, were performed after CT imaging and after dose delivery. We analyzed 21 data sets (belonging to 12 patients) in which the positions of 3 external and 1 internal reference sensor were measured concurrently to correct for patient motion. Therefore, the measurements of the integrated EMT sensor were corrected at each point in time. This was done by subtracting either the deviation of the three external reference sensors from their overall mean position or the deviation of the internal reference sensor from its overall mean position. Next, the corrected and uncorrected EMT-measured dwell positions were registered to their planned dwell positions (reconstructed from the CT images).

Results

The residual errors, defined as the Euclidean distances between the planned dwell positions and the corrected and uncorrected EMT measurements, were calculated and summarized in table 1. For one individual data set (19) with a relatively large mean residual error, correction using an internal reference sensor significantly decreased the mean residual error (fig.1).

	Mean residual error (mm)	Range of max. residual errors per data set (mm)
Uncorrected EMT measurements	1.8 (range 1.1 – 4.4)	2.5 – 9.5
EMT measurements corrected with 3 external reference sensors	1.9 (range 1.4 – 3.0)	3.6 – 8.6
EMT measurements corrected with internal reference sensor	1.7 (range 1.1 – 2.2)	2.2 – 7.7

Table 1: Mean and maximum residual errors for the 21 data sets

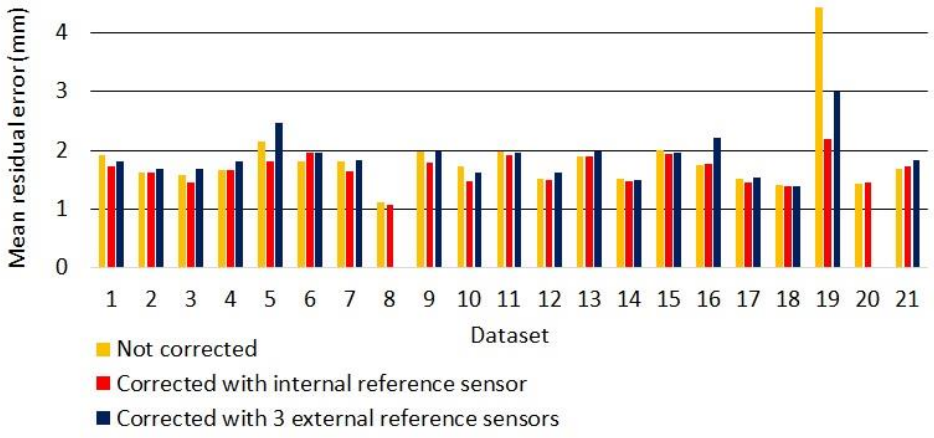

Figure 1: Mean residual errors for the 21 data sets

Conclusion

The low mean residual errors demonstrate the clinical feasibility of EMT for pre-treatment verification in HDR-BT prostate patients. False positive errors can be reduced by using an internal reference sensor.

OC-0065 Real-time electromagnetic guidance for GYN interstitial HDR brachytherapy: a proof-of-concept

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Purpose or Objective

The EMBRACE trial has demonstrated the need for interstitial catheters in gynecologic (GYN) high dose rate (HDR) brachytherapy and is a key part of the EMBRACE II trial. However, no commercial solution allows for real-time guidance of interstitial catheter placement. The goal of this proof-of-concept study was to evaluate the feasibility of an electromagnetic (EM) tracking system guidance workflow for GYN HDR brachytherapy treatment in a magnetic resonance imaging (MRI) and real-time transrectal ultrasound (TRUS) fusion scenario, bringing the high soft-tissue contrast of MRI, and high accuracy catheter guidance and reconstruction of EM tracking together.

Materials and Methods

The new real-time TRUS-guided EM-enabled HDR planning system prototype developed by *Philips Disease Management Solutions* was used. The EM tracking system calibration as well as the TRUS-to-EM registration were performed using the manufacturer protocol, and the reconstruction accuracy was evaluated in a water phantom. For this proof-of-concept study, the MR image of a patient treated with the ring applicator (*Elekta Brachytherapy*) was retrospectively selected. 3D T2 weighed MR images were acquired with a 1 mm isotropic resolution. The implant consisted of an intracavitary and interstitial brachytherapy applicators (intrauterine tube, ring and needles). A flexible EM sensor was created to fit the applicator inner channel and to automatically reconstruct the ring and intrauterine tube. The same implant was then reproduced in a water phantom to simulate a live TRUS-EM guided procedure. The planning system fusion tool was used to register the planning MRI and the TRUS scan. Finally, catheters insertion were guided and reconstructed using the EM tracking system and their positions were compared to the US scan.

Results

The accuracy of the EM tracking system was within 1 mm for both sagittal and transverse modes of the TRUS probe. For the proposed workflow, a target contour was delineated on the MRI in the HDR planning system segmentation tool. To optimize needle insertion, a pre-implant plan was generated. The fusion between the MRI and the acquired TRUS scan was then based on the applicator. The target delineated on the MRI was propagated on the TRUS (figure 1). It was possible to complete in real time the implant with the additional planned needles to improve the target coverage. The needle insertion was guided using the EM tracking system on the live TRUS image (figure 2). Needles and applicator were automatically reconstructed using the EM sensor. The reconstructed applicator and needles overlap perfectly with the TRUS images. The planned dosimetry was updated regarding the final implanted positions.

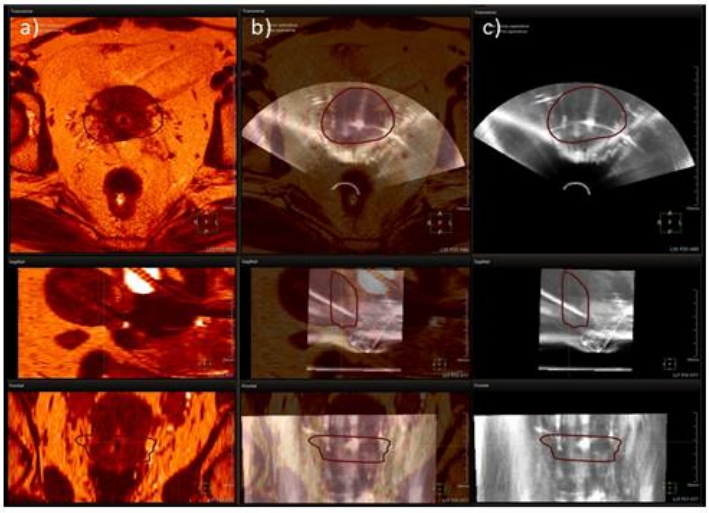

Figure 1: Axial, sagittal and frontal views of the MRI (a), the MRI-US fusion (b) and the US (c). Registration was made with the fusion tool and was based according to the ring applicator and the intrauterine tube. The target (in red) was delineated on the planning MRI and was propagated on the US based on this fusion.

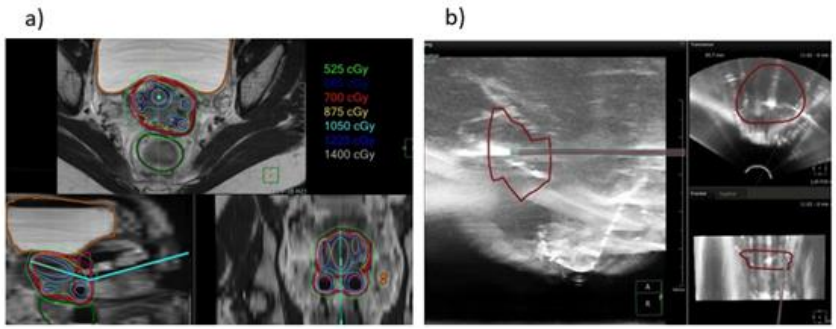

Figure 2: A pre-plan was made based on the MRI image set and contours (a). The implant was then reproduced in water. The insertion guidance was based on the MRI delineated target and pre-plan (contour in red). The needle was tracked real time using the EM tracking system and the US system. The tracked needle is shown and the automatic reconstructed needle fits with the US scan (b).

Conclusion

Based on this proof-of-concept, it could be possible to accurately guide the needle insertion for GYN HDR. The interstitial needle positions can be directly plan based on the MRI with the applicator in place to ensure optimal target coverage and guide in real time with the EM tracking system and TRUS imaging.

OC-0066 A multi-sensor-based dosimetry platform for real time source tracking in HDR brachytherapy

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Purpose or Objective
The aim of this study is to perform 3D source position reconstruction by combining in vivo dosimetry measurements from two independent detector systems.

Materials and Methods
Time-resolved dosimetry was performed during HDR brachytherapy irradiation with ^{192}Ir source using two detector systems. The first system was based on a multiple plastic scintillator detector (mPSD) system using BCF-60, BCF-12, and BCF-10 scintillators (1 mm core). The mPSD signal was monitored using a compact assembly of photomultiplier tubes, dichroic mirrors and filters at a rate of 100 kHz [1]. The second system was an inorganic scintillation detector (ISD) based on CsI:Tl (1.0 mm-diameter and 0.5 mm-long). The ISD signal was monitored with a Si-diode photodetector at a rate of 20 Hz. Brachytherapy treatments were simulated in water under TG-43U1 conditions, including an HDR prostate plan. Treatment needles were placed in distances covering a range of source movement of 120 mm around the detectors. Each scintillator-to-source distance was determined based on the measured dose rate. The three distances given by the mPSD were recalculated to a position along the catheter (z) and a distance radially away from the mPSD (xy) for each dwell position (a circumference around the mPSD). The absolute source location was extracted from the intersection between the mPSD's predicted circumference and the sphere around the ISD (Fig.1a). The uncertainty in the measured dose rates was transformed into uncertainty bands on the distances, and intersection areas were determined, Fig.1b.

Results
Approximately 4000 source dwell positions were tracked. An mPSD-ISD intersection was observed in 77.2 % of the dwell positions, assuming no uncertainty in the dose rate determined distance (0σ). This increased to 100 % if 1σ search regions were added. However, only 73(96) % of the expected dwell positions were found within the intersection band for 1(2) σ uncertainties. The agreement between the source's reconstructed and expected positions was within 3 mm for distances to the source up to 50 mm (fig 1d). The experiments on an HDR prostate plan (fig 2a), showed that having at least one of the detectors located in the middle of the prostate volume reduces the measurement deviations considerably compared to scenarios where the detectors were located outside of the prostate volume. The analysis showed a detection probability that generally, is far from the random detection threshold (fig 2b). Errors of 1(2) mm can be detected in ranges of 5-25 (25-50) mm from the source, with a true detection probability rate higher than 80 %, while the false probability rate is kept below 20 %.

Conclusion
By combining two detector responses, we enabled the determination of the absolute source coordinates. The combination of the mPSD and the ISD in vivo dosimetry constitute a promising alternative for real-time 3D source tracking in HDR brachytherapy.

[1] Linares Rosales et *al.*, Med. Phys. 47 (9), 2020.

OC-0067 Establishing a Fingerprinting Method for Fast Catheter Identification in HDR Brachytherapy

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Purpose or Objective
To use observables that can be measured with in vivo dosimetry, source-to-dosimeter distance and dwell-time, to build identifiers, or fingerprints, which leads to a fast catheter identification to detect brachytherapy errors, e.g. swaps or positional shifts of catheters. It was also possible to determine the number of dwell-positions needed to uniquely identify a specific catheter and the optimal dosimeter location.

Materials and Methods
A previously treated cohort of 360 patients diagnosed with prostate cancer who underwent high dose rate brachytherapy (16-25 catheters) was used. Based on the cohort, the number of dwell-positions needed to uniquely identify a specific catheter from all others for a given fingerprint approach was retrospectively explored. A detector was placed virtually at multiple positions in every treatment plan and the observables source-dosimeter distance (related to dose-rate) and dwell-time were determined for each dwell position in each catheter. These in vivo measurable quantities were compared across all catheters in a treatment dwell position by dwell position. A catheter was considered uniquely identified, if no other catheter had a dwell-position (same ordinal number) with its measurable within a given range. The source-dosimeter distance was further separated between radial (r) distance and vertical (z, parallel to the catheter insertion).

Results

When using only source-detector distances, catheters were uniquely identified after 7 dwell-positions, when no measurements uncertainty was considered. With independent dwell-time measurements, all catheters were uniquely identified after five dwell-positions (Fig. 1). Those measurable quantities have uncertainties which must be taken into account. With a 1 mm positional uncertainty (r,z), all catheters were identified in 97% of the plans, with the remaining 3% having one catheter pair not identified. Adding a 0.1s time uncertainty resulted in the identification of all catheters within only 3 dwell positions. As seen in Fig. 2, 3 groups of curves could be classified by the distance between the dosimeter and the implant center. The number of dwell positions needed to uniquely identify each catheter decreased with the distance

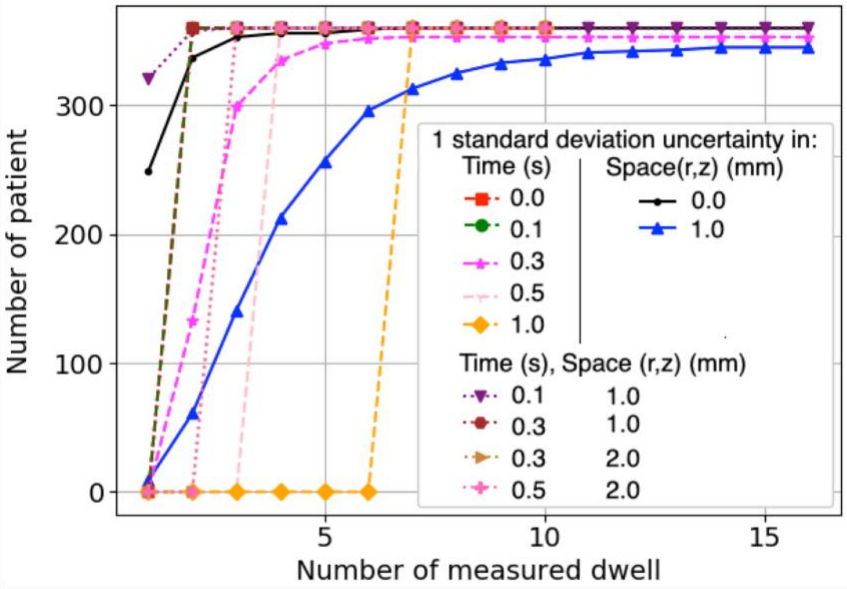

Figure 1. Number of measured dwell-positions needed to uniquely identify all catheters in a treatment for different uncertainty criteria (one standard deviation) on source-dosimeter distance (i.e. source tracking) and dwell-time measurements. The simulated dosimeter was placed in the catheter closest to the rectum.

(Fig. 2).

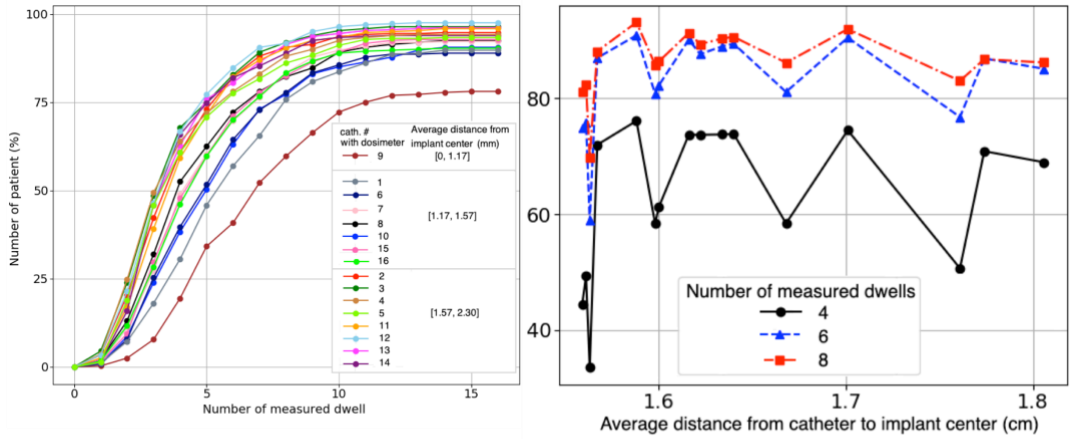

Figure 2. Number of patients with all catheters identified as a function of the number of measured dwell-positions for various dosimeter location inside a needle 1 to 17. Needle 18 to 25 were not shown here because there was less then 5 patients who had that many catheters. The one standard deviation positional uncertainty was r, z = 1 mm.

Conclusion

The most efficient fingerprinting approach involved combining both source-dosimeter distance (i.e. source tracking) and dwell-time, the latter being a strong differentiator. Combining those observables and using uncertainties that are experimentally achievable (1 mm and 0.1s), a catheter can be uniquely identified after the delivery of only three dwell-positions. Fingerprinting could therefore enable a fast and robust identification of potential delivery errors. The results indicate that the fingerprinting method is more efficient the farther the dosimeter position is from the center of the implant.

OC-0068 Accuracy of a source-tracking method based on in vivo dosimetry for HDR prostate brachytherapy

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Purpose or Objective
To determine the accuracy of an in vivo dosimetry based source tracking (ST) method for high-dose-rate (HDR) prostate brachytherapy (BT) by phantom experiments.

Materials and Methods
The ST was done by performing a least-squares fit of the expected to the measured dose rate for the dwell positions in each needle. The fitting parameters were the needle position relative to the detector in radial direction (away or towards the detector) and longitudinal direction (along the axis of the needle). The detector system used was an Al_2O_3:C crystal based detector which fit inside a BT needle and measured the dose rate at 20 Hz.
Five 8.5 Gy HDR prostate BT treatment fractions previously performed at our clinic were reproduced in a phantom for this study. The needle geometries were transferred from the planning MRIs to a PMMA structure which consisted of three plates with 5 mm x 5 mm grids of holes in them which fixated the BT needles. The PMMA structure was submerged into a water tank which added at least 17 cm of water to all sides. One irradiation was performed for each of the fractions with the detector positioned at what would correspond to the middle region of the prostate in caudal cranial direction. Four additional irradiations were performed for one of the fractions where the detector was retracted caudally in steps of 10 to 15 mm between each irradiation. The detector was calibrated before each irradiation to mirror how the detector is used in the clinic.

Results
ST could be performed for all 165 needles. For detector positions in what would correspond to the middle region of the prostate, the mean ± SD (k = 1) accuracy was -0.01 mm ± 0.38 mm in the radial direction and 0.3 mm ± 0.38 mm in the longitudinal direction (fig. 1 A). The ST generated accurate results also for the irradiations where the detector was retracted caudally, as long as the detector was positioned in the middle region of the prostate (fig. 1. B). However, for the detector positions in the prostate apex region, the accuracy was 0.7 mm ± 1 mm and -1.7 mm ± 1mm in radial and longitudinal directions, respectively. For the detector position 12 mm caudal of the prostate apex the accuracy was 2.8 mm ± 1.6 mm and -2.1 mm ± 1.1 mm in the radial and longitudinal directions, respectively (fig. 1. B).

Conclusion
In vivo dosimetry based ST was performed for five HDR prostate BT treatment fractions delivered in a water phantom. The ST had sub millimetre accuracy for detector positions in the middle region of the prostate up to the apex region. A decrease in accuracy was observed for detector positions in the apex region and caudal of the prostate apex.

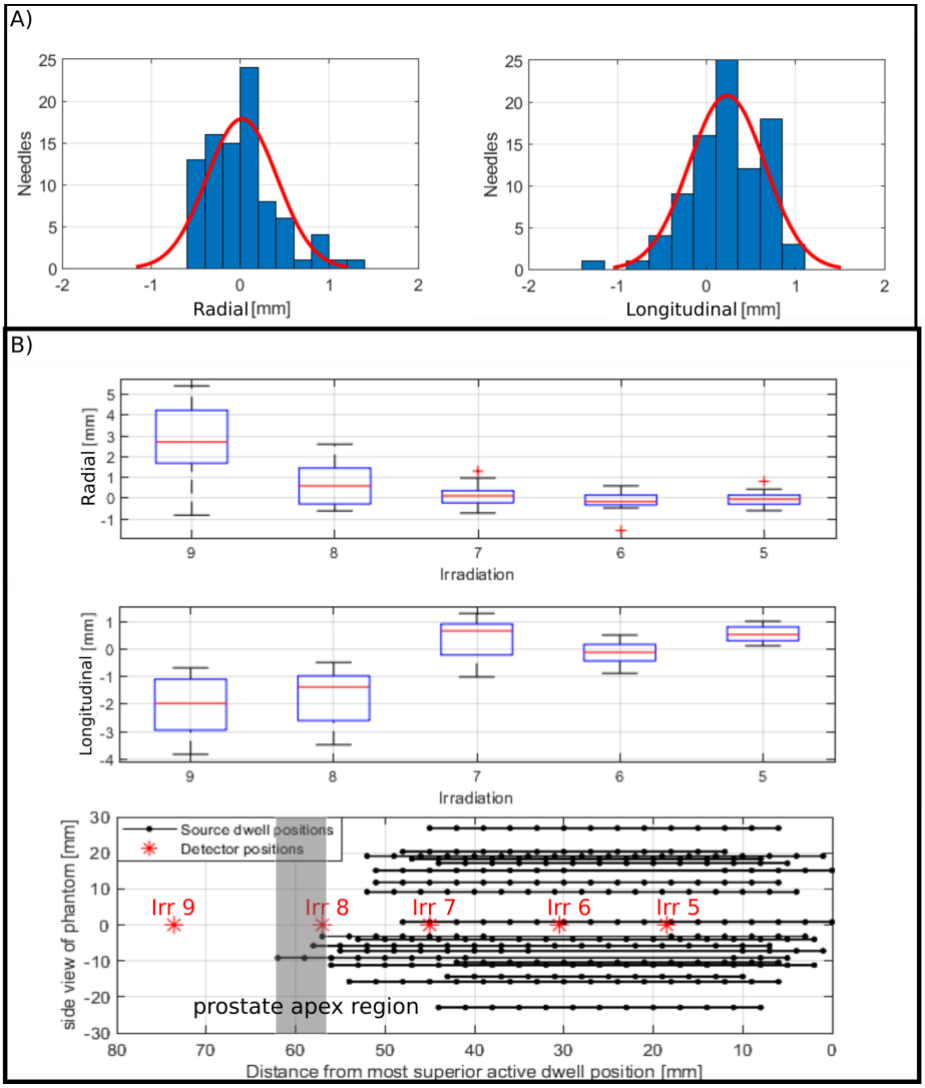

Figure 1: (A) Histograms of ST deviations for irradiations with detector position in the middle region of the prostate. The red lines are Gaussian fits. (B) ST deviations for the irradiations where the detector was retracted in caudal direction. The most caudal 5 mm with active dwell positions are marked as the prostate apex region (D'Amico AV et al, 1999, IJROBP).

OC-0069 Demonstration of 3D source tracking HDR brachytherapy treatment verification in a phantom

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Purpose or Objective
HDR brachytherapy treatment delivery can be verified by tracking the source during treatment, confirming the correct position of all planned dwells. Our system1, which has previously been shown to be able to track the source in 2D during delivery and compare to the expected locations2, has been extended to measure the source position in 3D allowing for more robust verification and the detection of errors arising in source deviations in the ANT-POST direction.

Materials and Methods
Our system utilises a flat panel detector (FPD) residing in a brachytherapy treatment couch that captures the source radiation throughout treatment delivery and provides imaging and registration to patient anatomy when combined with external xray imaging and implanted fiducial markers. The source is tracked during the delivery of each channel and shape analysis used to determine the 3D dwell positions and times, with quantitative and qualitative feedback provided to the user at the completion of each channel. The action level threshold, based on the measurement and registration uncertainty, for a delivery error is 5 mm in the coronal plane and 9 mm in the ANT-POST direction, provides sufficient sensitivity to detect gross treatment errors.
The source tracking system automatically segments each dwell position at the completion of each channel delivery, allowing for fast and automatic comparison between the measured and planned dwell positions. A plan of 117 dwells (2.5 mm step size) across 13 catheters was delivered to a 30x30x10 cm3 solid water phantom, with source tracking performed to verify correct delivery. Several clinically relevant delivery errors were introduced to test the capabilities of the system, including swapped channels, incorrect indexer length (simulating caudal implant shift), and incorrect step size.

Results
The delivered plan without introduced errors was verified as correct, with all dwells within 5 mm of the planned position in the coronal plane and all dwells within 6 mm in the ANT-POST direction.
The treatment verification system identified all the introduced treatment delivery errors. Error signatures for the introduced errors are summarised in Table 1 below.

Error	Potential cause	Signature	Magnitude of error detected
Swapped channels	Connection error	Deviation of each measured dwell from the plan in LEFT-RIGHT, ANT-POST, and/or SUP-INF	Catheters 12 mm apart swapped
Incorrect indexer length	Planning error Caudal implant shift	All dwells measured inferior of the planned position	9 mm inferior shift
Incorrect step size	Planning error	Distance between dwells deviating from plan	Step size increased from 2.5 mm to 5 mm

Conclusion
Our treatment verification system has been expanded to include the ability to measure the source position in 3D, enabling improved treatment verification. With more experience of the system and a better understanding of the increased uncertainties introduced in a clinical scenario, the use of this system will be extended into routine clinical treatment verification.

Plenary session: The next generation of brachytherapists

SP-0070 The next generation brachytherapists

D. Petereit
USA

Abstract Text
The decrease in brachytherapy (BT) utilization is an ongoing and worrisome trend in the United States and the world. Patients with locally advanced cervical cancer who undergo BT have some of the highest cure rates compared to patients with other locally advanced solid malignancies. Many cervical cancer patients in the US are medically underserved and are not treated with curative intent due to lack of access to high quality BT centers.[1, 2] Cervical cancer is a major health problem worldwide and is the second leading cause of cancer death among women who live in low middle-income countries (LMICs) where most women are not offered life-saving BT.[3] The data is irrefutable that when BT is inadequately performed or replaced with specialized forms of radiation, cure rates are dramatically compromised.[4] Prostate BT also achieves some of the highest cure rates for early stage disease[5], and the highest biochemical control rates for those with more advanced stages of prostate cancer when combined with EBRT as demonstrated in the randomized ASCENDE-RT Trial.[6] Inadequate resident BT case volumes, lack of public awareness, reimbursement, and competing radiation modalities (IMRT and SBRT) are some of the primary reasons patients do not receive BT in the US. [1, 7] From the ARRO (Association of Residents in Radiation Oncology) survey in 2018, only 54% of radiation residents expressed confidence in developing a BT practice.[8] To address this “brachytherapy crisis”, the American Brachytherapy Society (ABS) has implemented a 10-year strategy called 300 in 10. The goal is to ensure the training of 30 competent brachytherapy teams per year over the next 10 years through a multi-faceted approach including development of a US national brachytherapy curriculum, simulation-based training workshops, short-term focused fellowships at designated ABS certified centers, and competency evaluation by certified ABS experts with future goals of establishing a certification and maintenance of certification programs. In the last 3 years we have made significant progress providing hands-on workshops where we have trained 130 teams in prostate HDR and LDR brachytherapy. From these workshops, about 80% of these teams have implemented prostate brachytherapy within 6 months of the school.[9] Mentorship is a cornerstone of the 300 in 10 initiative, leading to the development of a new ABS mentorship program: NextGenBrachy. Through NextGenBT, early career radiation oncologists have been paired with experienced brachytherapists and physicists in a mentorship program for ABS members, designed to take place over at least one year. Because of COVID, The ABS now implemented several virtual education opportunities including our virtual reality training videos, webinars, virtual outreach events (VOEs), NEXTGenBT and in the future, SpotOnBrachy and Grand Rounds in Urology (GRU), to enhance BT education for our specialty, other medical specialties and the general public. The journal of Nature, recently highlighted role of prostate brachytherapy in the management of prostate cancer including efficacy and the cost effectiveness compared to other treatment modalities, the ongoing “crisis” of decreased BT utilization and the ABS solution of 300 in 10 (Michael Eisenstein: Prostate Cancer: A Declining Art). As brachytherapists, we need to increase the public demand for brachytherapy by informing the general public–particularly on social media. Increasing the the public demand for competent brachytherapists will fuel 300 in 10. ABS just launched a new marketing campaign with Virtual. The emphasis on this campaign will be Brachytherapy: Curing Cancer From Within. Preserving Quality of Life. We live in a world of social media and the time is here to reach out to non-ABS members, both physicians and patients, through innovative approaches. Developing these virtual media platforms will be an essential part of our strategy. We need a brachytherapy resurgence – similar to what the Seattle Prostate Institute successfully accomplished in the 1990s. Finally, the 300 in 10 initiative has global implications as our goal is to train competent brachytherapists worldwide through the ABS international committee and the International Cancer Expert Corp (ICEC, Dr. C Norman Coleman). 1. Petereit, D.G., et al., Where Have You Gone, Brachytherapy? . Journal of Clinical Oncology, 2015. 33(9): p. 980-982. 2. Petereit, D.G., et al., Increasing access to clinical cancer trials and emerging technologies for minority populations: The Native American project. Journal of Clinical Oncology, 2004. 22(22): p. 4452-4455, PMID: 15542797. 3. Petereit, D.G. and C.N. Coleman, Editorial: "Global Challenges in Radiation Oncology". Frontiers in Oncology, 2015. 5: p. 1-4. 4. Holschneider, C., et al.,

Brachytherapy: A Critical Component of Primary Radiation Terapy for Cervical Cancer: An Evidence-Based Review by the Society of Gynecologic Oncology (SGO) and the American Brachytherapy Society (ABS). Brachytherapy, 2019. In press: p. 1-20. 5. Grimm, P., et al., Comparative analysis of prostate-specific antigen free survival outcomes for patients with low, intermediate and high risk prostate cancer treatment by radical therapy. Results from the Prostate Cancer Results Study Group. BJU International, 2012. 109: p. 22-29. 6. Morris WJ, T.S., Rodda S, Halperin R, Pai H, McKenzie M, Duncan G, Morton G, Hamm J, Murray N, Androgen Suppression Combined with Elective Nodal and Dose Escalated Radiation Therapy (the ASCENDE-RT Trial): An Analysis of Survival Endpoints for a Randomized Trial Comparing a Low-Dose-Rate Brachytherapy Boost to a Dose-Escalated External Beam Boost for High- and Intermediate-risk Prostate Cancer International Journal of Radiation Oncology Biology Physics, 2017. 98(2): p. 275-285. 7. Holschneider, C., et al., Brachytherapy: A Critical Component of Primary Radiation Terapy for Cervical Cancer: An Evidence-Based Review by the Society of Gynecologic Oncology (SGO) and the American Brachytherapy Society (ABS). In Press. 8. Marcrom, S.R., et al., Brachytherapy Training Survey of Radiation Oncology Residents. International Journal of Radiation Oncology*Biology*Physics, 2018. 9. Frank SJ, Firas Mourtada F, Crook J, Orio PF, Stock RG, Petereit DG, Rossi PJ, Cox BW, MD, Tang C, Kudchadker RJ, Bruno T, Ma J, Sanders J, and Keyes M. The American Brachytherapy Society Prostate Brachytherapy LDR/HDR Simulation Workshops: Hands-on, Step-by-Step Training in the Process of Quality Assurance, Journal of Brachytherapy, Dec 2020.

Award lecture: Marie Curie Medal

SP-0072 Will Brachytherapy Survive the Radical Changes Facing Medicine?

A. Martinez
USA

Abstract not available

Symposium: 21st century brachytherapy: is it available, affordable and relevant?

SP-0073 Advocating global availability of cervical cancer brachytherapy

S. Chopra.[1]
[1]*Advanced Centre For Treatment- Research And Education In Cancer- Tata Memorial Centre-Mumbai, Radiation Oncology, Mumbai, India*

Abstract Text

Brachytherapy is an integral component of radiation treatment for cervical cancer. Unlike other cancers, there is no equivalentalternative for gynaecological brachytherapy. Omission of brachytherapy is associated with detriment in survival. While Global Task Force on Radiotherapy for Cancer Control (GTFRCC) and Global Impact of Radiation Oncology (GIRO) initiatives focus on mapping tele therapy resources worldwide, there is lack of initiative to map and report brachytherapy equipment for cervical cancer treatment. The talk will provide an update of the joint global initiative for worldwide mapping of radiotherapy and brachytherapy resources for cervix cancer and need for joint advocacy to highlight the deficit in various world regions and build a case for need of investment into brachytherapy.

SP-0074 Brachytherapy Disparity and Challenges of Reimbursement in the United States

P.Orio
Dana-Farber | Brigham & Women's Cancer Center
USA

In this presentation we will focus on the socioeconomic factors impacting brachytherapy in the United States. We will explore trends in prostate cancer treatment and discuss potential corrective strategies to reverse the declining utilization of prostate brachytherapy. In doing so we will focus on factors negatively impacting the utilization of brachytherapy in the United States, particularly regarding reimbursement. To frame this discussion, we will also explore the impact of PSA screening, active surveillance, radical prostatectomy, competing forms of radiotherapy and other factors affecting utilization of brachytherapy in a fee for service health care environment.
In addition, we will explore decreasing brachytherapy utilization in academic centers in the United States. These considerations are timely as both academic and nonacademic radiation oncology practices have demonstrated a significant reduction in the use of prostate brachytherapy in the past fifteen years. With the case volume continuing to decline, it is unclear whether we are prepared to train the next generation of residents in this critical modality. Furthermore, we will suggest strategies to combat these trends to train the next generation of residents, to potentially include simulation-based training, the creation of centers of excellent, national brachytherapy organization training opportunities as well as worldwide educational opportunities.
Finally, we will discuss where brachytherapy fits into current treatment recommendations and how we as brachytherapists can capitalize on such recommendations to expand the utilization of brachytherapy worldwide.

SP-0075 Utilizing time activity based costing to determine the real costs of brachytherapy

M. Kamrava.[1]
[1]*Cedars-Sinai Medical Center, Radiation Oncology, Los Angeles, USA*

Abstract Text

Brachytherapy is known to be a “cost effective” treatment relative to external beam radiation therapy for several different disease sites. Determining the “costs” of treatment are variable depending on how you define them. Time-driven activity-based costing (TDABC) is a methodology that quantifies and aggregates all resources utilized throughout a full cycle of patient care. It can help determine the true costs to the system for any given treatment. The purpose of this session is to review TDABC methodology and recent data using this technique to evaluate the costs of brachytherapy versus other treatment modalities in prostate, gynecologic, and breast cancers.

SP-0076 Motivating the next generation of brachytherapy trainees

A.Sturdza
Austria

Abstract not available

Debate: Partial Breast Irradiation with 1-3 fractions

SP-0077 For the motion

J. Hannoun-Levi[1]
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Abstract Text

By using “hypofractionated, radiation therapy and breast cancer” as key-words in PubMed, the oldest citation came in 1990 from a famous French Professor in Radiation Oncology, François Baillet, with the results of a Phase III randomized trial comparing 45Gy / 25f / 33d versus 23Gy / 4f / 17d in 230 patients reporting no significant difference in terms of oncological outcome. Since this period, numerous new prospective phase II and III clinical trials aimed to provide more consistent proof level to consider hypofractionated regimen for breast cancer irradiation. The initial rational to shorter this adjuvant treatment was to improve the irradiation observance by reducing the burden of 25 to 30 fractions during 5 to 7 consecutive weeks and consequently better patient quality of life. New protocols were progressively validated using moderate (13 to 16 fractions) to extreme (4 to 5 days) hypofractionation regimens by reducing the treated volume from whole breast to partial breast respectively. In case of accelerated partial breast irradiation (APBI), patient selection with low-risk breast cancer remains crucial to achieve optimal oncological toxicity outcome.
Following the initial rational supporting the hypofractionated irradiation, it appears meaningful to think about a shorter irradiation (very accelerated partial breast irradiation – vAPBI) which can be performed in less than 3 days. Currently two different technical approaches are described: brachytherapy (with 4, 3 or 1 fraction - balloon based or multicatheter interstitial) and intra-operative radiation therapy (IORT – 1 fraction). However, because of these technical differences, it remains debatable to adequately compare the irradiated volume and the equivalent dose at 2 Gy assuming the fact that the LQ model is not applicable for dose/fraction higher than 8 Gy. While IORT was evaluated in phase III randomized trials and remains under debate due to unconvincing final results, brachytherapy based vAPBI was only evaluated in prospective phase II trials with encouraging results in terms of local control as well as toxicity profile.
The debate of hypofractionated regimen based on vAPBI will need to be discussed in regards to the evolution of breast cancer incidence in the next following decades. Elderly women will represent a high-interest sub-group of patients for whom the burden of a conventional irradiation is not acceptable while no adjuvant treatment lead to negatively impact the local control. In the meantime, it will be crucial to lower health care costs (patient transportations, medical human resources, technological investment …) and preserve the organization of our radiation therapy departments.

SP-0078 Against the motion

O. Kaidar-Person

Abstract not available

SP-0079 For the motion rebuttal

R. Kuske

Abstract not available

SP-0080 Against the motion rebuttal

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Abstract Text

Partial breast irradiation (PBI) represents a standard treatment option for selected patients with low-risk early stage breast cancer (BC). Advantages of PBI included shorter treatment time (if accelerated, APBI), potentially improved safety profile and cost-effectiveness, as compared to whole breast irradiation (WBI). The available PBI techniques include single-entry balloon catheter, multi-field external-beam, interstitial/intracavitary brachytherapy, intra-operative electron- and low-energy photon beams. The role of PBI has been investigated in large-scale prospective randomized phase 3 clinical trials,

demonstrating the non-inferiority (only external beam radiation therapy and brachytherapy testing trials) of PBI versus WBI for local recurrence (LR) risks and overall similar/lower long-term toxicity, the latter depending on the adopted technique and fractionation. Comprehensive patient reported outcome measures (PROMs) in the IMPORT LOW trial showed that the average number of adverse events (AEs) per person was lower in PBI versus WBI group and decreased over time in all groups. The RAPID trial showed that accelerated APBI was not inferior to WBI in preventing LR and was associated with less acute toxicity but showed increased late toxicity and adverse cosmesis, probably related to the dose/fractionation with a twice-daily regimen and the treated-volume issues (in agreement with preliminary results from IRMA trial). The NSABP B-39/RTOG 0413 trial - at a median follow up of 10.2 years – showed low breast events and a 10-year IBTR difference (0.7%) small and clinically not relevant, thus considering APBI an acceptable alternative to WBI for a consistent proportion of women undergoing breast conserving surgery (BCS). Surgical techniques for contemporary breast conservation can be sophisticated, depending on aesthetic considerations. In most cases of straightforward small volume excisions, the breast parenchyma is carefully closed (simple excision or up to level 1 oncoplastic procedures). However, even in these cases the skin incision is often placed remote from the tumour in a cosmetically optimal location. In more challenging cases, where resection volumes are larger or more extensive breast reshaping is required using a variety of dermo glandular pedicles, the primary tumour bed margins may be substantially repositioned within the breast volume with margins often separated both from each other and from the surgical scars (≥level 2 oncoplastic procedures). Identifying the tumour bed, which does generally not equate with the lumpectomy cavity, is a very challenging process: reliance on the skin scar and seroma cavity has been shown to be inaccurate even in the case of standard BCS, resulting in poor localization of the target volume in over half of cases. Accurately positioned surgical clips in the lumpectomy cavity improve surgical bed identification on the planning CT scan, which contributes to more accurate delineation of the primary tumour bed both in volume and in location. This should lead to a better cosmetic outcome. Hence, the success of more localised RT strategies, such as APBI, may be jeopardised by a lack of communication between surgeons, radiologists, pathologists and radiation oncologists who all need to work closely together to ensure that the tumour bed and the margins around it to the CTV can be reliably identified. At present, only few studies evaluated the efficacy and effectiveness of preoperative PBI. Among the benefits of preoperative PBI are improved visibility of the primary tumour, resulting in smaller target volumes, higher accuracy, and minimized risk of geographical error. In addition, surgery is performed after preoperative PBI and can therefore remove the area of the breast that received the highest RT dose, possibly leading to limited fibrosis and a good cosmetic result. Even though preoperative APBI appears to be a feasible and widely available technique with promising results for low risk breast cancer patients, uncertainties remain with regard to tumour delineation, adequate planning target margins, optimal fractionation and timing of surgery. Concerning the optimal treatment schedule for APBI, the long-term results of the UK FAST trial show that postoperative whole-breast RT is equivalent to 50 Gy/25 fractions in terms of late cosmesis, and the UK FAST-Forward Trial (26 Gy in 5 fractions) tested - as the Florence phase 3 trial (30 Gy in 5 fractions) - a 5-fraction schedule with excellent results (both local control and safety). Similarly, postoperative fractionated multi-catheter brachytherapy appears to have less late skin toxicity than 50 Gy/25 fractions WBI. The existing level-1 evidence supporting the use of PBI derives from schedules based on 5 or more fractions.

Symposium: Accelerated partial breast irradiation - Phase 3 trial results

SP-0082 Results of brachytherapy trials

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Abstract Text

Accelerated partial breast irradiation using interstitial brachytherapy has been evaluated in huge number of Phase 2 trials and in three Phase 3 randomized trials. The Groupe Europeen de Curietherapie of European Society for Radiotherapy and Oncology (GEC-ESTRO) published a randomized Phase 3 non-inferiority trial in 2015. The trial randomized 1184 patient with low risk invasive ductal and ductal carcinoma in situ after breast conserving therapy to either whole breast irradiation (WBI) or accelerated partial breast irradiation (APBI) using the multi-catheter interstitial technique. At 6.6-year follow-up, APBI was not inferior with a cumulative incidence of 5y.-cumulative local recurrence rate of 1.44% for APBI vs. 0.92% for WBI. In addition, the risk of late side effects, overall survival, and disease-free survival were not found to be significantly different between arms. Polgar et al. (Budapest trial) published already a 10-year update of a prospective clinical trial randomizing 258 patients between partial breast irradiation (PBI) and whole breast irradiation (WBI). The primary end point was local recurrence , and the secondary end points were overall, cancer-specific, and disease-free survival. With a median follow-up of 10.2 years, the actuarial LR was 5.9% in the WBI arm and 5.1% in the APBI arm. There was no significant difference in the secondary end points between the two arms. Excellent to good cosmetic outcomes were statistically significantly superior in the PBI arm at 81% compared with 63% in the WBI arm. Subsequent to these trials a third prospective randomized Phase 3 trial - NSABP B-39/RTOG 0413 trial - was performed. This trial differed from the prior trials as it was an equivalence trial, enrolled patients from age 18 and included more high-risk subgroups. A total of 4216 patients were enrolled and randomized between WBI or APBI using either external beam 3D conformal therapy (71% pts.), a single entry brachytherapy catheter (23.3% pts.) or interstitial brachytherapy (5.7%). The primary outcome was ipsilateral LR as a first recurrence and a secondary outcome of survival. At a median follow-up of 10.2 years, the cumulative incidence of ipsilateral breast tumor recurrence was 4.6% in the APBI arm vs. 3.9% in the WBI arm. The absolute difference was 1% at 10 years but fell just short of the equivalence criteria. There was no difference in survival end points, and the toxicities were similar. Notably, this study was not designed to test for differences in outcomes from the various APBI techniques and as consequence particularly for ABPI with interstitial brachytherapy it´s not possible to give any statement.
In summary based on current available published data of large number Phase 2 and phase 3 trials it´s evident that APBI with brachytherapy is a proven treatment method for selected breast cancer patients with robust Level 1 evidence.

SP-0083 Results of external beam radiotherapy trials

I. Bhattacharya
UK

Abstract Text

Partial breast irradiation is an attractive option for patients and clinicians as a smaller region of the breast is irradiated in (usually) a shorter time period compared with whole breast radiation therapy (RT). The hypothesis for this approach is that a smaller irradiated volume is likely to translate into decreased toxicity, whilst maintaining good local control and survival (efficacy). This presentation will examine in detail the efficacy and toxicity of the 4 randomised partial breast RT trials using external beam radiotherapy. These include Florence, IMPORT LOW, RAPID and NSABP B-39/RTOG 0413 studies.

SP-0084 Results of IORT (Intra-Operative Radiation Therapy) trials

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Abstract Text

Background: The effectiveness of accelerated partial breast irradiation (APBI), especially concerning intraoperative radiotherapy (IORT), is still controversial. In 2013 we reported (Veronesi U, Orecchia R, Maisonneuve P, et al. Lancet Oncol 2013) the 5-year results of the ELIOT (ELectron IntraOperative Therapy) trial, an equivalence randomised phase III study, registered with ClinicalTrials.gov, number NCT01849133. This study was done at a single institution, the European Institute of Oncology (Milan, Italy). Women aged 48-75 years with early breast cancer, a maximum tumour diameter of up to 2.5 cm, and suitable for breast-conserving surgery (BCS) were randomly assigned in a 1:1 ratio to receive either whole-breast external radiotherapy (WBI) or intraoperative radiotherapy (IORT) with electrons. Study coordinators, clinicians, and patients were aware of the assignment. Patients in the IORT group received one single dose of 21 Gy to the tumour bed during surgery. Those in the WBI group received 50 Gy in 25 fractions of 2 Gy each, followed by a boost of 10 Gy in 5 fractions. The primary endpoint was occurrence of ipsilateral breast tumour recurrences (IBTR). After a medium follow-up of 5.8 years, 35 patients in the IORT arm and 4 patients in the WBI arm had an IBTR ($p<0.0001$). The 5-year event rate for IBRT was 4.4% in the IORT group and 0.4% in the WBI group (hazard ratio 9.3). During the same period, 34 women allocated to IORT and 31 to WBI died ($p=0.59$). Five-year overall survival was 96.8% in the IORT arm and 96.9% in the WBI arm. In patients with data available (n=464 for IORT; n=412 for WBI) we noted significantly fewer skin side-effects in women in the IORT arm than in those in the WBI arm ($p=0.0002$).
Aims: Hereafter we reported the long-term outcomes, in terms of local (IBTR) and regional recurrences and overall survival (OS), of the ELIOT trial.
Methods: Between November 2000 and December 2007, 1305 women were randomised using a random permuted block design, stratified for clinical tumour size, to receive WBI (n=654) or IORT with electrons (n=651). The main analysis was by intention to treat, but also a per-protocol analysis was performed. Cumulative incidence of local, loco-regional, distant events and OS were presented at 5-, 10-, and 15 years of follow-up.
Results: After a medium follow-up of 12.4 years, 86 (6.6%) patients developed IBTR, with 70 (10.7%) cases in the IORT cohort and 16 (2.4%) in the WBI cohort ($P<0.0001$) (hazard ratio 4.62). The 5-, 10-, and 15-year event rates for IBRT in the IORT arm were 4.2%, 8.1%, and 12.6%, respectively, and in the WBI arm 0.5%, 1.1% and 2.4%. Most patients in the ELIOT arm who developed an IBTR received a second course of surgery, with 35 (50%) of the 70 patients who repeated BCS, and 24 (34.3%) underwent total mastectomy. Thirteen women developed axillary of other regional lymph node metastasis, of which 11 (1.7%) in the ELIOT arm and two (0.3%) in the WBI arm. A lower number of contralateral breast cancer was recorded in the ELIOT arm (18 cases) than in the WBI arm (27 cases), but the difference was not statistically significant ($p=0.42$). We analysed factors associated with IBTR, and defined a group of women (75 in the ELIOT arm and 66 in the WBI arm) at "very low risk" of IBTR, consisting in women with three concomitant characteristics (tumour size <1cm, grade 1, and Luminal A [Ki-67<14%]), each associated with an IBTR rate <10% after ELIOT at 15-year. The incidence of IBTR in this subgroup was extremely low with either modality. Similar results were found in the per-protocol analysis. No statistical difference was also observed for the development of distant metastasis, 46 in the ELIOT arm and 54 in the WBI arm ($p=0.60$). Ten- and 15-year OS were 90.7% and 83.4% in the IORT group, and 92.7% and 82.4% in the WBI group, respectively. Similar results were found in the per-protocol analysis. No further data about long-term toxicity were collected, and earlier effects were reported in the previous published analysis.
Conclusions: This is the study with the longest follow-up among all the APBI and IORT trials. Long-term results confirmed the higher rate of IBTR in the IORT arm compared to WBI arm, but, of great importance, without any impact on distant metastasis and survival rates. We conducted this trial over the period 2000-2007, when the use of APBI, and particularly by IORT, was quite pioneering, and very few selection criteria were adopted. This allowed to identify a small group of patients at "very low risk" who fared well with IORT. For other women a careful assessment of risks and benefits is required in the context of a fully informed and shared decision making. Finally, the results of this study stressed the importance of the proper selection of women candidate to IORT.

SP-0085 Ongoing clinical trials and future trends of APBI

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Abstract Text

- Review the design, entry criteria, randomization, and target enrollment of on-going Phase III trials investigating APBI in the post-operative setting (IRMA, SHARE, TROG)
- Review on-going trials of novel technologies used for APBI in the post-operative setting (protons, SBRT, PBSI, NIBB)

· Review on-going trials designed to test accelerated courses of APBI in the post-operative setting (ACCEL (5 fraction IMRT), TRIUMPH-T and Mayo Clinic (ultra-short course brachytherapy)
· Review on-going trials of intra-operative brachytherapy with image guidance and adaptive dosimetry (University of Virginia)
· Review on-going clinical trials of pre-operative APBI (NKI, Duke, and others)
· Review on-going trials of ablative PBI using SBRT techniques

Symposium: Head and Neck recurrences after full course Radiotherapy

SP-0086 Why surgery?

K. Bruchhage
Germany

Abstract not available

SP-0087 Why EBRT?

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Abstract Text
In over 60% of cases, the diagnosis of squamous cell carcinoma of the head and neck (SCCHN) occurs at a loco-regionally advanced stage, carrying by itself a suboptimal prognosis with a long-term overall survival rate of about 50%. The predominant pattern of failure is loco-regional: a recurrence in the head and neck after primary treatment is associated with poor outcome and a marked detriment to patients' quality of life. Only up to a third of patients are amenable to salvage surgery, and up to 50% of the operated ones are at risk of a further disease recurrence, particularly in case of adverse pathologic features such as positive surgical margins or extranodal extension. In last 10 years, the recognition of the strong, independent reduction of risk of death and disease progression carried by a positive human papilloma virus (HPV) status has changed the historical "one-size fits-all approach" of head and neck cancer. The exquisite radio and chemo-sensitivity of HPV positive oropharyngeal cancer has allowed to decrease the rate of loco-regional failures in comparison with HPV negative counterparts, with a proportionally higher competing risk of distant metastases. However, still today loco-regional recurrence remains the most frequent event of disease progression for the overall population with SCCHN. Other than salvage surgery, the only therapeutic option which retains a potential curative intent is re-irradiation. The aim of this presentation will be to report on the role of EBRT in this scenario, according to the following outine
- analysis of the pattern of failure of HNSCC after definitive chemo-radiotherapy, addressing "historical" data (such as the MACH-NC and MARCH meta-analyses) and providing an insight on modern studies with prevalent HPV population
- focus on the key aspects related to patient selection criteria for re-irradiation, overall the most relevant issue faced in clinical practice
- focus on the evidence in support of re-irradiation, analyzing the available data on IMRT, SBRT and protons
- report on the available evidence and future perspectives on the integration of systemic therapies and re-irradiation

SP-0088 Why Brachytherapy?

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Abstract Text
Background: Patients with previously irradiated, recurrent head and neck cancer or second primary tumors arising in a previously irradiated field present a therapeutic dilemma. Salvage surgery with complete microscopic (R0) resection is the standard of care but can be performed in only a minority of cases. The use of adjuvant reirradiation after salvage surgery remains a controversial issue. A Phase III trial of observation vs. combined chemo-reirradiation achieved improved locoregional control after combined modality therapy but had no effect on survival (Janot et al., 2008). Adjuvant reirradiation using non-standard radiation modalities such as adjuvant LDR (Khan et al., 2019), PDR (Strnad et al., 2003), or HDR brachytherapy (Martinez-Fernandez et al., 2017)have the potential to decrease adverse events while retaining local control rates because these approaches require smaller treatment volumes (Figure 1).

Purpose/Objective: To discuss the rationale, technicalities, patient selection, treatment schedules, dosimetric guidelines and results of reirradiation with adjuvant brachytherapy in previously irradiated, recurrent head and neck cancer or second primary tumors arising in a previously irradiated field.

Material/Methods: Update of well-designed and mature clinical trials with enough sample size. All types of brachytherapy trials (i.e, LDR, HDR, permanent brachytherapy,etc.) pertaining to the above category will be considered. Considerations for boosting the scope of adjuvant brachytherapy as a must in the armamentarium of recurrent head and neck cancer.

Results: Data from clinical trials will be structured into three main sections: a) Toxicity, b) Locoregional Control and c) Survival. The main learning objective of the toxicity section is to provide an understanding of the risk of soft tissue necrosis (STN) and bone necrosis (BN) in head and neck brachytherapy as well as to provide recommendations to minimize their occurrence. Locoregional control and survival at 2 and 5 years will be provided with emphasis on patient selection.

Conclusions: Surgical resection and adjuvant is a successful treatment strategy in selected patients with previously irradiated head and neck cancer. Long-term locoregional control and cure can be achieved in a substantial number of cases despite a high rate inadequate surgical resections although at the expense of a substantial toxicity.

Teaching lecture: How to implement and execute an incident learning system

SP-0089 How to implement and execute an incident learning system

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Abstract Text

Incident Learning plays an essential role in improving quality and safety in radiation oncology. National and International Organizations have developed incident reporting and learning systems where institutions can participate and submit cases. Additionally, there has been an increase interest from individual institutions to develop and implement their own systems, which allows them to customize system features to meet their specific needs and clinical processes, as well as giving access to the data more readily. The purpose of an institution-specific Incident Learning Systems (ILS) goes beyond capturing only events that reach the patient, but also near misses, issues and situations that arise from everyday clinical operations. By capturing this information, groups can implement an evidence-based continuous practice improvement framework. The following presentation will provide the methodology and experience of implementing an ILS at a large academic institution across several geographic locations. The presentation will cover different steps starting from pre-implementation work, system design and deployment; continuing incidents reviewing and practice quality improvement processes, as well as a summary of outcomes originating from the ILS. Session participants will have an opportunity to learn key points and areas to think about when implementing their own ILS.

Debate: Optimal treatment for periorificial high risk non-melanoma skin cancer

SP-0090 This house believes that surgery should be considered for lip high risk non-melanoma skin cancer

C. Newlands
UK

Abstract not available

SP-0091 This house believes that radiotherapy/brachytherapy should be considered for lip high risk non-melanoma skin cancer

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Abstract Text

Management of periorificial tumours is challenging due to its location and impact on functional and cosmetic outcome. For early stage lip cancers single modality treatment either surgery or radiation therapy (RT) is considered. While for advanced disease combined modality treatment which includes surgery, RT with or without chemotherapy is considered. Various surgical series have reported excellent local control rates and overall survival in the range of 65-90%. However the main issue with surgery is cosmetic and functional impairment.
Brachytherapy with its ability to deliver high dose to the tumour bed and rapid fall off of the dose beyond the target appears to be a suitable method for treatment of lip cancers. Brachytherapy for lip cancer is performed under anaesthesia. Typically 2 plane implants are done with needles inserted in submucosal and subcutaneous planes. This ensures adequate coverage of the target. There have been many series which have used low dose rate brachytherapy (LDR) for lip cancers. All these series have reported local control rates in the range of 75-95%. Additional advantage of brachytherapy is preservation of functional outcome as well as cosmetic outcome. These have a large impact on quality of life of patients especially social interactions and eating in public.
Since last 2 decades there has been change from LDR to pulse dose rate (PDR) or high dose rate (HDR) brachytherapy. HDR brachytherapy has an advantage of short treatment time, radiation protection to the staff and convenience for the patients. Various fractionation schedules have been used for treatment of lip cancer with dose per fraction ranging from 3.5Gy to 5Gy per fraction. The local control rates of HDR series are in the range of 85-95%. Although the data of HDR is limited, it has been associated with lesser bone and soft tissue toxicity which has been one of the major concerns with brachytherapy. One of the drawbacks of brachytherapy is the lack of management of neck. In situations where neck managements appears necessary combined external beam RT and brachytherapy can be considered as on option and has shown encouraging outcomes.
Overall brachytherapy appears to be an excellent modality of treatment for management of lip cancers resulting in comparable local control rates with surgery with better cosmetic and functional outcomes. Hence brachytherapy should be considered as the standard of care and surgery should be reserved for salvage in lip cancers.

SP-0092 This house believes that surgery should be considered for nose high risk non-melanoma skin cancer\r

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Abstract text

The main issue concerning periorificial non melanoma cancer of the nose is classification, several inconsistencies and inadequacies of AJCC site definition and TNM staging need to be addressed.
In the “periorificial area” there are true skin lesions, usually arising away from the mucocutaneous junction, for which the general considerations concerning cancers of the skin are in general valid, and there are tumors of the muco-cutaneous junction and in particular of the nose vestibule with many often underestimated but nevertheless critical peculiarities.
For “true” skin cancers, in the absence of serious reconstructive concerns surgery remains the primary option.
For nose vestibule tumors which are put by AJCC together with posterior nasal cavity and ethmoid malignancies, TNM classification is clearly inadequate, as the most ominous finding, which is bone invasion, does not even make for a T2, while the constant feature of skin involvement, which is not an issue under an oncological point of view, always determines an upstaging to cT4. In these cases the Wang classification for T works much better.
Another peculiarity of such lesions is the very easy surgical resection alongside the frequent impossibility to obtain a satisfactory reconstruction. This feature, together with very low toxicity, easy implantation and resistance of cartilage to irradiation if the implants are “anatomic” (without piercing of the perichondium), makes brachytherapy the standard treatment for non-previously irradiated primary SCCs of the vestibule.
Preliminary evidence and personal experience show promising results with brachytherapy also for BCC.
Surgery remains the most validated option for nose vestibule primaries infiltrating the bone (T3 according to Wang classification) and for recurrences after irradiation.

SP-0093 Brachytherapy a useful tool for nasal and peri-nasal tumours

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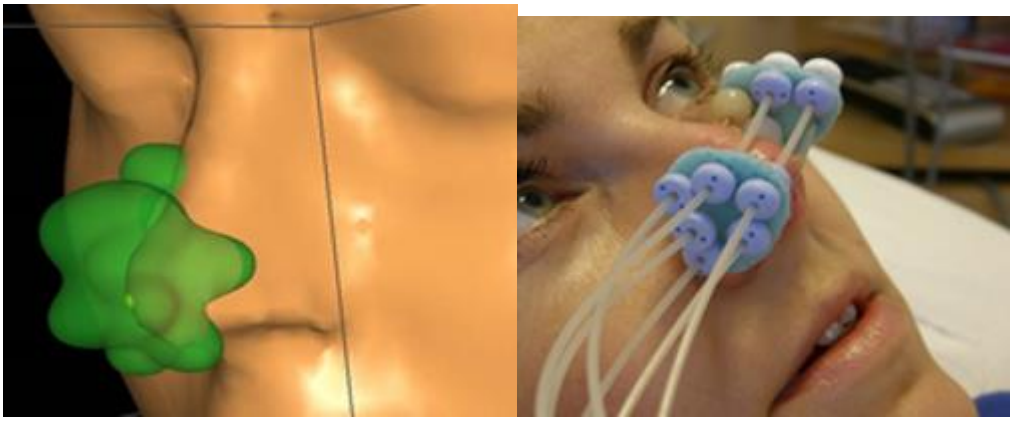
Abstract Text

There is an increasing incidence of Basal cell carcinoma (BCC) and Squamous cell carcinoma (SCC) on the external nose. Surgery is the main treatment but often face problems with respect to cosmetic defects and non-radical resection.
Brachytherapy (BT) can be used in the primary treatment to preserve cosmetic appearance and to treat with appropriate margins. Brachytherapy are also indicated in tumor recurrence after surgery and in case of non-radical resection.
Long-term local control rate (LCR) in literature is 90-95 %. Treatment time is short 1-2 weeks.
There are different BT techniques available such as -Surface BT (Valencia applicator or Mould BT), -interstitial BT (trans-nasal or along nasal) or a combination of both.
The choice of BT technique is depending on; -thickness of the tumor, -location on the nose (cartilage part vs bony part), -tumor growth (flat part, curvature part, exophytic part), -extension to peri-nasal areas (upper lip, cheek, medial eye corner).
Usually a full dose of BT is prescribed like 60 Gy PDR (0.83 Gy/ 2nd hour) or 45, 5 Gy HDR (3.5 Gy 2fx/d) (GEC-ESTRO recommendations for head/neck BT RTO 20016:10 and skin RTO 2018:126.) Own experience 1998-2019 in 121 patients confirms published results of 93.4 % long-term LCR.
Side effects are uncommon and include: septum perforation, telangiectasia, atrophy and sclerosis.
Multidisciplinary conferences and teaching of plastic surgeons about potential benefits of BT are fundamental to avoid unnecessary mutilation.



Symposium: Guidelines and recommendations in gynaecological cancers

SP-0095 IBS/GEC-ESTRO recommendations for CT based treatment of cervical cancer

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Abstract Text

Background and Rationale: MRI based 3D-IGABT has become an advanced standard for cervical cancer brachytherapy (BT) and has shown improved clinical outocmes (local/pelvic control, survival, morbidity). Although MRI is regarded as « gold standard » for IGABT, its wide applicability is limited by its availability, logistics and financial implications. Hence, use of CT and UltraSound (US) has been explored. In order to arrive at a systematic, uniform and international approach for CT based definition and contouring of target structures, GEC ESTRO, IBS and ABS agreed to jointly develop such recommendations. They are based on the concepts and terms as published in the ICRU report 89, defining the advanced standard approach with repetitive clinical examination at diagnosis (DG) and at BT with 3D documentation and with MRI at DG (MR_{DG}) and at BT (MR_{BT}) with the applicator in place. The following recommendations represent a first draft designed by the two first authors.

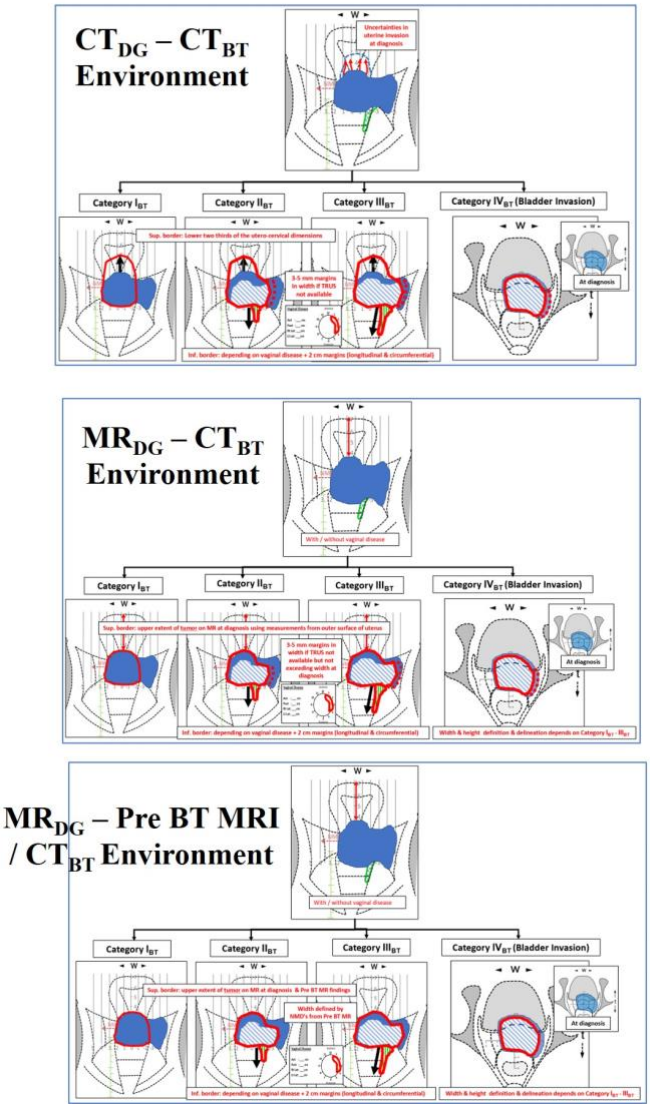
Development of CT based Recommendations: The minimum requirements for CT based contouring are clinical $examination_{DG,BT}$ with 3D documentation and CT_{DG} and CT with applicator in place (CT_{BT}). The recommendations are based on GTV and CTV assessment (clin exam, US, MRI), on classification of clinical remission patterns within various clinico-radiological scenarios.

1. Assessment of GTV and CTV_{HR}: The cornerstone for CT based target contouring is the repetitive clinical examination with a revised scaled diagram for documentation. The CTV_{HR} definition focusses on dimensions related to width, height and thickness. For width the new "Near Maximum Distance" (NMD) is introduced which is related to the cervical canal (os) and specified for each parametrium (left, right). The different volumetric imaging methods (MRI, CT, US, TRUS) are outlined with emphasis on strengths & limitations. Protocols for CT and US (TRUS) are suggested to define appropriately anatomical structures for contouring in the various imaging environments.
Uncertainties are associated with assessment of GTV at diagnosis (major for CT) and of GTV response (least with MRI). These uncertainties can be reduced by repetitive clinical examination and TRUS, beside MRI.
2. Classification of Clinical Remission: A classification of common clinical remission patterns is introduced (« restaging ») related to anatomical structures which are reproducible both on CT and on other assessment methods (clinical, MRI, US). For the CTV_{HR} definition 4 categories are defined (I_{BT}-II_{BT}-III_{BT}-IV_{BT}) for the cervix, parametrium, vagina and uterine corpus **(Table 1).**
3. Definition of different clinico-radiological environments: Based on the availaibility of imaging modalities at DG and at BT these environments are classified into 3 major categories: CT_{DG} - CT_{BT}; MR_{DG} - CT_{BT}; MRI_{DG} - *Pre BT MRI*/CT_{BT}. Each environmenrt is divided into 2 sub-categories - *with or without real time TRUS* - depending on the use of real time trans-rectal ultrasonography during BT application (6 categories).
4. CT contouring recommendations for definiton and delineation of CTV_{HR} and OAR: CT based contouring recommendations were formulated in general for width, height and thickness of CTV_{HR} and elaborated in detail for the 4 categories of remission pattern classification related to cervix, parametrium, vagina, and uterine corpus for the 3x2 clinico-radiological environments **(Figure. 1).**
For CT_{DG} - CT_{BT}, GTV_{CT} contouring at BT imaging is not recommended, but is supported for the other environments. The definition of width, height and thickness of CTV_{HR} on CT imaging is mandatory for all environments, but represents a challenge and accounts for major uncertainties and inter-observer variations, in particular in CT_{DG} - CT_{BT}. These shortcomings can be minimized through repetitive clin exam with clinical documentation and more valid and reliable volumetric $imaging_{DG/BT}$ (TRUS, MRI), all classifying systematically the clinical remission patterns.
For CT based OAR contouring, a reproducible organ filling status, preferably empty, and defined protocols of contrast within the organs are vital, especially for bladder and recto-sigmoid. The major OAR's are rectum, bladder, sigmoid and bowel.
Discussion: For each clinico-radiological environment there is an attempt to minimize the specific uncertainties in order to arrive at the best possible contouring accuracy. CT based target (OAR) contouring recommendations based on 4 remission categories within 6 defined environments aim at improving the contouring accuracy for IGABT using CT, US MRI as available. They will be further discussed in international expert rounds during the next months and then decided through IBS, GEC ESTRO (ACROP), ABS before publication.
Evaluating feasibility and reproducibility of these recommendations and further clinical research on clinical outcome for CT Based IGABT following these recommendations will become the next steps.

Table 1: Definition of four BT target categories according to assessment and restaging taking into account the pattern of residual disease at BT for CT based contouring of the adaptive HR CTV_{CT}

Category of BT HR CTV_{CT}	Cervix	Parametrium	Vagina	Uterine corpus
I_{BT}	No residual disease Or Residual disease confined to cervix	No residual disease	No residual disease Or Residual disease < 2cm of upper vagina	No residual disease Or Residual disease in proximal third of utero-cervical junction
II_{BT}	Significant residual disease	Proximal parametrial disease	Residual disease within upper one third	Residual disease not beyond mid corpus
III_{BT}	Significant residual disease	Distal / Up to pelvic wall parametrial disease	Residual disease in mid or lower third	Residual disease into distal corpus / Up to fundus
IV_{BT}	Significant residual disease involving neighbouring organ wall/ mucosae (bladder/ rectum)	Proximal parametrial disease	Residual disease within upper one third	Residual disease not beyond mid corpus
		Distal / Up to pelvic wall parametrial disease	Residual disease in mid or lower third	Residual disease into distal corpus / Up to fundus

Figure 1. Showing adaptive $CTV_{HR\text{-}CT}$ Concepts for different environments



SP-0096 JASTRO recommendations for CT based brachytherapy for cervical cancer

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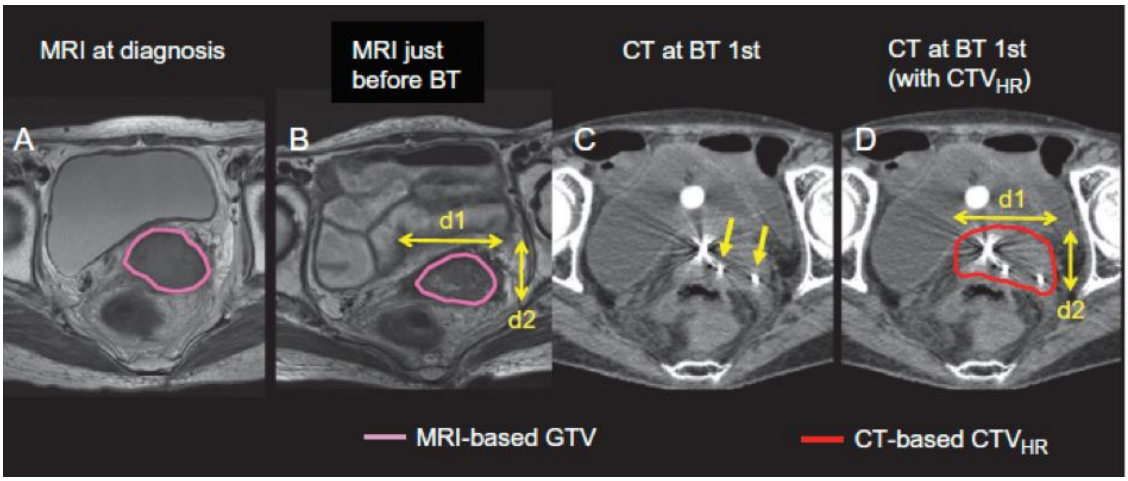
Abstract Text

Purpose/Objective: In radiation therapy for uterine cervical cancer, three-dimensional image-guided brachytherapy (3D-IGBT) using magnetic resonance imaging (MRI) or computed tomography (CT) has shown promise for improving local control without increasing the risk of severe complications. Although MRI is the gold standard for 3D-IGBT for cervical cancer, its global application is still limited. Recent surveys on IGBT for cervical cancer demonstrated that CT is the most commonly used imaging modality for dose specification in clinical practice in Japan. Considering the fact that CT is a mainstay for 3D-IGBT in the majority of institutions, the resulting dose uncertainty from such CT-based CTV contouring must be minimized. Therefore, we conducted a multi-institutional study of CT-based CTV_{HR} delineation in order to standardize 3D-IGBT application in regions where the availability of MRI with applicator in place is limited.
Material/Methods: A 15-member Japanese Radiation Oncology Study Group (JROSG) committee with expertise in gynecological radiation oncology initiated guideline development for CT-based CTV_{HR}, based on a comprehensive literature review as well as clinical experience, in July 2014. Extensive discussions occurred during 4 face-to-face meetings as well as frequent e-mail communication until a consensus was reached.
Results: The CT-based CTV_{HR} boundaries are defined by each anatomical plane (cranial-caudal, lateral, or anterior-posterior) with or without tumor progression beyond the uterine cervix at diagnosis. Since the availability of MRI with applicator insertion for 3D planning is currently limited, T2-weighted MRI obtained at diagnosis and just before brachytherapy without applicator insertion is used as a reference to accurately estimate the tumor size and topography. Furthermore, utilizing information from clinical examinations performed both at diagnosis and brachytherapy is strongly recommended. The first version was reviewed by 2 external advisors; the value of MRI and limitations of CT in 3D-IGBT for cervical cancer were updated based on discussions between the external advisors and JROSG members. Finally, the revised recommendations were completed and approved by all members in June 2016.
Conclusions: We develop recommendations for contouring computed tomography (CT)-based high-risk clinical target volume (CTV_{HR}) for three-dimensional image-guided brachytherapy (3D-IGBT) for cervical cancer. Our recommendation was adopted in the JASTRO Guidelines for Radiotherapy Treatment Planning in 2020. We initiated a comparison study for contouring CTV_{HR} between CT- and MR-based brachytherapy. In addition, a multi-center clinical study using this recommendation is on-going at eight institutions with limited availability of MRI for 3D treatment planning.



SP-0097 GEC-ESTRO/IBS/ABS recommendations for treatment planning

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Abstract text

Rationale
The GEC-ESTRO recommendations and ICRU 89 developed a comprehensive methodology for unified target and organs at risk (OAR) contouring and for using a common language in dose prescribing and reporting based on the equi-effective dose concept in locally advanced cervical cancer. The ICRU 89 report meets different environments of resources and clinical practice by defining basic and advanced levels of prescribing, recording and reporting. Currently, a number of clinical approaches are being applied all over the world with regard to applicators, treatment planning, and dose and fractionation in cervix cancer brachytherapy. Until recently there was no strong evidence available for preferring one clinical approach

to another. With the dissemination and adoption of the joint principles of 3D image-guided brachytherapy, there are more opportunities to compare techniques, dose administration and clinical outcomes across patients and institutions. Clinical evidence correlating dose-volume parameters and clinical outcomes has been established for an increasing number of clinical endpoints including targets and OARs. For the purpose of providing international recommendations for brachytherapy treatment planning based on evidence, an interdisciplinary group has been established with representatives from Groupe Européen de Curiethérapie and European SocieTy for Radiotherapy Oncology (GEC-ESTRO), Indian Brachytherapy Society (IBS) and American Brachytherapy Society (ABS). The work of the group will be ongoing throughout 2020 and the recommendations are expected to be published in 2021. This abstract outlines the purpose and contents of the upcoming GEC-ESTRO/IBS/ABS brachytherapy treatment planning recommendations in locally advanced cervical cancer.
Purpose
To provide clinical and physics evidence-based guidelines for treatment planning in cervix cancer brachytherapy using the methodology (concepts and terms) as outlined in GEC-ESTRO recommendations (I-IV) and the ICRU report 89. To define various clinical-radiological environments according to variable clinical resource availability. To describe the impact that the disparate environments have on treatment planning and performance of appropriate cervix cancer brachytherapy. To define practical treatment planning approaches which take into account the various basic and advanced levels of clinical-radiological environments. The recommendations will cover treatment planning based on MRI with applicator in place as the gold standard, as well as alternative infrastructures where clinical examination together with combinations of CT, ultrasound, and 2D x-ray imaging are applied. To enable centers with different levels of clinical experience to perform treatment planning in cervix cancer brachytherapy appropriately according to tumour extension and topography to maximize chance of cure while minimizing morbidity within the context of a particular center's environment and resources.
Outline of topics
Brachytherapy treatment planning in locally advanced cervical cancer is not an isolated process limited to performance of brachytherapy, but involves the entire radiotherapy planning workflow including diagnostic imaging and external beam radiotherapy (EBRT) treatment planning. The brachytherapy treatment planning recommendations provided in this recommendation broadly cover considerations of imaging and clinical examination at time of diagnosis and brachytherapy as well as important factors for high quality brachytherapy treatment planning. The recommendations are based on clinical and technical evidence whenever this is available. Furthermore, other international guidelines will be considered to collect and evaluate different approaches (e.g. ABS, IBS, JASTRO).

- Evidence for correlations between dose/volume and clinical outcome as well as between brachytherapy technique and dosimetric outcome (tumor, OARs)
- Description of different clinical-radiological environments for imaging (diagnostic and during radiotherapy) and performance of brachytherapy as well as uncertainties related to imaging modalities and combinations of imaging
- Process of treatment planning and performance of brachytherapy: description and definition of the steps of treatment planning including pre-implantation preliminary treatment planning and applicator selection
- Practical approaches for planning and performing appropriate brachytherapy within different clinical-radiological environments to arrive at the best possible chance of cure within the given practical frame of basic or advanced technology as available in the various treatment centers:

o Dose planning aims and dose prescription protocols
o Dose optimization, loading patterns and conformality
o Dose and fractionation

SP-0098 GEC-ESTRO/ABS/CBG recommendations on target definition in vaginal recurrence

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Abstract Text

Purpose or Objective
During the last decade image guided adaptive brachytherapy (IGABT) using MRI/CT based volumetric imaging has greatly evolved. Target volume concept recommendations issued by the Gynaecological Groupe Européen de Curiethérapie and the European Society for Radiotherapy & Oncology (GYN GEC-ESTRO) working group and the following multicenter introduction and evaluation of IGABT for cervical cancer in the EMBRACE study provided clinical validation of these concepts for cervical cancer that have more recently found their way into the ICRU-89 report.
While single institution experiences of IGABT in primary vaginal cancer and recurrences have been published, a common target concept is lacking, hampering further advancement of brachytherapy for these women. In 2013 a task group was initiated in GYN GEC-ESTRO with the purpose to introduce IGABT for vaginal cancer, leading to the recently published recommendations for primary vaginal cancer. There are distinct differences between primary vaginal cancer and vaginal recurrence, in particular with regard to site, involvement, histology and previous oncological treatment(s) For the topic of vaginal recurrence an international collaboration between GEC-ESTRO, the American Brachytherapy Society (ABS) and the Canadian Brachytherapy Group (CBG) was established, and the aim of this presentation is to provide an update of these proceedings.

Methods and Materials
A 2-day workshop style consensus meeting was organized prior to ABS 2019, with equal contribution from all societies. Prior to the workshop a questionnaire on existing practice with regard to IGABT and target volume concepts was circulated and 3 cases were contoured based on institutional practice. During the workshop existing literature and views within the three societies were discussed, followed by an in depth evaluation and discussion of target delineation based on the 3 cases.

Finally, summary points for joint target concept recommendations were formulated. As next steps the group agreed on combining the review process of full text recommendations with a second round of target delineation. ResultsAn update will be provided of proceedings from the workshop in 2019. These include of summary points for definition of the residual GTV, a high risk CTV and intermediate risk CTV at time of brachytherapy.

Conclusion
In order to further improve outcomes of women with vaginal recurrences a joint effort was initiated by GEC-ESTRO, ABS and CBG to establish common target concept recommendations.

Proffered papers: Urogenital cancers

OC-0099 Long-term outcomes of patients treated with I-125 seed implant versus surgery for prostate cancer

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Purpose or Objective
Management strategies for localized prostate cancer include radical prostatectomy (RP) and low dose rate brachytherapy (LDR-BT) however there is a lack of randomized evidence directly comparing LDR-BT to RP. The American College of Surgeons Oncology Group Phase III Surgical Prostatectomy Versus Interstitial Radiation Intervention Trial (SPIRIT) suffered from poor accrual and was closed early. We report on the long-term biochemical control rates of men treated prospectively as part of SPIRIT at our institution.

Materials and Methods
Patients approached for SPIRIT between 2003 and 2004 at our institution who either chose or were randomly assigned to RP or LDR-BT following a multidisciplinary educational session, were included in this analysis. Biochemical failure (BF) after RP was defined as a PSA level ≥ 0.2 ng/ml and the phoenix definition of PSA of ≥ 2 ng/ml above the nadir was used to define BF after LDR-BT. A sensitivity analysis using a PSA > 0.5 ng/mL to define BF after LDR-BT was performed to test the robustness of the results. To account for the competing risk of death, Gray's test was used to test the equality of the cumulative incidence function (CIF) of BF between treatment groups. The Kaplan-Meier method was used to estimate prostate cancer specific survival (PCSS). A two-tailed p-value ≤ 0.05 was considered statistically significant.

Results

Of 156 patients, 100 received LDR-BT and 56 underwent RP. Median follow-up was 12.5 (9.2- 15.8) and 14.2 (IQR: 8.3-15.9) years for LDR-BT and RP cohorts respectively (p = 0.633). The median age was 60 (IQR: 56-65) years, median pre-treatment PSA was 5.51 (IQR: 4.32-7.12). All patients had Gleason Score ≤ 6. 55 patients were clinically staged as T2a and 101 patients had T1c disease. No statistically significant differences in patient characteristics were found between groups. 2 RP patients received adjuvant external beam RT and 15 had positive surgical margins. Two patients had a BF in the LDR-BT cohort versus 10 patients in the RP arm. The latter received salvage external beam RT. 85% of patients treated with LDR-BT had a PSA ≤ 0.05 at the last follow-up. The CIF of BF was 0.0% and 1.1% (CI: 0.09-5.34) at 5 and 10 years respectively in the LDR-BT arm versus 8.5% (CI: 2.6-18.7) and 15.6% (CI: 6.8-28.2) in the RP cohort (p <0.001) as shown in Figure 1. These results were robust when varying the definition of BF; The CIF of BF at 10 years after LDR-BT was 2.5 % (0.4-7.9), p = 0.009. There was no statistically significant difference in PCSS between interventions.

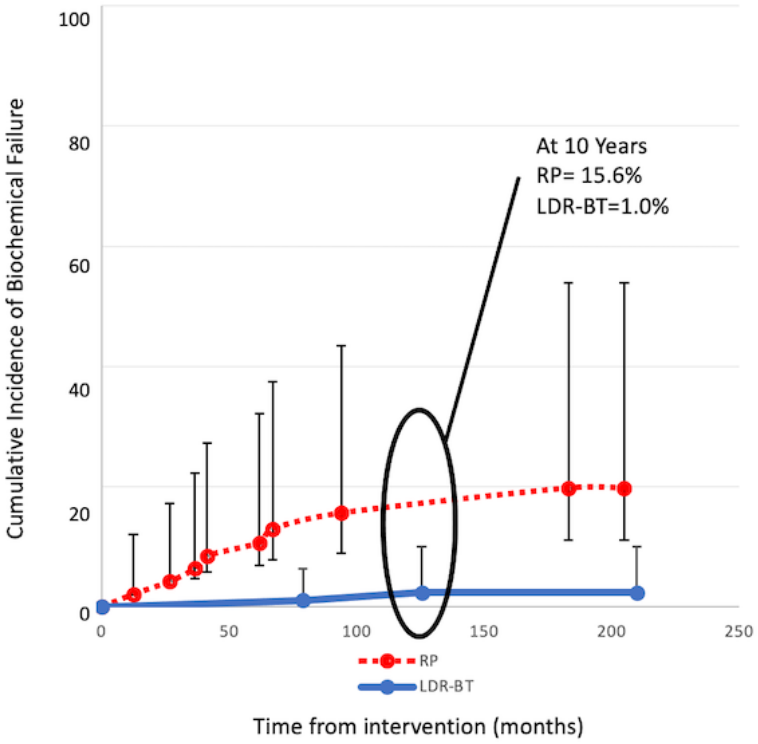

Figure 1. Cumulative Incidence of Biochemical Failure in RP and LDR-BT Patients Over Time with 95% Confidence Intervals.

Conclusion
This analysis was undertaken on a cohort of men with similar patient and tumour characteristics who were prospectively enrolled and were candidates for both RP and LDR-BT. Recognizing the differences in defining BF, these results suggest LDR-BT provides superior biochemical control compared to RP for patients with low risk prostate cancer, in addition to the previously suggested advantage for LDR-BT in urinary and sexual quality of life domains and patient satisfaction.

OC-0100 20 years of iodine-seed prostate brachytherapy: monotherapy-outcomes in 1013 patients

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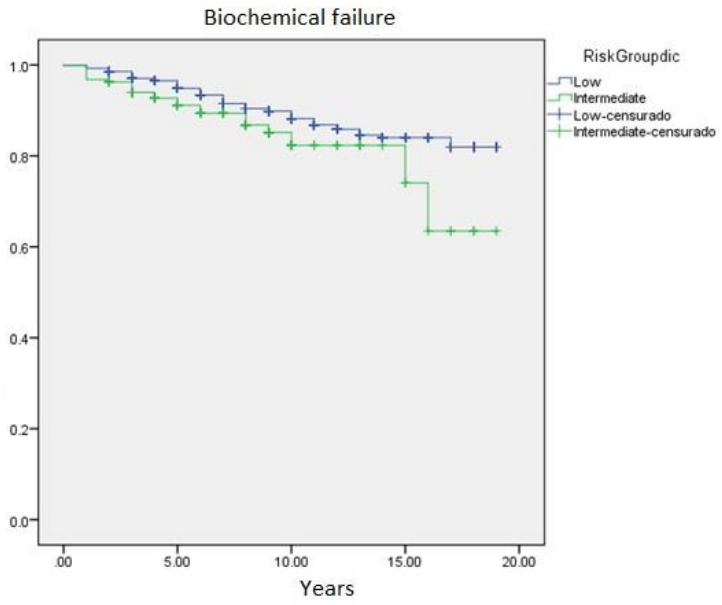
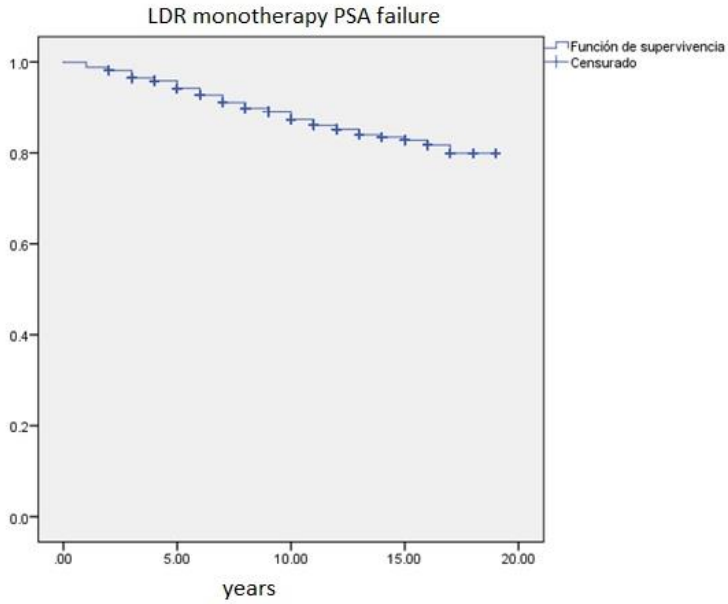
Purpose or Objective
To report biochemical failure and survival long-term outcomes of patients undergoing permanent low dose rate brachytherapy as monotherapy for prostate cancer in a single institution.

Materials and Methods
Patients with diagnosis of low and intermediate risk prostate cancer treated with I-125 at our institution (between june-1999 and january-2019) were examinated. Those with less than 2 year followup and less than two post brachytherapy prostate-specfic antigen were excluded. 22% of patients received 3-6 months of androgen deprivation therapy.

Results
About 1013 from 1302 patients satisfied inclusion criteria. With median followup of 102 months, biochemical failure ocurred in 114 patients. Freedom from biochemical failure as defined by the Phoenix criterion was 94%, 87% and 83% at 5, 10 and 15 years, worse for intermediate risk as compared with low risk, with 15-year freedom from biochemical failure of 74% versus 84% respectly. On multivariable análysis, pre-therapeutic PSA was associated with biochemical failure. Gleason 4 + 3 and no receipt of androgen deprivation therapy was not associated with biochemical relapse. No differerence in outcomes between patients with clinical stage T1 and T2 was observed.





Conclusion
Permanent prostate brachytherapy monotherapy with I-125 provided excellent outcomes in this large series of patients. Freedom from biochemical failure at 15 years was as high as 83%. Higher pre-treatment PSA was the only factor associated with biochemical relapse. Androgen deprivation therapy and Gleason score has no association with biochemical failure.

OC-0101 17 years' of EBRT plus HDR brachytherapy boost in high risk localized prostate cancer patients

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Purpose or Objective
Reports of clinical outcomes for high-risk prostate cancer (PCa) patients treated with external beam radiation therapy (EBRT) and brachytherapy are mainly with LDR boost. Data about high-dose rate boost (HDRB) in high risk PCa is scarce. Our aim is to present our 17 years' experience of HDRB in this patient population.

Materials and Methods
The cohort includes 396 high-risk PCa patients treated with EBRT and HDRB at our institution between 1999 and 2016. The majority of them received a single fraction HDRB of 15 Gy (83%) and 44 Gy in 22 fractions EBRT (76%). Some received 19-21 Gy in 2 fractions HDRB (15%). Biochemical relapse (BCR) and metastasis cumulative incidence functions (CIF) were calculated by competing risk analysis using death as a competing event. Overall survival (OS) was computed by the Kaplan-Meier method. Associations between initial PSA level, age, Gleason score, tumor stage and androgen-deprivation therapy

(ADT) with BCR were assessed by Fine and Gray regression models. For metastasis, the Fine and Gray models also included BCR as a prognostic factor. Associations between clinical and disease characteristics with OS were evaluated by Cox regression models.

Results
The mean age of the patients at treatment time was 69.6±7.3 years. The median follow-up was 55.5 months. The most frequent tumor stages were T1C (31.3%), T2A (16.2%) and T2C (25.5%) while 15.5% of patients were in the T3 category. A majority had a disease of Gleason score 8 (53.0%) with many being scored 7 (24.5%) or 9 (14.4%). The pre-treatment PSA levels were between 0 and 10 for 58.6% of patients, from 10 to 20 for 24.0% and higher than 20 for 17.4%. Most patient received over 18 months of ADT but 40 patients in the cohort (10.1%) did not receive any. The 10 years CIFs for BCR, metastasis and death in our cohort were 10.6%, 7.2% and 28.2%, respectively. Patients not receiving ADT had a significantly higher BCR incidence (p=0.008). On Fine and Gray models for 10-year BCR, only tumor stage T3 (HR=7.31, p=0.003) and no ADT (HR=3.03, p=0.016) were significantly associated with increased hazard. For 10-year metastasis CIF, pre-treatment PSA level showed a trend towards significance (HR=1.01, p=0.051) while BCR very significantly increased the risk (HR=119. p<0.0001). For 10-year OS, both age (HR=1.06, p=0.005) and progression to metastatic disease (HR=4.28, p<0.0001) had increased hazard in Cox models.

Conclusion
The results of this study show an excellent tumor control at 10 years for high-risk PCa patients treated with EBRT and HDRB at our institution: 10.6% BCR and 7.2% metastasis incidence. The data suggests that patients with a clinical tumor stage T3 are at higher risk of biochemical relapse. The best predictor of metastasis disease was BCR and to a lesser extent PSA. In addition to age, the progression to a metastatic disease was associated with higher risk of death.

OC-0102 HDR brachytherapy as a single-day monotherapy: Survival results of a phase II randomized trial

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Purpose or Objective
Multiple fractions of high-dose-rate (HDR) brachytherapy (BRT) as monotherapy are effective. The downside of this attitude is the use of multiple implants over several days. The aim of this study is to report on the efficacy results of a randomized phase II trial of a single implant, single day monotherapy delivered in one or two fractions.

Materials and Methods
206 patients with low or intermediate-risk prostate cancer were recruited. 199 were randomized between one fraction of 19.5Gy or two fractions of 14.5Gy on an HDR-BRT single day monotherapy protocol (BRP2, NCT03424694). Treatment was delivered in both arms in a single-implant one-day schedule. Patients in the 2 fractions arm had their treatment delivered 6h apart and had 2 set of imaging and 2 dosimetries. Dosimetry was post implant MRI-based contouring with dominant intra prostatic lesion (DIL) boost allowed. Post-treatment evaluation was at 1, 3, 6 weeks, 3 months, 6 months and every 6 months subsequently. The Phoenix definition was used to define biochemical failure. Failures were confirmed by biopsy and/or TEP PSMA.

Results
Pre-treatment median PSA for 19.5Gy arm and 29Gy arm 2 were 6.58±2.78 and 6.74±2.71 respectively. Gleason scores were 6(3+3) 18.2% and 13% ,7(3+4) 54.5% and 58%, 7(4+3) 27.3% and 29% respectively. Per NCCN risk grouping low risk were 6.53%, favourable intermediate risk were 33%, and 60.45% unfavourable intermediate risk were 60.45%.
All patients were discharged the same day. Dosimetric parameters were well achieved, and criteria for CTV coverage were reached in 100% of the fractions. As for organs at risk, the dose constraints were well achieved except for the bladder dose which was exceeded in one fraction accounting for less than 1% deviation on dosimetric plans.
Median follow-up was 46 (8.9-64.9) months. PSA nadir was 0.95±0.87 for 19.5Gy arm and 0.52±0.82 for 29Gy arm. At 4 years, 19 patients in arm 1 and 5 patients in arm 2 experienced recurrence.
The 4-years biochemical disease-free survival (bDFS), local control rate is 80.8% and 95% (p=0.008) and 76% and 93% (p=0.004) for in 19.5Gy and 29Gy arm, respectively. Control rates were 100% in both arms for low risk group, 84% and 97% for arms 19.5Gy and 29Gy respectively, for the favorable intermediate risk group, and 76% and 93.4% in arms 19.5Gy and 29Gy respectively, in unfavorable intermediate risk group.
Disease specific survival is 98% and 100% for arm 19.5Gy and 29Gy respectively.

Conclusion
Our results confirm the feasibility of a single day HDR-BRT monotherapy and achieved to yield good results. Two fractions HDR brachytherapy monotherapy seems to give better results.

OC-0103 Comparative study of brachytherapy vs. radical cystectomy for cT1-2 muscle-invasive bladder cancer

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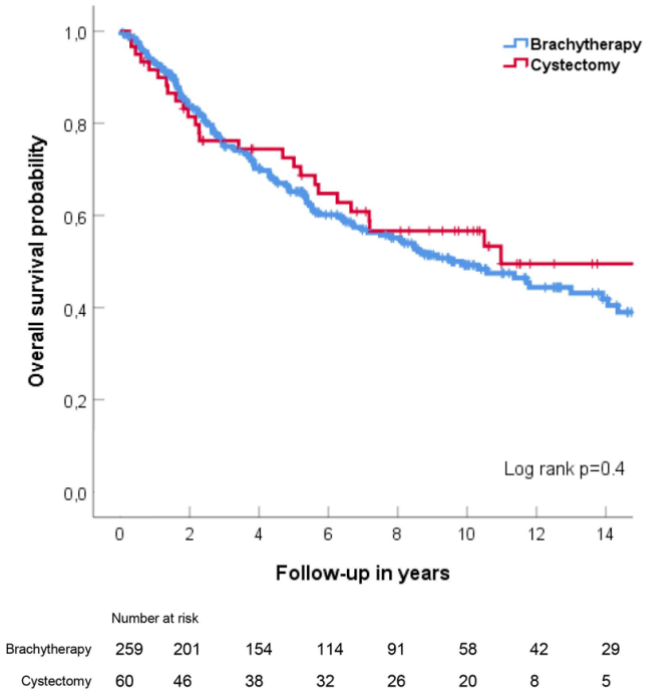
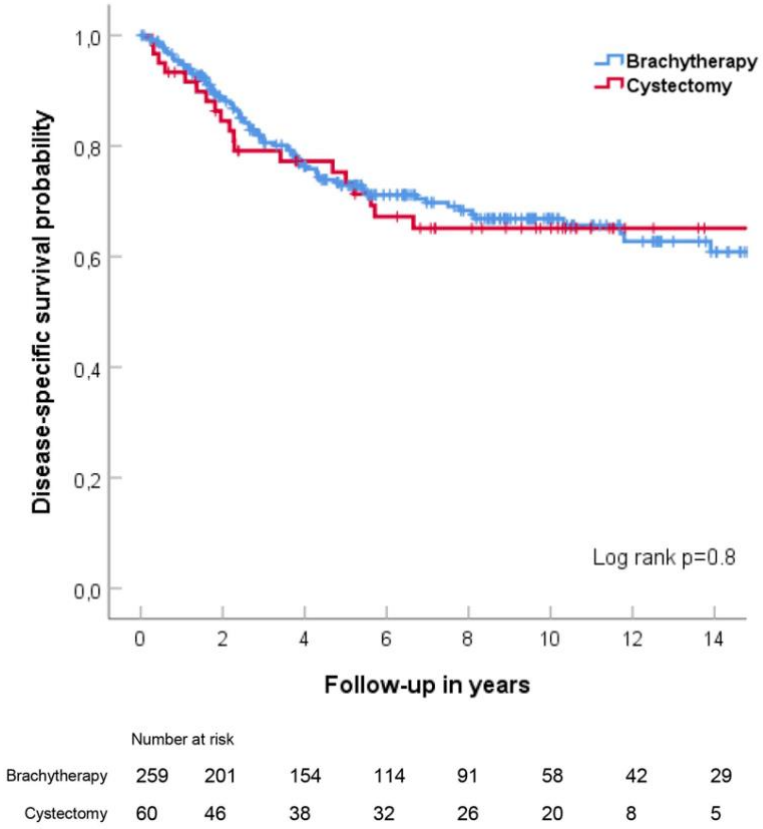
Purpose or Objective
Radical cystectomy (RC) with or without neoadjuvant chemotherapy is considered the standard treatment for muscle-invasive bladder cancer (MIBC). Alternatively, bladder sparing is offered for selected cases to preserve bladder function. One modality to preserve the bladder is the combination of external beam radiotherapy (EBRT) with brachytherapy (BT). There is scarce data on the comparison of treatment outcome of RC to EBRT-BT. Therefore, we investigated treatment outcome regarding survival and complication rate for a patient population treated in the same time period.

Materials and Methods
Patients treated in the period 1988 to 2016 of two institutes performing both EBRT-BT and RC were analyzed. In total 268 evaluable patients were treated by EBRT-BT. Selection criteria were mainly solitary tumors ≤ 5cm, cT1-2 and no carcinoma in situ, located in an implantable area. The EBRT-BT cohort was compared to 60 RC patients that were not suitable for BT due to impaired bladder capacity, patient's preference or due to a tumor location unsuitable for brachytherapy. Patients who underwent RC instead of EBRT-BT for oncological reasons were excluded from analysis.
Patients were followed-up by yearly imaging (chest and abdomen) and cystoscopy for the EBRT-BT cases.
Kaplan-Meier curves for overall survival (OS) and disease-specific survival (DSS) after EBRT-BT and RC were constructed and compared using the log-rank test.
Late (> 90 days) complications was assigned according to Common Terminology Criteria for Adverse Events (CTCAE) v5.0.

Results
Median follow-up was 9.6 years after EBRT-BT and 10.6 years after RC.
Five/10-year OS after EBRT-BT was 65% (95%CI: 59-71) and 49% (95%CI: 43-57), and after RC 68% (95%CI: 61-73) and 53% (95%CI: 48-59; P=0.4). Five/10-year DSS after EBRT-BT was 73% (95%CI: 67-77) and 67% (95%CI: 60-73), and after RC 75% (95%CI: 66-78) and 65% (95%CI: 58-72; P=0.8).
Intravesical recurrence occurred in 58/268 (22%) EBRT-BT patients, whereas 17 true in-field and 22 elsewhere in the bladder. In 19 cases the vesical recurrence location was unknown.
In 25/58 (43%) patients the recurrence was Non-MIBC and in 33/58 (57%) MIBC.Salvage cystectomy was performed in 32 patients.
Late complication rates were similar after EBRT-BT and RC (18% vs 17%, P=0.8).
After RC, all late complications were grade 3-4 (10/10, 100%); whilst after EBRT-BT, 63% (30/48) of late complications were grade 3-4 (P=0.02).
In total 84% of EBRT-BT treated patients preserved their bladder.





Conclusion
In this largest comparative study of EBRT-BT and RC with the longest follow-up it is shown that for selected patients with solitary, ≤5cmcT1G3-T2N0M0bladder tumours EBRT-BT is a bladder-sparing therapy with good survival outcome. In the majority of cases the bladder could be preserved. The complication rate of EBRT-BT has a favorable outcome compared to RC.

OC-0104 high-dose rate brachytherapy in localized penile cancer: clinical outcome analysis

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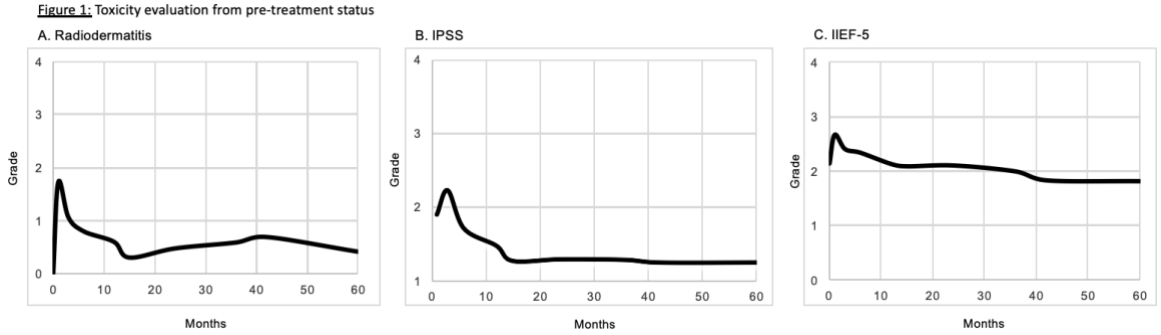
Purpose or Objective
To analyse the oncological outcome and toxicity profile after conservative treatment based on multicatheter interstitial high-dose rate brachytherapy (MHB), for patients presenting a localized penile cancer.

Materials and Methods
Patients with histologically proven, non-metastatic (T1-T2 N0-N2 M0) localized penile cancer were treated with MHB. Under general anesthesia, needles were placed into the target volume using a dedicated template. Treatment planning was performed using a post-implant CT-scan to deliver 35 Gy or 38 Gy in 9 fractions over 5 consecutive days for adjuvant treatment or monotherapy respectively. The dose-volume adaptation was carried out by graphic optimization. Five-year oncological outcome was evaluated with local (LC) and regional control rates (RC), metastatic disease-free survival (MDFS), specific (SS) and overall survival (OS). In pre-treatment and follow-up consultations (1, 3, 6 and 12 months then every 6 months during the 5 first years of follow-up then annually), skin, urinary and sexual toxicities were investigated using CTCAE v4.0 classification, International Prostate Symptom Score (IPSS) and International Index of Erectile Function 5-items (IIEF-5). Dosimetric data were also analysed.

Results
From 03/2006 to 05/2020, with a median follow-up of 72.4 months [3-173.6], 29 pts, mainly T1 (75.9%) and N0 (89.7%) regarding TNM classification, were treated with MHB. Brachytherapy was performed as adjuvant treatment in 11 pts (38%) and as a definitive approach in 18 pts (62%). Five-year LC, RC, MDFS, SS and OS were 86%, 83%, 69%, 88% and 73% respectively. Six patients (20.7%) experienced local relapse and underwent salvage penectomy leading to a penile preservation rate of 79.3%. Acute skin toxicity (radiodermatitis) was consistently reported 1 month after MHB, with 28% G1, 66% G2 and 6% G3. Regarding late skin complications, 5 pts (17%) presented telangiectasia and 2 pts (7%) presented necrosis requiring hyperbaric oxygen therapy sessions allowing complete skin recover. Comparing pre- and post-treatment status, no significant change was observed for skin appearance, IPSS and IIEF-5 (Figure 1A, 1B, 1C). Tow pts (7%) presented urethral meatus stenosis requiring dilatations.



Conclusion
In order to propose an organ preservation treatment, MHB is an excellent first line option for penile cancers limited to the glans, in the absence of involvement of the corpus cavernosum. Most local relapses are efficiently salvaged by second intent radical surgery. Larger-scale studies with longer follow-up are necessary to increase the good practice recommendation grade.

Proffered papers: Imaging and more

OC-0105 MRI-guided robotic needle insertion for prostate brachytherapy: proof of principle study in patients

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Purpose or Objective
A robotic needle implant device for MR guided high dose rate (HDR) prostate brachytherapy is under development at the University Medical Center Utrecht. The robot fits in a 1.5 T MR scanner and is placed between the patient's legs. While scanning, the needle is stepwise inserted using a pneumatic tapping device to reduce prostate deformation. The needle can be shifted and angulated to have access to the prostate while avoiding the pubic bone. The purpose of this patient study is to test the feasibility and accuracy of inserting a brachytherapy needle into the prostate to a defined target point using the robotic device.

Materials and Methods

2 patients were included in this study. GTV and CTV were delineated based on diagnostic MRI and PET, and a preplan was made to assess needle configuration. An MR scan was made in treatment position and fused with the diagnostic MR images. One of the preplanned needle positions was selected for robot insertion. The robot coordinates and angles were set for the target point, and the needle was tapped in while monitored with dynamic MRI. At final depth, an MR scan was made to verify the needle position and adapt the treatment plan, after which the dose was delivered. Accuracy of robotic needle insertion was analyzed by comparing the planned needle tip position with the realized position in MR coordinates. For analysis of prostate movement due to needle insertion the translations and rotations between the MR scans before and after needle insertion were determined using the fusion module of the treatment planning system. Duration of the robotic procedure was recorded.

Results
The robotic device was able to tap the needle into the prostate to the planned needle depths of 105 and 104 mm with respect to the perineum surface for patient 1 and 2, respectively. The robotic needle insertion and dose delivery (including setup, anesthesia, catheter insertion, MR scanning, reconstruction and planning) took 2 hours, of which the needle insertion itself took 10 minutes. Δx (LR), Δy (AP), Δz (CC) deviations between the realized needle tip position and the planned position were 7.1, 5.5, -3.4 mm and 0.5, 3.0, 1.1 mm for patient 1 and 2, respectively (see figure 1). The translation and rotation of the prostate between the prescan and the postscan amounted 1.5, -1.1, 0.9 mm and -1.0°, 0.5°, 1.5° for patient 1 and -0.2, -0.1, -0.7 mm and -0.3°, 0.0°, 0.0° for patient 2. There was no indication of bending of the needle in both patients.

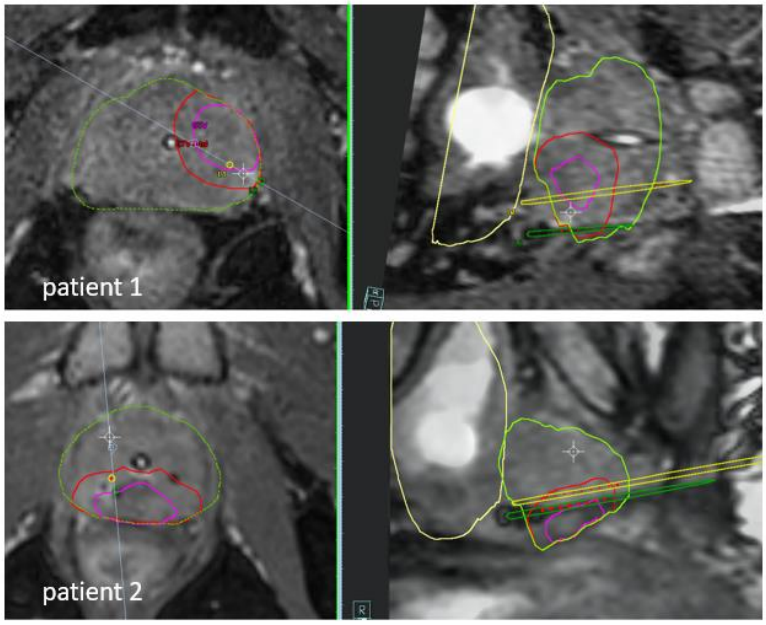

Figure 1: transversal and oblique MR images of the prostate with planned (yellow) and realized needle position (green), prostate (green), bladder (yellow), CTV (red) and GTV (purple); the white line in the transversal images depicts the oblique plane through the planned and realized needle.

Conclusion
This first in vivo test shows that MRI guided robotic needle insertion is feasible with increasing accuracy to <3 mm and limited prostate movement in the order of 1 mm and rotation in the order of 1.0°.

OC-0106 US-guided EM tracked system compared to OncentraProstate for HDR brachytherapy: a first in-men study

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Purpose or Objective
To report on a first-in men clinical trial using an ultrasound-guided EM tracked HDR planning (EMT) system for intra-op US based prostate HDR brachytherapy. The accuracy of automatic reconstruction offered by the EM tracking system is also evaluated.

Materials and Methods
A clinical trial was implemented in order to compare the OR procedure times for two different treatment planning systems: an EMT-enabled investigational device from Philips Disease Management Solutions, and the actual clinical system used since 2015, OncentraProstate (OCP) from Elekta. In this prospective trial, 60 patients with a 15Gy HDR prostate boost will be randomised and equally distributed between both systems. As the EMT treatment planning software is not Health Canada approved, all obtained plans were recomputed in the OncentraBrachy software (v 4.5) and exported from there to the Flexitron (v 3.2.1) afterloader.

Results
A total of 31 patients (16 EMT and 15 OCP) have been treated so far. Procedure times were faster for EMT compared to OCP. The overall procedure time (median values) from patient positioning to treatment was 86.5min (ranging from 71min to 143min) for EMT compared to 95min (ranging from 70min to 161min) for OCP. Results are presented in Fig.1 and Table 1. A notable difference resides in the patient positioning and equipment setup which take longer for EMT compared to OCP with median values of 23min and 15min respectively. This is explained by the time spent to set up the EM generator and EM sensors for EMT as well as the manipulation of the US holder which is more complex than the OCP one. On the other hand, the catheter reconstruction time is faster for EMT, with median values of 7min compared to 16min for OCP. The automatic reconstruction offered by EMT also exclude any mistake related to the visual localisation of catheters or the catheter tips which is a frequent issue in US images. When there is no EM disturbance or catheter motion due to the EM stylet stiffness, minimal manual corrections of reconstructed catheters were required for less than 4 catheters per case. Finally, dose optimizations, calculations and review times were similar for OCP (median time= 10min) compared to EMT (median time=11min). After 16 cases, no learning curve phase was observed with the EMT technology as it could have been expected since it is a new technology and procedure workflow.

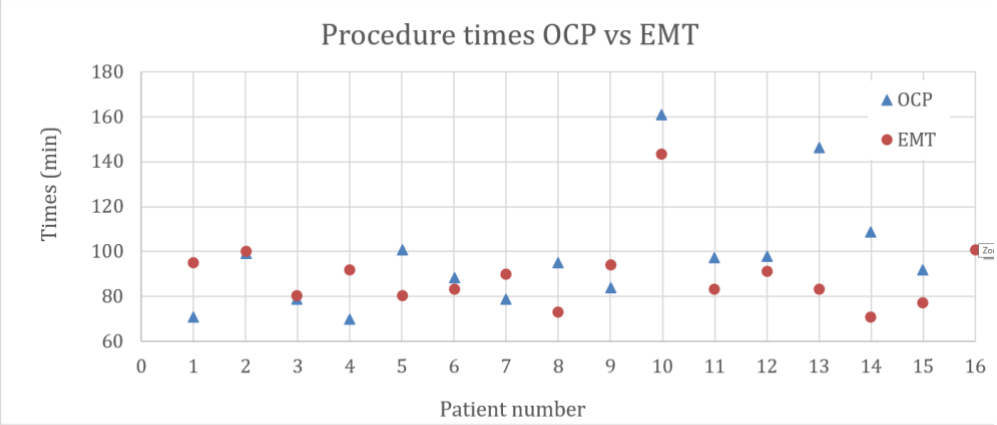

Fig.1 Procedure times for OCP and EMT from patient positioning to treatment

Table 1: Durations for different steps (median times): comparison between OCP and EMT.

	Median Time in OCP (min)	Median Time in EMT (min)
Patient and Equipment setup	15	23
US pre-scan	1	---
Catheter insertion	18	19
US scan and contours	22	16
Catheter reconstruction	16	7
Dosimetry	10	11
Plan validation and verification	12	15

Conclusion
EMT allows for shorter procedure times in the OR in comparison to OCP, which is in use since 2015 and over 200 cases/year. It was also found that EMT offers a fast solution for catheter reconstruction. Its EM technology provide an accurate and fast identification of catheters and catheters tips during catheter reconstruction.

OC-0107 Dosimetric Impact of CT and TRUS vs MR based volumes for Brachytherapy of Cervical Cancers

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Materials and Methods
Patients (n=21) with histologically proven cervical cancer, who were enrolled in the EMBRACE-I study from our institution were included. Patients underwent real time TRUS followed by MR and CT. On CT, high risk clinical target volume was contoured with assistance of TRUS and clinical drawings (CTV-THR-CT+TRUS). Likewise, gross tumor volume at BT, CTV-THR-MR and OARs were delineated. For each patient, two treatment plans were made: MR and CT plan. CT and MR images at the time BT were fused based on the applicator, followed by the transfer of CTV-THR-MR to the CT images. CTV-THR-MR when transferred to CT images was referred as CTV-THR-MRonCT. The agreement between the dosimetric parameters (D90, D98, D50) of CTV-THR-MRonCT vs CTV-THR-CT+TRUS were evaluated based on Bland-Altman plots, linear Regression analysis, standard two-tailed paired t-test, and Wilcoxon signed ranked test.

Results
Mean± standard deviation (SD) volumes of CTV-THR was 35±14 cm3 (r =0.92), for MR and CT+TRUS. No statistically significant systematic difference in the dosimetric parameters was found between MR and CT plans for target structures. Mean D90, D98 and D50 of CTV-THR-MRonCT was higher by 1.9, 1.2 and 5.6 Gy respectively, as compared to CTV-THR-CT+TRUS.

Although the mean dose-difference was small in magnitude for D90 and D98, the limits of agreement (2 SD) was wide, ranging from -17 to 21 Gy for D90, -18 to 20 Gy for D98, and -16 to 28 Gy for D50, however, 19/21, and 20/21 patients were inside the limits of agreement for D90 and D98 respectively. The number of patients who have met the dose constraints of D90 > 85 Gy were 90% (19/21) and 80 % (17/21) in MR and in CT plans respectively. The rest of the 20 % (4/21) of the patients in CT, were in the borderline, and received a minimum dose of 80 Gy. The mean ±SD dose-difference between MR and CT plans for bladder was 5±13 Gy for D0.1cm3. For other organs, rectum and sigmoid, the dose-difference was found to be less than ±3 Gy and not statistically significant.

Conclusion
No significant systematic differences in dose-volume parameters for target and OARs were found. However, considerable variations were seen on individual patient level which needs to be considered during clinical practice, which also needs further investigations. These findings provide useful information to optimally utilize various imaging modalities for BT planning.

OC-0108 Impact of patient positioning on interstitial multicatheter HDR brachytherapy of the breast

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Purpose or Objective
One of the treatment options after receiving breast conserving surgery is high dose rate (HDR) multicatheter interstitial brachytherapy (iBT). For quality assurance (QA) purposes an electromagnetic tracking system (EMTS) is introduced as a tool to detect treatment uncertainties in general. In this contribution, a patient study is currently conducted with the aim to detect the uncertainties and mainly to investigate the influence of patient positioning on the treatment quality.

Materials and Methods
For this objective, an afterloader prototype (Flexitron, Elekta, Veenendaal, The Netherlands), was equipped with an additional EM sensor drive and an EMTS (Aurora, NDI, Canada), which were used in this study. In combination with a field generator inducing an electromagnetic field above the patient's breast, the position of the sensor moved inside the catheters can be tracked. After each fraction an EMT measurement was conducted.
The measured EMT data are rigidly registered to the catheter geometry based on CT imaging and dwell positions (DP) are reconstructed using a polynomial of third degree. Afterwards, the Euclidean distance ΔDP between DPs reconstructed from EMT and the corresponding DPs of the treatment plan is calculated. A large deviation in ΔDP indicates a planning and/or treatment delivery error, which is analyzed using graphics created using an in-house developed MATLAB routine. For evaluation of the influence of the patient´s position, the arm or torso are repositioned during additional measurements (M_{add}) after the common fraction measurement (M_{ref}), used as reference. Two additional positions were evaluated: first, the ipsilateral arm was positioned under the head instead of next to the body. Second, the torso was set to an upright position by raising the treatment table while the arm remained next to the body as in M_{ref}.

Results
Up to now, 56 patients participated in the study, in which 14 patients received a boost therapy (2×6 Gy) and 42 an APBI treatment (9×3.8 Gy).
To date, M_{add} was conducted with a varied arm position for 13 patients and 11 patients were measured with a varied torso position. A median ΔDP of 2.19 mm for all patients over all fractions was determined for the reference positions. Regarding the arm repositioning, the median ΔDP increased from 2.55 mm during M_{ref} to 3.57 mm. With respect to repositioning the torso an increase from ΔDP=2.29 mm during M_{ref} to 3.20 mm was observed.
The impact of patient positioning on the dosimetry is currently analyzed. Patient recruitment continues.

Conclusion
The evaluation of more than 500 measurements with over 8,000 measured catheters showed that EMT can be integrated into the clinical workflow. The study proved that positioning of the patient has an impact on the median deviation between EMT-based DPs and the DPs in the treatment plan.

OC-0109 Implant-based CT estimation towards adaptive breast brachytherapy

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Purpose or Objective
The need for adaptive planning in interstitial multi-catheter HDR breast brachytherapy has long been an unnoted topic due to the lack of both evidence and dose-free methods to detect interfractional changes. However, within a retrospective study of 55 breast cancer patients assessing the need for adaptive treatment planning, we found that 4 % of the patients would have benefitted from replanning in the course of the treatment [Kallis et al., Radiother Oncol 2019]. To date, in our workflow no extensive routine measures are undertaken to ensure the correct position of the catheter implant prior to every fraction, apart from a follow-up CT (FCT) after the fourth out of nine treatment fractions. Our goal is to develop an implant-based CT estimation (estCT) based on the data from the planning CT (PCT) and from a dose-free electromagnetic tracking (EMT) system to describe interfractional changes of the implant geometry. EMT data are recorded with an afterloader prototype (Flexitron, Elekta, Veenendaal, The Netherlands) equipped with an EMT sensor (Aurora, NDI,

Waterloo, Canada). We generate the estCT by a thin-plate spline based warping of the PCT using the implant geometry from treatment planning and the daily EMT implant reconstruction. Thus, the acquisition of a FCT could eventually become unnecessary. To assess the quality of EMT-based CT estimation, we compare the computed estCT to the rigidly registered FCT (rFCT) as a clinical ground truth.

Materials and Methods
In a retrospective evaluation of routine clinical data of 15 breast cancer patients, EMT implant reconstructions acquired immediately after the PCT and the FCT were used to calculate a deformation vector field by means of thin-plate splines, a widely used interpolation method for image warping. The deformation field was subsequently applied to the PCT, resulting in a warped estCT. For a quantitative analysis of the estimation, the estCT was compared to the rFCT in terms of Hounsfield unit differences (ΔHU) in the planning target volume (PTV) and in a convex hull (CH) around the catheters.

Results
The HU difference (mean ± STD) between estCT and rFCT over all patients is 45.1 ± 81.5 HU for the PTV and 83.5 ± 217.3 HU for the CH (see Figure 1). For reference, calculation of ΔHU for PCT and rFCT yields similar values: 46.4 ± 80.6 HU (PTV) and 79.3 ± 203.9 HU (CH). The obtained results are best in the vicinity of the catheters. In domains far from the implant, the estimation becomes worse. A dosimetric evaluation of estCTs is currently ongoing.

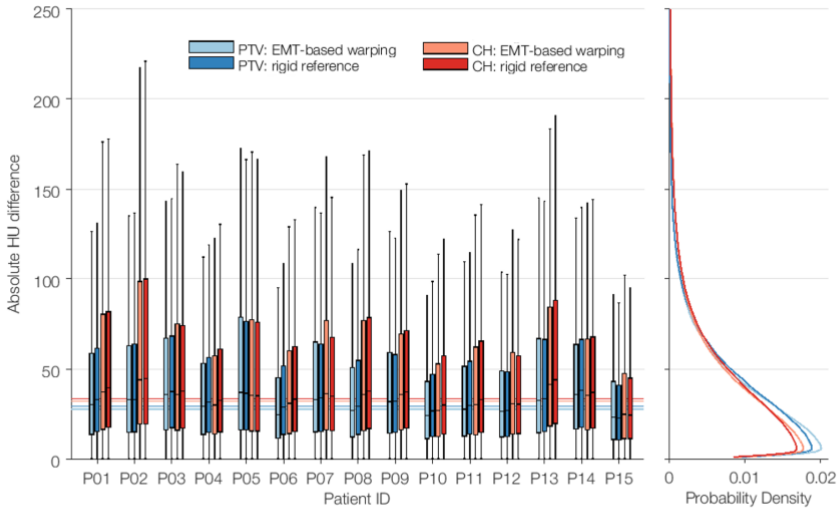

Figure 1. (Left) Absolute HU differences visualised by boxplots (median, minimum, maximum, first quartile, third quartile) for the PTV (blue) and the convex hull (red). Horizontal lines represent the overall medians of all 15 patients. **(Right)** The corresponding probability density functions of the absolute HU differences over all patients.

Conclusion
The presented thin-plate spline approach for CT estimation using EMT data successfully reproduced interfractional changes of the catheter implant. The results are a promising step towards EMT-based adaptive brachytherapy with no need of extra dose exposure by a FCT.

OC-0110 Characterisation of an inorganic scintillation detector system for time resolved in vivo dosimetry

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Purpose or Objective
To characterise an inorganic scintillation detector (ISD) system for *in vivo* dosimetry (IVD) during High-Dose-Rate (HDR) and Pulsed-Dose-Rate (PDR) brachytherapy (BT).

Materials and Methods
An ISD system developed for real time IVD during BT was characterised using ^{192}Ir HDR BT sources. The system consisted of an inorganic scintillator-based detector probe, which fits inside standard BT needles, and a diode-based read-out system (20 Hz sampling rate). The system was characterised for two materials ZnSe:O and CsI:Tl. These materials were selected because their high scintillation outputs eliminate the need for stem-effect correction [1]. Three quantities were characterised.
Signal-to-noise ratio (SNR): The SNR was defined as the ratio between the measured signal and the SD of the signal. The ratio was determined for several source-to-detector distances (SDD) ranging from 5 to 50 mm.
Energy dependence: A 2D map of the energy dependence was measured in full scatter conditions. The source was placed in a large water phantom. The detector was moved in a 2D grid with 2 mm steps using a robotic arm (Meca500). The grid covered y = 6 – 60 mm (transversal plane) and z = -50 – 50 mm (along source axis). The measured signals were divided by TG43 values and normalized to the 20 mm transaxial position.

Temperature dependence: The probes were placed in a water phantom. The water was heated in steps of ~2 degrees from 22 °C to 37 °C using a water heater (SuperFish ECO heater 300W). Irradiations were performed at each temperature (SDDs: 5-55 mm). The signal as a function of temperature was normalized to the signal measured at 22 °C for ZnSe:O and at 25 °C for CsI:Tl.

Results

SNR: The measured SNR ranged from 728(459) at 5 mm to 117(62) at 50 mm for ZnSe:O(CsI:Tl) respectively, when a source activity of S_k = 32641 U was used. For IVD measurements, this will correspond to a 3(6) % uncertainty on the signal for a 1 s dwell time using a weak PDR source (S_k = 2000 U) at 50 mm, and 0.4(0.7) % for a weak HDR source (S_k = 16000 U) at 50mm.
Energy: Fig. 1 shows the measured 3D energy dependence for the two scintillators. The energy dependence is a non-linear relation of up to 3 %/mm, and is dependent on both distance and angle.
Temperature: Fig. 2 shows the temperature dependence for the two scintillators including a linear fit. The linear temperature dependency for the two scintillators were determined to -0.82 ± 0.06 %-point/ °C (ZnSe:O) and -0.39 ± 0.02 %-point/ °C (CsI:Tl).

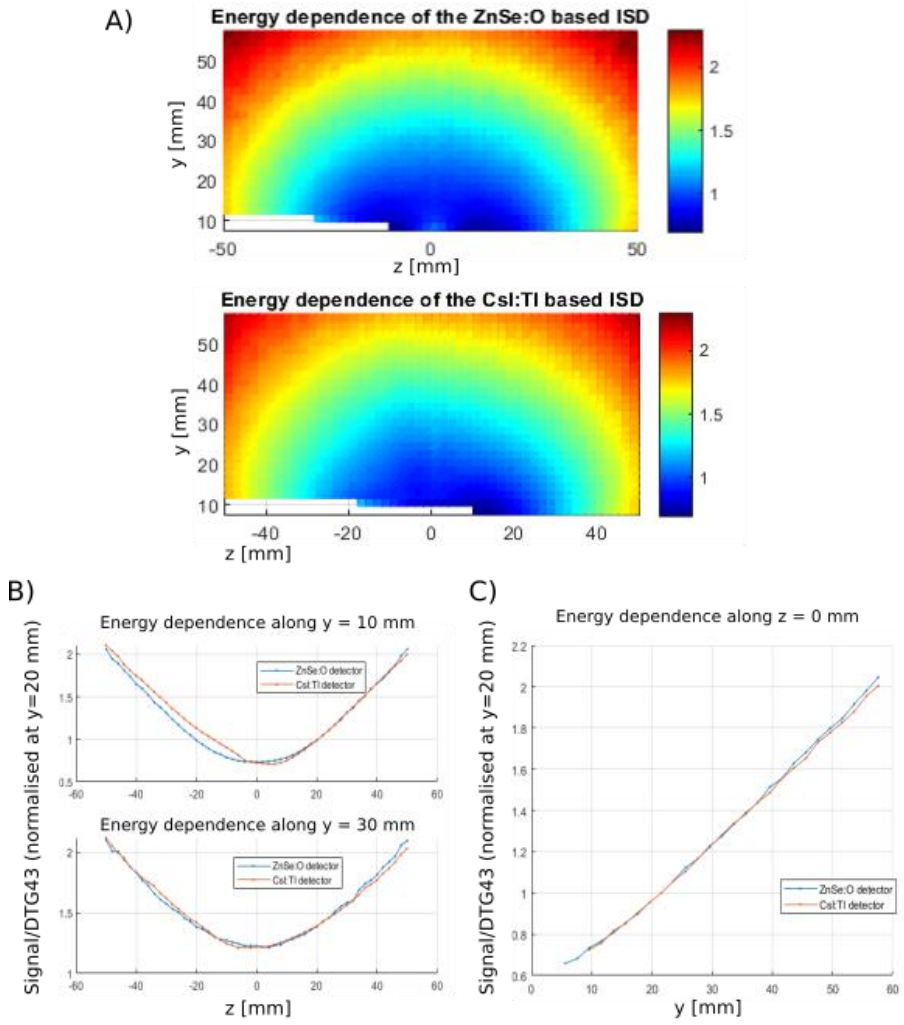

Figure 1: (A) 3D maps of the energy dependence in spatial coordinates for ZnSe:O and CsI:Tl. (B) The energy dependence profile along the source axis at y =10 mm and 30 mm. (C) The energy dependence profile perpendicular to the source.

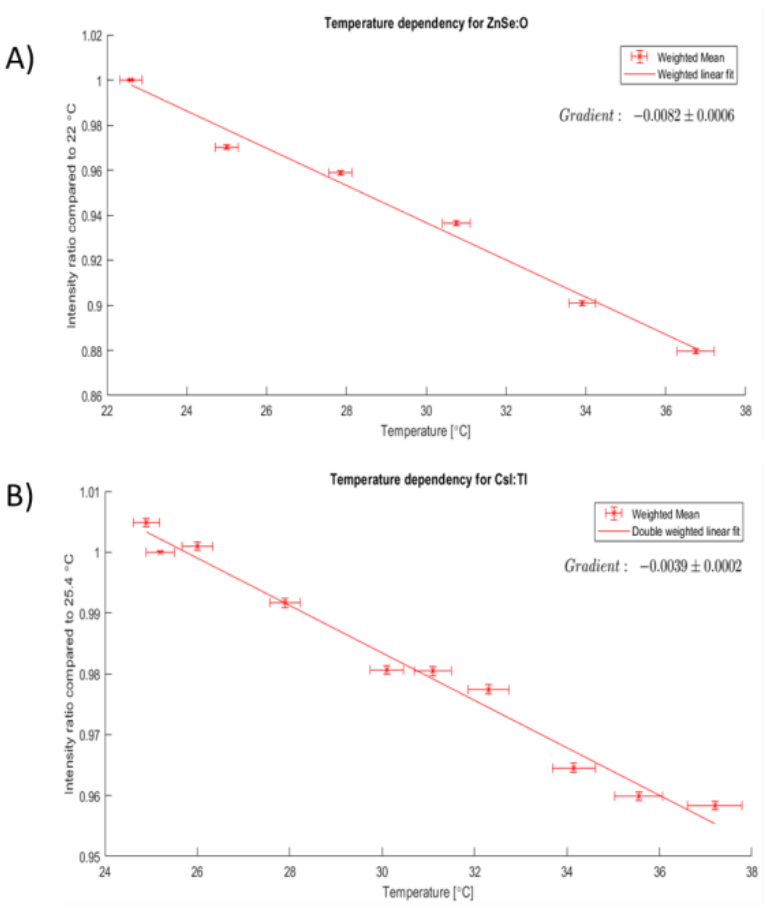

Figure 2: Temperature dependence of ZnSe:O (A) and CsI:Tl (B) including the linear fit to the data points. The temperature dependence is normalised to 22° C for ZnSe:O and 25° C for CsI:Tl.

Conclusion
The performance of the ISD system was appropriate for real-time IVD in HDR and PDR BT. The crystals showed clear energy and temperature dependencies. Accurate determination of these quantities is necessary for real-time IVD BT

[1] Kertzscher G and Beddar S, Inorganic scintillation detectors for 192Ir brachytherapy. Phys Med Biol. 2019

Proffered papers: Training, GI and Eye

OC-0111 Intraluminal brachytherapy with chemoradiation versus chemoradiation alone in carcinoma of esophagus

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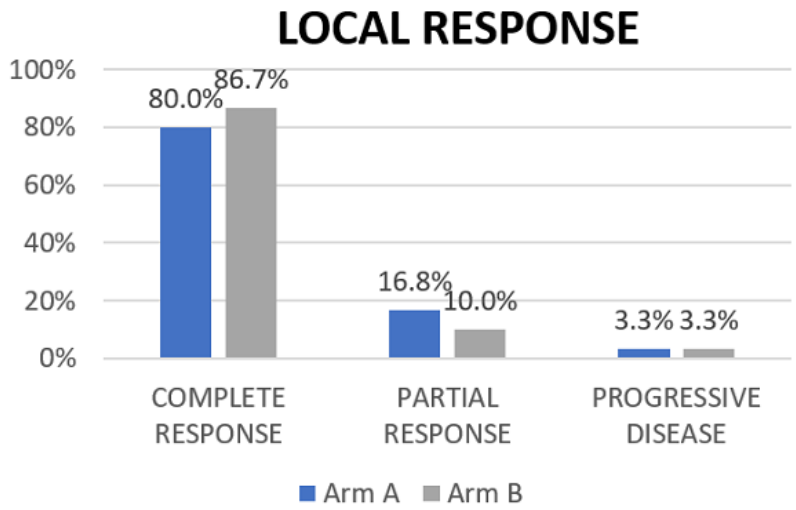
Purpose or Objective
In locally advanced esophageal cancers chemoradiation is considered as definitive therapy, due to improved survival rates but loco-regional tumor control remain a challenge. ILBT in esophageal cancer offers an advantage of delivering higher dose of radiation to the tumor while sparing the surrounding normal tissues.
The objective of this study was to evaluate and compare, response and toxicities in patients treated with chemoradiation alone and chemoradiation with high dose rate intraluminal brachytherapy in carcinoma of the esophagus.

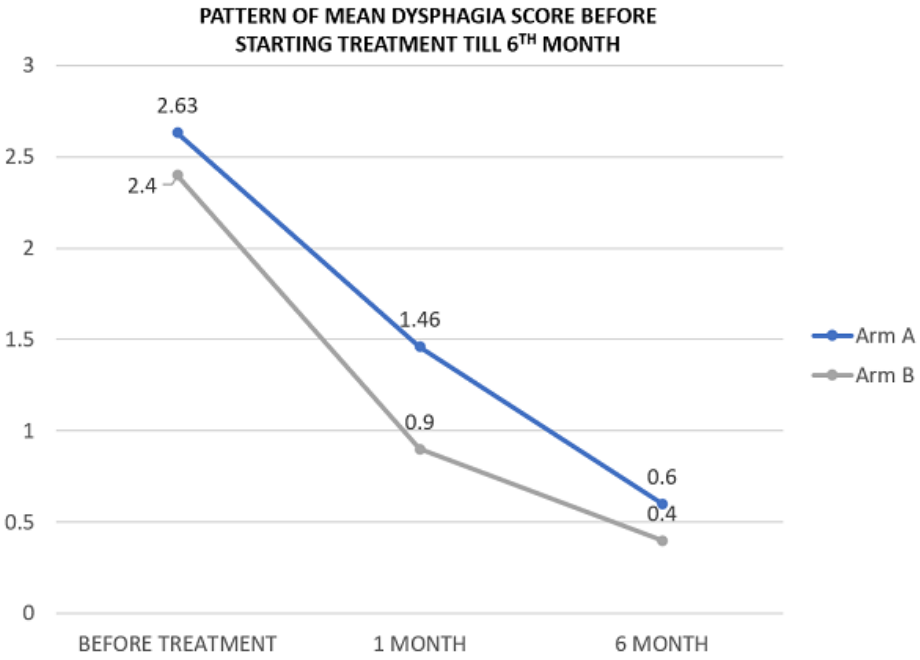
Materials and Methods
A total of 60 patients were included in the study who were randomly assigned to 2 arms namely Arm A and B with 30 patients in each arm. All patients underwent a CT scan of the thorax and an upper GI endoscopy for staging evaluation. Arm A received definitive chemoradiation 54Gy in 27 fractions with concurrent weekly Cisplatin and Arm B received definitive chemoradiation 50Gy in 25 fractions with concurrent weekly Cisplatin followed by two sessions of intraluminal brachytherapy of 4 Gy each 1 week apart. EBRT was delivered using IMRT on a 6MV linear accelerator. ILBT was delivered through a 6mm ILBT applicator using HDR remote after loading system with Iridium source. 4Gy was delivered to the visible tumour plus a 2 cm cranio-caudal margin at 1 cm from the center of the applicator.
Evaluation of early response was done at one and six months post completion of treatment on a by upper GI endoscopy and CT scan. Dysphagia scores were recorded before, on completion of treatment and on 1st and 6th month of follow up. Patient

was evaluated for Gastro-intestinal toxicities including esophagitis, stricture, ulcer and fistula. Comparison between both the groups were done with Student t test. Statistical analysis was done using SPSS version 21.

Results

The mean age was 58.7 years in arm A and 60 years in arm B. At 6 months, 80 % of the patients in Arm A had complete response and 86.7 % in arm B had a complete response (p=0.48). 50% of the patients in Arm A could tolerate normal diet without dysphagia at 6 months compared to 66.7% of patients in arm B (p=0.04). Dysphagia scores showed a significant improvement in patients of arm B compared to arm A (p<0.05). 5 patients in each arm developed esophagitis. Grade 2 esophageal ulceration was seen in 5 patients in arm B. Grade 3 stricture was seen in 1 patient in arm A and 3 patients in arm B at 6th month. None of the patient in both the arm developed fistula. None of the patients required surgical or endoscopic intervention for toxicities.





Conclusion

Chemoradiation with ILBT for carcinoma of the esophagus provides excellent local control of the disease with acceptable toxicities when compared with chemoradiation alone.

OC-0112 development of a dynamic-shielding intensity modulated endorectal brachytherapy applicator

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Purpose or Objective

Surgical resection is the primary curative treatment for rectal adenocarcinoma, preceded by neoadjuvant chemoradiotherapy. External beam radiation therapy is the best-studied form of neoadjuvant radiotherapy but is associated with significant toxicities. An alternative is high dose rate (HDR) brachytherapy (BT), with initial results indicating fewer toxicities and similar perioperative outcomes. However, radiation sources used in BT conventionally provide rotationally-symmetric dose distributions, which deliver a high dose to the tumor, but often with poor target conformity. This results in dose spillage to the organs at risk (OAR). By incorporating dynamically-rotating metallic shields, intensity modulated BT (IMBT) opens the possibility to deliver more conformal dose distributions by directing the radiation towards the tumor and away from OAR. The goal of this study was to develop an MRI compatible dynamic-shield IMBT applicator for the treatment of rectal cancer and compare the results with static shield HDR-BT.

Materials and Methods

Two single-grooved tungsten dynamically-rotating shields with diameters 15 and 18 mm were designed. Currently, in our clinic, static shield HDR-BT is performed by using a flexible cylindrical intracavitary mold applicator (length 28 cm, diameter 2 cm) (Elekta Brachytherapy, Veenendaal, The Netherlands). The central lumen fits an 8 mm diameter tungsten rod for OAR shielding. Computer models of the static shield and IMBT applicators were imported to an in-house Monte Carlo based treatment planning system called RapidBrachyMCTPS and superimposed onto the patient geometry to retrospectively compare static shield HDR-BT with IMBT using a generic Ir-192 source for 2 patients. The prescribed dose was 3 fractions of 10 Gy. Treatment plans were optimized for both modalities using the fast mixed-integer method. The distance between dwell positions was 5 mm and the shield rotation was limited to 15° increments. Dose was scored by simulating 10^8 radioactive decays using a 1 mm^3 voxel grid. Measurements with Gafchromic film were performed in solid-water for the 18 mm IMBT shield to demonstrate the safety of the new system.

Results

Preliminary results show that the dose to the clinical target volume (CTV) and OAR is similar between static shield HDR-BT and IMBT with the 15 mm shield, which indicates that this method can effectively be used in cases where static shielding is not possible. Additionally, the CTV D_{90} is significantly increased when using the 18 mm shield compared to static shield HDR-BT (9.87 ± 0.11 Gy vs 9.99 ± 0.04 Gy, P = 0.02) and the contralateral rectal wall D_{2cc} is significantly decreased (7.19 ± 0.95 Gy vs 5.29 ± 1.14 Gy, P < 0.01). Radiochromic film measurements in solid water with the 18 mm shield showed that the dose decreased by 90.07% ± 3.80% on the shielded side.

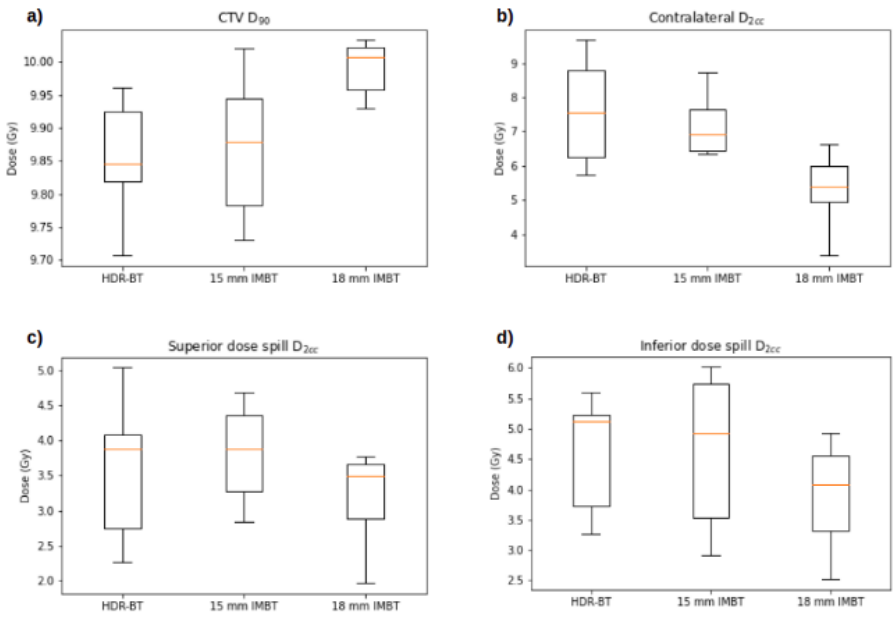

Figure 1: Delivery method comparing static shield HDR-BT to dynamic-shield IMBT calculated with a generic Ir-192 source. (a) Clinical target volume D_{90}, (b) contralateral rectum wall D_{2cc}, (c) superior ROI D_{2cc}, (d) Inferior ROI D_{2cc}.

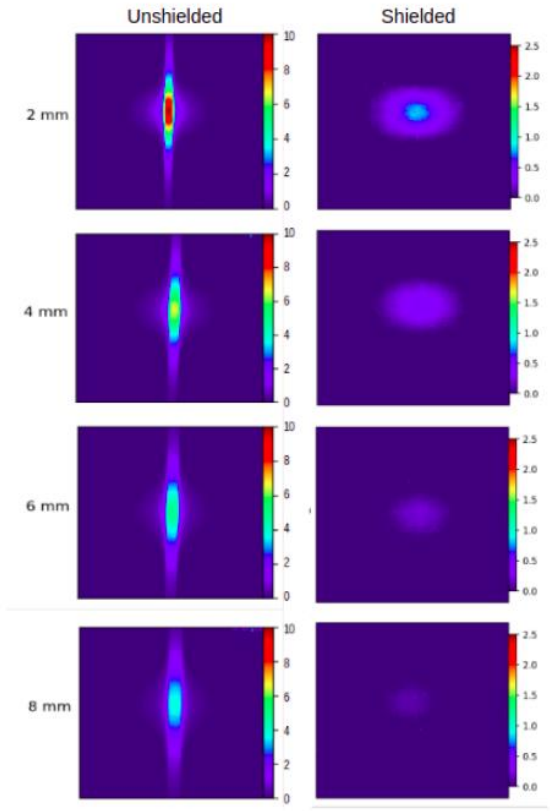

Figure 2: Coronal cross-section of dose distributions (in Gy) measured by EBT3 Gafchromic film in solid-water with the 18 mm shield at 2 mm, 4 mm, 6 mm, and 8 mm from the emission window and shielded side of the applicator.

Conclusion
An applicator enabling dynamic-shield IMBT for rectal cancer was developed with the possibility to increase the dose to the tumor while more effectively shielding OAR.

OC-0113 Evaluation of early clinical response of CT-guided HDR interstitial brachytherapy in HCC

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Purpose or Objective
The treatment options for hepatocellular carcinoma involve several local ablative methods, such as radiofrequency ablation (RFA) or microwave ablation (MWA). Interstitial CT-guided brachytherapy (BT) is a safe and effective alternative. We report on the treatment and clinical outcome of consecutive patients treated between 07/17 and 06/19.

Materials and Methods
60 consecutive patients (m:f 50:10; age 67+/-12 years) treated with CT-guided HDR interstitial brachytherapy for hepatocellular carcinoma were evaluated. Patients received local ablation of up to 3 lesions per treatment session, with a prescribed dose of 15Gy. 48 patients had a Child Pugh Score (CPS) A and 12 patients CPS B. 14 patients were on a waiting list for liver transplant.

Results
A total of 77 treatment sessions on 111 HCC lesions were evaluated. In 53 treatment sessions a single lesion was treated, in 14 cases 2 and in 10 cases 3 lesions were treated. Mean GTV diameter was 3.5+/-1.8cm and mean GTV volume was 24+/-47ccm. Brachytherapy was performed in a single fraction with an aimed prescription dose of 15Gy, taking into account constraints of organs at risk. A mean dose of D100=14.74 Gy was applied, D95=19.55Gy, D90=21.87 Gy. The mean total liver volume was 1682+/-475ccm, the mean liver volume receiving >5Gy and >10Gy was 301+/-244ccm (18+/-13%) and 133+/-128ccm (8+/-7%), respectively.

After a mean clinical follow-up of 10+/-7month, 41 patients were alive, 7 patients died during follow-up and 12 patients were lost to follow-up. Out of 60 patients, 7 patients underwent liver transplant, of which one patient died due to transplant rejection. Overall 43 patients showed no hepatic progression and 14 patients had progressive distant hepatic disease. Regarding local control by lesion, complete response was documented for 88/111 lesions (79%), 15 lesions showed local recurrence and no follow-up was available for 8 lesions.

Conclusion
Interstitial CT-guided BT is an effective treatment option with a good rate of local control. However, longer follow-up is needed to definitively assess its role in this setting.

OC-0114 Results from the First Spanish National Survey on Epiescleral Brachytherapy for Uveal Melanoma

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Purpose or Objective
Perform a national survey to establish the use of epiescleral brachytherapy as a treatment option for uveal melanoma over a 10-year period and describe patient and tumour characteristics, work-up studies, dosimetry and planning, as well as patient follow-up and treatment complications.

Materials and Methods
Seven reference hospitals at the national level with considerable experience in epiescleral brachytherapy for uveal melanoma (performance of at least 10 implants per year) participated in the study. The survey was carried out using Google Forms with 42 questions, and the resulting descriptive statistics were done in Microsoft Excel. Epiescleral brachytherapy was performed with *ROPES*, Collaborative Ocular Melanoma Study (*COMS)* and *Eckert & Ziegler BEBIG's* plaques loaded with Iodine^{125} seed models 6711 y 125.S16, and Rutenio^{106}. Planning followed American Association of Physicists in Medicine (AAPM), American Brachytherapy Society (ABS) and COMS guidelines.

Results
Between 2007 and 2017, 1350 patients were treated with epiescleral brachytherapy, a mean of 25 patients' year. All centres used echography and ophthalmoscopy for diagnosis. According to the COMS classification, 17%, 70% and 13% reported tumours were small, medium and large respectively. Median age was 65 years old; 54,2% were women and 45,8% were men. Five out of seven centres used both I^{125} and Ru^{106}. Dosimetry and three-dimensional reconstruction were performed by a computer system developed by Dr. Astrahan at the University of California, using version 2.16. The clinical target volume was defined through echography with a 2mm margin around tumor base. Prescription dose was to the tumour apex. Dosimetry for I^{125} was calculated using COMS. Dose prescription was 85Gy for both I^{125} and Ru^{106}. Maximum and minimum dose for I^{125} treatment ranged from 0,4Gy/hour to 1,25Gy/hour, which implied five to seven-day hospitalization. All centres performed patient follow-up.

Conclusion
This was the first Spanish national survey performed to determine the use of epiescleral brachytherapy for uveal melanoma. Although the treatment is highly defined, there are variations among centres on which it would be convenient to reach a consensus. A closer patient follow-up is highly needed to achieve accurate results in terms of local control rate and brachytherapy side-effects.

OC-0115 Detector-based quality assurance of assembled brachytherapy eye plaques

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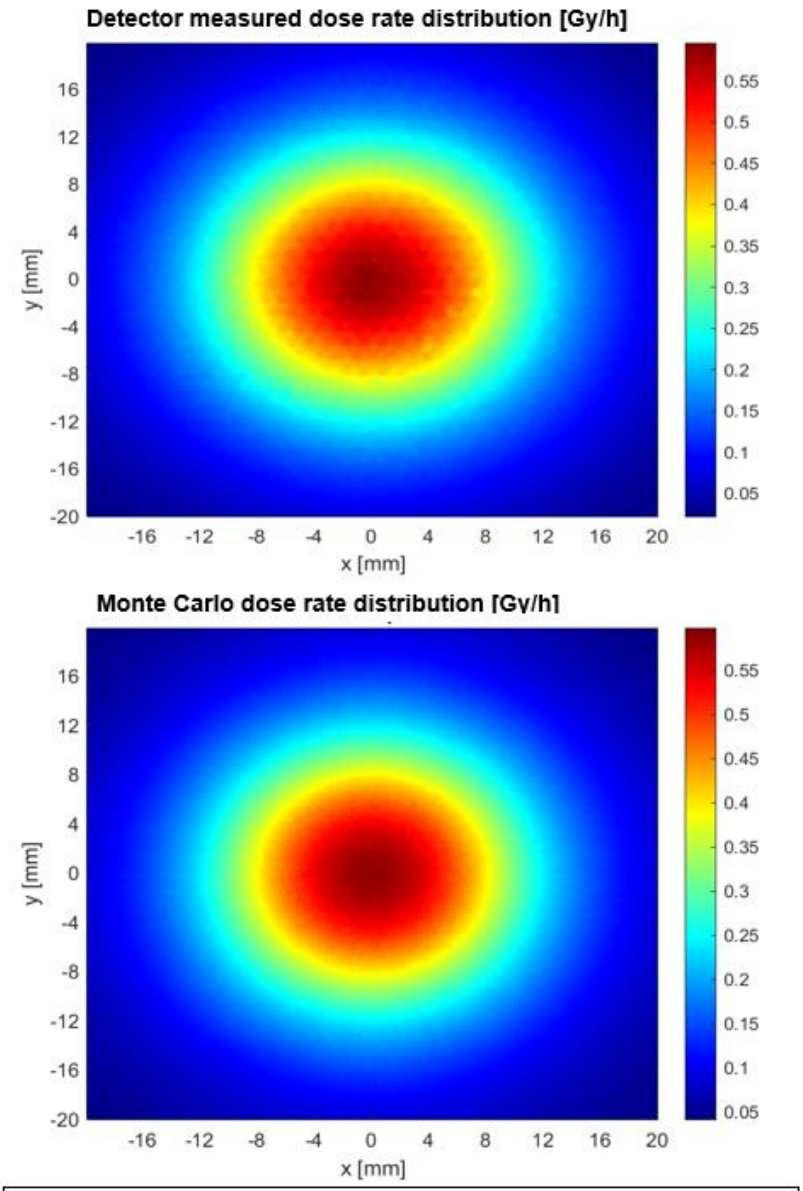
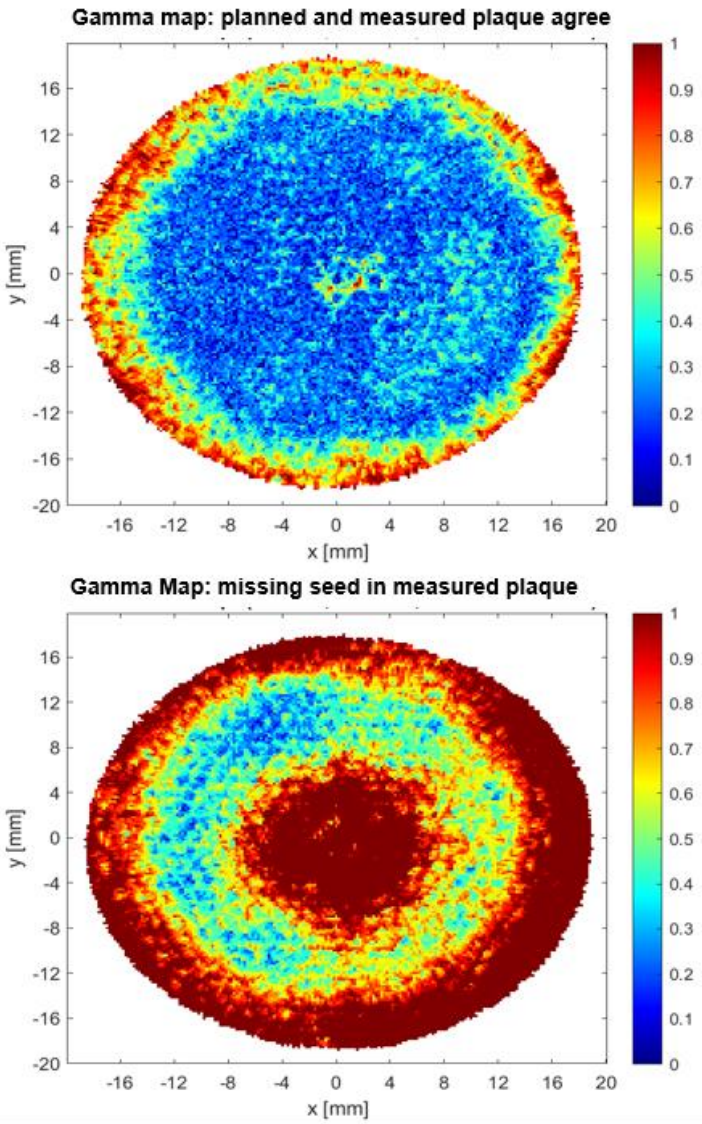
Purpose or Objective
This study presents an experimental dosimetry system for pre-insertion quality assurance of assembled brachytherapy eye plaques using a high-resolution CMOS flat-panel x-ray detector. A calibration method using Monte Carlo (MC) simulations is established and experimental results are compared to MC calculations for various plaque configurations. Fast measurement times and easy handling make it viable for everyday QA and provide a means of independent source strength validation for pre-assembled plaques.

Materials and Methods
A Dexella 1521 CMOS flat-panel x-ray detector [Varex Imaging, Salt Lake City, USA] with a 75 um pixel size is used in conjunction with a 6 mm high, dome-shaped acrylic plaque holder and an in-house manufactured acrylic eye plaque, loaded with either Pd-103 seeds [IAPd-103, IsoAid, Port Richey, USA] or I-125 seeds [AgX100, Theragenics, Buford, CA]. For calibration of the detector and validation of the method, individual source strengths were measured with an ADCL calibrated HDR 1000 PLUS well chamber [Standard Imaging, Middleton, USA] before plaque assembly. egs_brachy, a brachytherapy specialized application for the EGSnrc radiation transport software, is used for MC simulation of the eye plaque dose distribution in the plane of the detector. The detector is calibrated by spatially registering the geometric central region of the measured and MC-calculated 2D dose distributions of three calibration eye plaques per source type, each loaded with various configurations of seeds.

Results
The calibration shows a linear dose response of the detector. Using this, the measured dose distributions of various plaque configurations show good agreement with MC calculations. The central dose rate is predicted by the measurements to within +-7% of the MC calculated central dose rate, allowing independent verification of the air-kerma strength of the assembled plaque. In addition, gamma-index analysis isused to compare measurements and MC calculations in the plane of the detector. This enabled the detection of individual mispositioned or dead seeds, as well as seeds that are out of specification enough to affect the dose distribution of the plaque.



Dose distribution of an 18 seed Pd-103 eye plaque in the detector plane as measured using the calibrated detector (upper image) and calculated using a Monte Carlo simulation of the detector (lower image).



Gamma map (3%/1mm dose difference/distance criteria) comparing measured and Monte Carlo calculated dose for a 17 seed I-125 plaque. **Top:** the planned and measured plaque agree. The measured central dose is 1.4% higher than MC central dose. **Bottom:** One seed is missing close to the center of the measured plaque. The measured central dose is 6.1% smaller than MC central dose.

Conclusion
A calibrated flat panel detector for low energy x-rays is suited for quality assurance of assembled brachytherapy eye plaques using I-125 or Pd-103 seeds. It is more reliable, faster, and easier to use than approaches using film measurements or detector measurements in a water phantom*, making it viable for everyday use. It also provides more detailed spatial information than could be achieved using a well chamber. A detector-based method is especially useful for QA of pre-assembled plaques, providing a method to independently validate overall air-kerma strength and dose distributions pre-insertion and detect packing errors.
* Weaver et al., Radiat. Meas., 46 (2011), pp. 2010-2013

OC-0116 Cervical cancer brachytherapy training by 3D printing tissue equivalent patient anatomy from DICOMs

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Purpose or Objective
Globally, the declining use of brachytherapy (BT) in radiation oncology has diminished cure rates for patients with cervix cancer. Central to decreased physician BT implementation is lack of opportunity to gain personal expertise in the clinical practice of complex BT. We present our experience in creating a cost-effective BT simulation trainer to help address the gap in physician clinical experience. Objectives for the trainer include development of a pelvic tissue model with tactile and ballistic properties that allow for simulated cervix positioning, os identification and dilation with insertion of interstitial applicator and needles with placement feedback.

Materials and Methods
We developed a process to fabricate pelvic models that reproduce cervical cancer patient anatomy as it would present at the time of BT. The internal pelvic anatomy was derived by segmentation of the normal and cancerous tissues and organs from a patient's MRI scans. These models were then 3D printed, poured, and modified to form anatomic components. Silicone acts as interstitial tissue to provide an ultrasoundable environment free of air spaces. Dragon Skin silicone of various densities, Ecoflex, and graphite were used in order to achieve the appearances, textures, ballistic properties and ultrasound characteristics of the tissues being modeled. The pelvic module was designed for placement in a mannequin and coverage with a Dragon Skin silicone flap that models the skin and external genitalia. Insertion forces of needle applicators were measured between cadaveric and trainer models to characterize the validity of material choices for interstitial tissues. A standard surgical template was used to guide needle placement and make location comparisons for needle insertion.

Results
We developed a BT trainer starting with a Stage IIB cervical cancer patient that faithfully reproduced the patient's anatomy clinically. The pelvic module had trans-rectal ultrasound characteristics similar to that of the patient's images. The average insertion force (N) of the cadaveric model was 15.3; the trainer tested at 19.1. The majority of insertion sites on the surgical template measured within one standard deviation between models. The pelvic module is CT and MRI compatible, allowing analysis of implants after insertion. The cost of creating a pelvic module is less than $200 in materials. A radiation oncology residency program found the product to be very useful, and modules will be included in an intensive BT training program for radiation oncology residents for further elaboration.

Conclusion
3D printing allows for generation of complex gyn pelvic training models that can incorporate TRUS as well as visual and tactile queues allowing for cost-effective simulation training to facilitate education and confidence in gyn BT among practicing radiation oncologists.

Poster presentation: GEC-ESTRO Best Poster Presentations

PP-0117 HDR BT in Non melanoma Skin Cancer: Results and toxicity with different techniques and applicators.

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Purpose or Objective
To analyze retrospectively the clinical results and toxicity of NMSC patients treated with HDR brachytherapy (HDRBT) with two techniques (interstitial and superficial) and different superficial applicators.

Materials and Methods
104 treatments in 80 patients with NMSC were performed between 2/2005 and 8/2018. Median age 79 yrs (range 34-97) Radical/definitive (33, 32%) or adjuvant/postoperative (71, 68%. Close margins (< 1 mm) (7), affected margins (44), perineural spread (15), recurrences (4) or T3 (1)). Superficial BT was delivered with **Valencia radionuclide-based applicators** (23, 22%), **manufactured flaps (Fleiburg flap** NUCLETRON/ELEKTA) (39, 38%) for flats areas or **individual customized molds** (16, 15%) for uneven surfaces when the CTV depth to be treated were ≤ 5 mm (defined by ultrasound). Macroscopic tumors, medial canthus areas, lower eyelid, irregular/curve surfaces or CTV depths > 5 mm were treated with **interstitial implants** (26, 25%). Doses: 10 fr/4-4,5 Gy, 6 fr/7 Gy, 7 fr/6 Gy for macroscopic disease or 10 fr/ 3-4 Gy in adyuvant indications. Doses were prescribed 3-4 mm in Valencia applicators, 5 mm from surface of the Fleiburg flap and optimized on CT in customized molds or interstitial implants.

Results
SPSS Statistics (Version 18.0) was used for statistical analysis. Median follow-up is 36 months (5-141 months). Toxicity has been analyzed following CTCAE 4.0 criteria. Acute toxicity was G1, 8%; G2, 54% and G3 38%. Mean time to resolution after finishing the implant has been 28 days (14-50 days). Acute Toxicity grade G3 has exclusively correlated in the multivariate analysis with the type applicator when Fleiburg flap is employed ($p < 0,01$). Chronic toxicity G1 has been developed in 20 treatments areas (20%), 3 alopecia and 17 hypopigmentation. At October 2020, 41 patients have dead (51%), one of them because of local recurrence/progression and other because of lymph node progression. Local control was achieved in 95 treatments (91%). We have analyzed the potencial factors for the local failures:
1. Tumor of 6 cm in leg (Interstitial).
2. Bone contact of the primary tumor in the first surgery (Fleiburg flap). Intraorbitary recurrence.
3. Medial canthus area. (Interstitial) Marginal depth recurrence. 2 patients.
4. Inmunodepression (Fleiburg flap). 3 patients.
5. Tumor in the tip of the nose (Valencia applicator). Erroneous selection of the technique. 1 patient.

Conclusion
In our experience, despite the different fractionations and techniques used, local control is homogenous for all of them. The acute toxicity found, is similar for all these techniques and fractionations employed, except for patients treated with flaps, in G3 epitelitis, reaching statistical significance. BT is a safe treatment in NMSC with low toxicity and higer levels of local control always that an adequate indication of the technique and applicator is made.

PP-0118 Dosimeter evaluation for measurement of radial dose distributions for electronic brachytherapy

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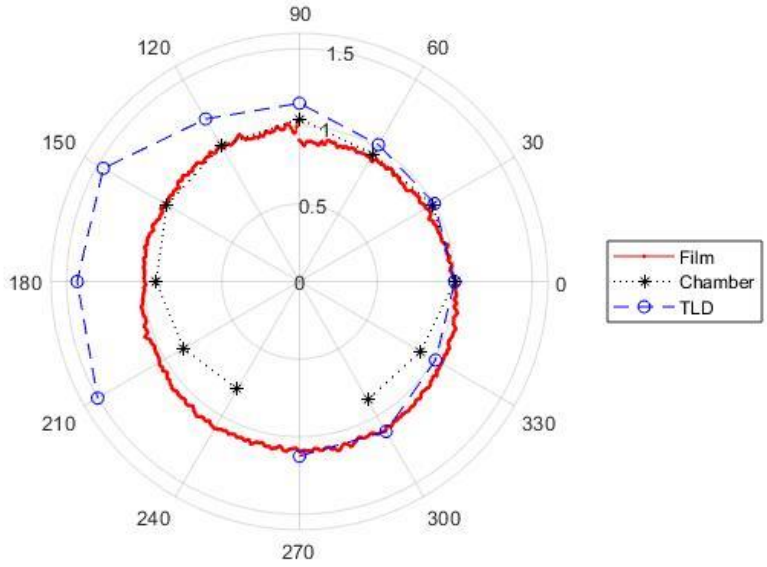
[1]*University of Wisconsin Madison, Medical Physics, Madison, USA*

Purpose or Objective
Determination of dosimetric parameters for the Xoft Axxent EBT source has traditionally been performed using TLD-100 microcubes due to a stable response and high-resolution for microdosimetric applications. While these detectors are ideal for these measurements, they are sensitive to positioning with respect to the Axxent source. Radiochromic film (RCF) and micro-chambers may provide a new means of determining these parameters by providing real time information about alignment errors. Thus, the purpose of this work was to compare use of TLD-100 microcubes, RCF, and micro-chambers for determination of the radial dose distributions for the Axxent source.

Materials and Methods
Three S7600 Xoft Axxent sources were used for this study. Phantoms used were manufactured in-house to ensure reproducible positioning of the dosimeters relative to the source anode. TLD-100 microcubes were sorted to a response of ±2%. TLDs were secured to Virtual Water posts and placed at 30˚ increments about the source anode. An Exradin A16 micro-chamber was used to monitor the source output and apply a timing correction factor. Measurements were taken in water for distances of 1 to 4 cm from the source. The same phantom was used to repeat these measurements in water with an Exradin A26 micro-chamber, replacing one post at a time to measure at each position. Note, the tip of the chamber was placed at the respective distance from the source. These preliminary measurements were used to test signal strength and source positioning within the phantom. Acrylic film phantoms were used to place Gafchromic EBT3 film strips around the source at the same 4 distances to measure continuous radial dose distributions in-air. All relative radial dose distributions were normalized to the 0˚ position for each distance.

Results
Figure 1 shows radial dose distributions for one source at 4 cm as measured with each dosimeter. Good agreement was seen between the A26 and film measurements, and an average deviation from the TLD measurements of 10% was observed. Average standard deviations for a given measurement position for the micro-chamber measurements ranged from 0.05% to 0.50% for distances of 1 and 4 cm, with 4 cm measurements having the largest amount of variation. Similarly, average standard deviations ranging from 2.2% to 5.5% between 1 and 4 cm for the film measurements were observed. Variability in the TLD measurements did not depend on distance from the source, and a maximum standard deviation of 4.0% was observed.



Conclusion
Overall, good agreement was observed between the three dosimeters, and reproducible measurements were performed within the uncertainty expected for each device. A shift in the radial dose distribution as measured with TLDs is indicative of a systematic shift in the measurement phantom, emphasizing their positional dependence. While TLDs have been best characterized for this application, both the micro-chamber and RCF show potential for the use of both relative and absolute dosimetry for EBT applications.

PP-0119 8-Gy single-fraction HDR brachytherapy boost after WBI on localized breast cancer in young women

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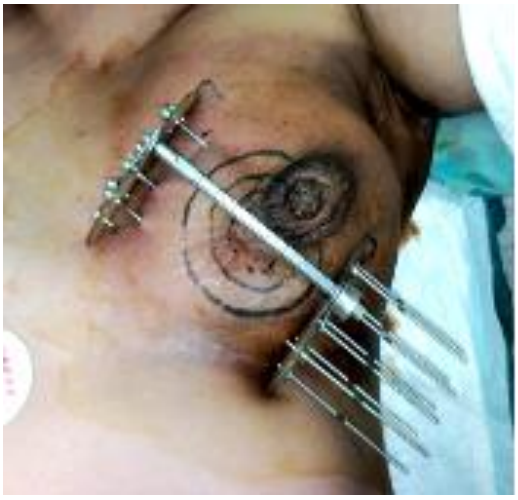
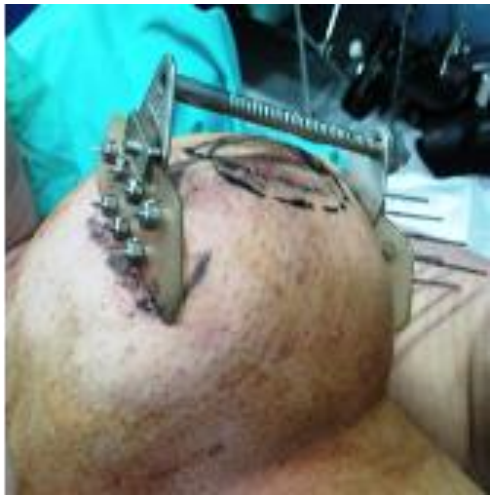
Purpose or Objective

The primary objective was to evaluate locoregional control survival outcomes in localized breast cancer in young patients treated with a single 8Gy high-dose-rate boost of brachytherapy (HDR-BT) after whole breast irradiation (WBI). The secondary objectives were to determine the short- and long-term adverse effects of the treatment comparing results by risk groups.

Materials and Methods

A prospective, single center, analytic study was conducted with 70 patients under 41 years old diagnosed with localized breast cancer treated with breast conserving therapy (free margin lumpectomy and 50Gy WBI) plus 8Gy single-fraction boost of HDR-BT between January 2008 and October 2012.

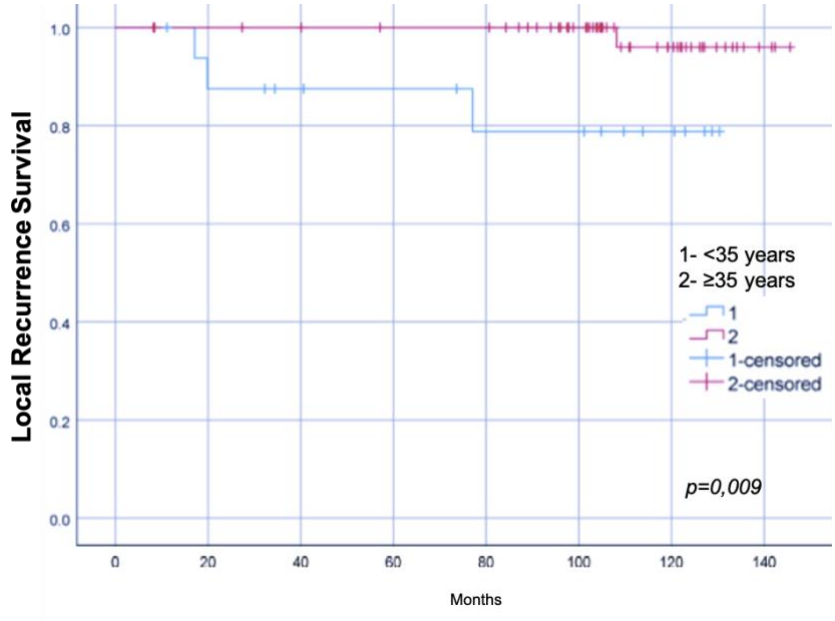




Results

The study included 70 patients (24.3% under 35yo), with a median age of 37 years old. Invasive ductal carcinoma was the predominant histology (97.1%) of which 55.7% had a grade 3 of differentiation. At a median follow up of 107 months (8-146); 4 (5.7%) patients locally relapsed; 6 (8.6%) died, 5 due to cancer progression, finally 15 (21.4%) patients progressed to metastatic disease. 8 patients were lost during the follow up. From the total of 70 patients, 16 (22,8%) were categorized as triple negative, 4 (25%) of them were younger than 35 years old, including 2 (50%) who developed local recurrence.

The overall survival for 5 and 10 years were 97,1% and 91,4% respectively. Local recurrence survival was 97,1% at 5 years and 94,3% at 10 years. Patient 35 years old or less had higher rate of recurrence compared with the 35 to 40 years old group (17.6% vs 1.9%; p=0.009); difference also seen for overall (88,2% vs 92,5%; p=0,5), disease specific (88,2% vs 94,3%; p=0,3) and metastasis free survival (82,4% vs 90,6%; p=0,3). Stratifying patients by hormone receptor status, we found a tendency, no statically significative, for worst outcomes in patients with the absence of receptors (triple negative); OS (93,8% vs 90,7%; p=0,7), LCS (87,5% vs 96,4%; p=0,2) and MFS (87,5% vs 88,9%; p=0,9). In terms of cosmetic outcomes, it was valuated in 57 patients. 54 (94,7%) had an excellent-good result and 3 patients (5,3%) were classified as bad.



Conclusion

The study showed that 8Gy single-fraction HDR boost after whole breast irradiation was well tolerated. An improved local tumor control with good cosmetic outcomes were observed as well as a low rate of complications. The <35yo subgroup causes special concerns due to the high rate of local recurrence observed, raising the question whether a dose escalation or a less conservative surgery treatment should be considered.

PP-0120 Applicator visualization using ultrashort echo time MRI for HDR endorectal brachytherapy

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[1]Leiden University Medical Center, Radiation Oncology, Leiden, The Netherlands; [2]Leiden University Medical Center, C.J. Gorter Center for High Field MRI, Radiology, Leiden, The Netherlands; [3]The Netherlands Cancer Institute, Radiation Oncology, Amsterdam, The Netherlands

Purpose or Objective
High-dose rate endorectal brachytherapy (HDREBT) is often applied with the intracavitary mold applicator set, which is a flexible eight-channel applicator (Elekta). Applicator reconstruction is currently performed on CT as the individual channels of the applicator are not visible on anatomical MRI images due to the short T_2 relaxation time of the applicator. However, MRI is the primary imaging modality for tumor delineation due to its superior soft tissue contrast. To be able to omit the CT, and thereby overcome registration uncertainties due to changes in applicator positioning between CT and MRI, applicator visualization on MRI should be further investigated. The aim of this study was to test whether an ultra-short echo time (UTE) sequence could be used to visualize the individual channels of the applicator. We evaluated the visibility of the individual channels in the applicator using a phantom and we acquired the UTE sequence in two rectal cancer patients with applicator in situ.

Materials and Methods
We used a radial 3D UTE pulse sequence (voxel size 0.98x0.98x2.5 mm^3, echo time 0.15 ms, repetition time 6.86 ms, FOV 376x376x315 mm^3, readout bandwidth 916 Hz/mm) on a Philips 3T Ingenia scanner. A phantom was constructed by filling a box with agarose gel with the applicator placed in the center. We rigidly registered a UTE sequence and CT scan of the phantom based on the outline of the applicator. One observer manually selected channel positions on CT and MRI in five slices spaced 25 mm apart to compare visualized channel positions.

Results
On the UTE sequence, the channels have sufficient contrast relative to the applicator itself to be able to discern the individual channels (Figure 1). The difference in selected channel positions on the UTE sequence compared to the CT was on average 0.1 ± 0.1 mm (LR) and 0.1 ± 0.3 mm (AP). On the UTE sequences of two patients with applicator in situ, the individual channels within the applicator can also be identified (Figure 2).

Conclusion
The endorectal applicator and the individual channels can be visualized using a UTE sequence, which makes MRI-only treatment planning for HDREBT feasible.

Figure 1. Axial slices of the phantom on CT (A) and UTE MRI (B).

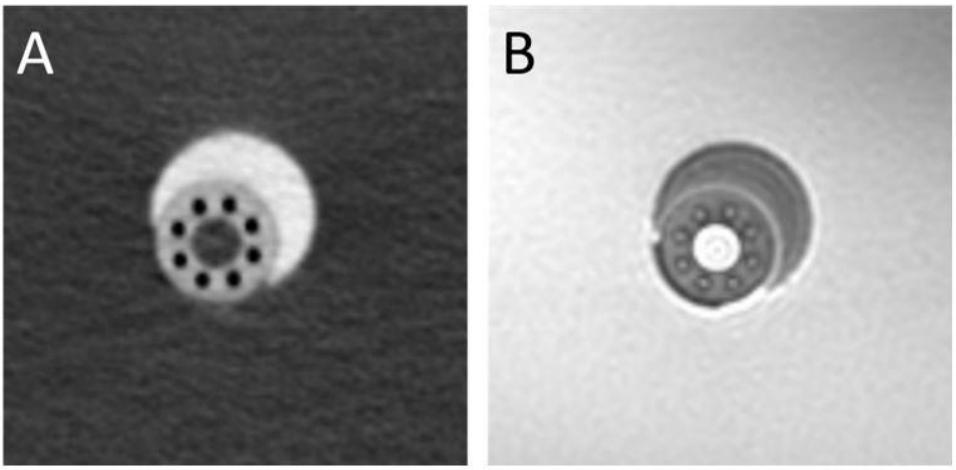
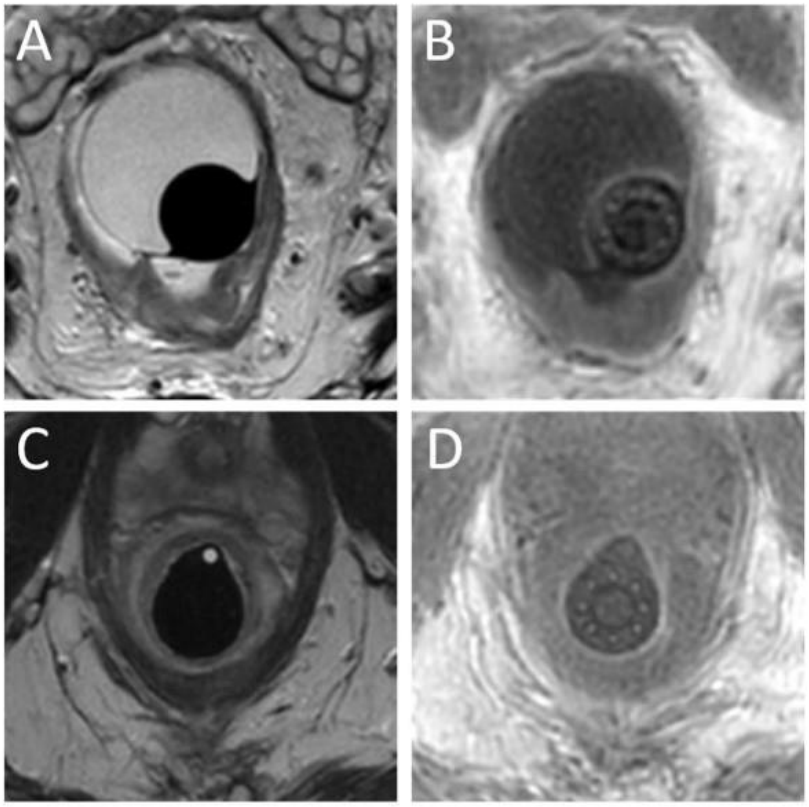


Figure 2. Axial slices of a T2-TSE sequence (A and C) and a UTE sequence (B and D) in two rectal cancer patients (A+B and C+D) with applicator in situ.



PP-0121 HDR Brachytherapy as Monotherapy for Prostate Cancer: Early Toxicity of a Randomized Phase II Trial

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Purpose or Objective
HDR brachytherapy seems to be a valid option for low and intermediate risk prostate cancer. The purpose of this study is to determine acute toxicity of one 19.5 Gy fraction or two 14.5 Gy fractions of HDR brachytherapy monotherapy delivered on a one day schedule.

Materials and Methods
We recruited 206 patients with low or intermediate-risk prostate cancer. 199 were eligible and randomized between one fraction of 19.5Gy (Arm 1) or two fractions of 14.5Gy (Arm 2) (BRP2 protocol, NCT03424694). In both arms treatments were delivered with a single implant on a one-day schedule. Patients in the 2 fractions arm had their treatment delivered 6h apart and had 2 set of imaging and 2 dosimetries. For all patients dosimetry was MRI based with dominant intra prostatic lesion boots allowed. Toxicity was evaluated at 1, 3, 6 weeks and 3, 6 and 12 months after treatment. CTCAE v4.0, IPSS and IIEF-5, were used to evaluate toxicity at each visit and compared to baseline. paired t test, Pearson Chi-Square and Fisher Exact test were used. Statistical significance was 0.05.

Results
Median follow-up is 46 (8.9-64.9) months. Pre-treatment median PSA for 19.5Gy arm and 29Gy arm 2 were 6.58±2.78 and 6.74±2.71 respectively. Gleason scores were 6(3+3) 18.2% and 13% ,7(3+4) 54.5% and 58%, 7(4+3) 27.3% and 29% respectively. Per NCCN risk grouping low risk were 6.53%, favourable intermediate risk were 33%, and 60.45% unfavourable intermediate risk were 60.45%.
Baseline IPSS was 6 and 6.3 for arm 1 and arm 2 respectively. Compare to baseline, IPSS increase significantly at one week in both arms. It returned to baseline at 3 months and will remain as such at 6 months.
For arm1 and arm2 post treatment CTCAE acute urinary toxicity were at 1 week: grade 2, 7% and 9%; grade 3, 0% and 1%, respectively. At 6 weeks: grade 2, 1% and 3%; grade 3, 0% and 0%. At 3 months: grade 2, 2% and 1%; grade 3, 0% and 0%. At 6 months: grade 2, 4% and 5%; grade 3, 0% and 1%. At 12 months: grade 2, 10% and 9%; grade 3, 0% and 1%. However, no predictors of GU toxicity were founded. All gastrointestinal toxicities (GI) were grade 1. Few patients had GI CTCAE toxicities. At 6 weeks 4% and 5% had CTCAE grade 1 (p=1). At 12 weeks, only 2 patients in arm 1 and 1 patient in arm 2 presented anal pain and hemorrhoids. At 6 months 12 patients and 12 months 8 patients.
For sexual function, there is a significant statistical decrease between IIEF-5 at baseline and at 12 weeks post treatment values in arm 2 ($p<0.001$).

Conclusion
In this HDR brachytherapy as monotherapy protocol both arms, either the single fraction of 19.5Gy or 2 fractions of 14.5Gy, are well tolerated. Early GI and GU toxicities are the same in both arms. IPSS score returns to baseline at 3 months. At this point he statistical difference on erectile scores in arm 2 has no clinical significance. Further report will follow.

PP-0122 MRI based tumour radiomics in carcinoma cervix: a potential predictor of response to chemoradiation

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Purpose or Objective
To determine if tumour radiomics based on pre-treatment T2weighted (T2W) MRI texture parameters can predict response to chemoradiation prior to brachytherapy in cervical carcinoma.

Materials and Methods
Seventy-four patients of locally advanced carcinoma cervix treated with definitive chemoradiation (45Gy/25 fractions along with weekly concomitant cisplatin) and image-guided brachytherapy within 2 ongoing clinical trials between 2017 and 2019 were included in this study. T2W MRI sequences were utilized for delineating the gross tumour volume (GTV) and high-risk clinical target volume (HRCTV) of the primary tumour at baseline and at brachytherapy. As per ICRU 89, tumour regression >75% was considered a surrogate of good response. Initial GTV was also delineated on the texture analysis software. Multiple tumour slices were sampled individually. First-order statistics applied to pixel intensity histograms produced 6 texture parameters, namely mean intensity, standard deviation, entropy, mean positive pixels, skewness and kurtosis. Using fine, moderate and coarse anatomical filters a total of 36 texture variables were generated. Separately, histological subtype, tumour grade, FIGO stage and nodal status were documented. These clinical variables along with texture parameters were compared with treatment response using the Mann-Whitney U test. Subsequently, lasso regression was used for selection of texture parameters that best correlated with treatment response. Chosen parameters were used to develop support vector machine (SVM) models which were validated using 10-fold cross-validation. The most parsimonious model was described in terms of AUC and metrics of diagnostic accuracy.

Results
The median age of the study cohort was 50 years (range 34 to 65). Overall, 63 (85%) had squamous cell carcinoma. Half of the included patients (37/74) had positive pelvic or para-aortic lymph nodes. As per FIGO 2009 recommendations, 51 (69%) and 23 (31%) patients, and as per FIGO 2018 criteria 23 (31%) and 51 (69%) patients were stage II and III, respectively. Good response was seen in 10/74 patients, which translated into 73/454 tumour cross-sections. None of the clinical variables discriminated between response. However, high mean and skewness, and low entropy and kurtosis did significantly correlate with poor response. Using 15 selected features, the best SVM model had an AUC of 0.85 and accurately classified 86.5% cases, with sensitivity and specificity of 55% and 93%, respectively.

Conclusion
Tumour radiomics can be utilized to predict response to chemoradiation, where clinical parameters fail. This information regarding expected tumour biology may provide an opportunity for formulating individualised treatment protocols in the future.

Symposium: Gastrointestinal brachytherapy

SP-0123 Can Imaging technique affect treatment planning in brachytherapy of rectal and anal canal carcinomas?

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Abstract Text

Indication, intent and techniques
Brachytherapy in anal canal and rectal carcinoma can be performed using different techniques. In anal canal Squamous cell carcinoma, Iridium trans-perineal implant (ITI) is the main technique aiming at local control usually after chemo-radiotherapy (CRT). While there is a strong rationale for using brachytherapy (Small volume/high dose), no high level of evidence is currently available (1 Peiffert). In rectal cancer three techniques can be used with different aims.1) Endoluminal High Dose rate Iridium (E-HDR) either for preoperative treatment as an alternative to External Beam Radiotherapy (EBRT) or to achieve clinical complete response (cCR) and organ preservation (OP) (2 Vuong Garand). 2) Contact x-ray brachytherapy 50kVp alone or combined with EBRT or CRT mainly aiming at planned cCR and OP (3 gerard EJC). The Lyon R96 and OPERA trials (4-5) are giving good evidence to this approach. 3) ITI in some rare cases of distal adenocarcinoma invading the anal canal combined with CRT.
Imaging for diagnosis vs imaging for performing brachytherapy
At base line to accurately classify the tumor, different imaging techniques are used in association with digital rectal examination (DRE), endoscopy and biology. After accurate staging the decision of performing a brachytherapy is taken. Imaging technique used for treatment planning (TP) are different and must be clearly distinguished from imaging used for diagnosis and staging. The type and relevance of imaging techniques for TP depends on the type of cancer and type of brachytherapy.
Three different brachytherapy and "imaging" techniques
Anal carcinoma and iridium implant: ITI can be performed with pulse or high dose rate. When taking the decision to perform ITI the radiation-oncologist (RO) must have clearly in mind the Tumor stage: initial volume (size) and site (along the anal canal and mostly clockwise) while the depth (thickness) is best evaluated using per-operative DRE. Size and site

after CRT (downsizing) must be assessed with great care. Using the Paris system (or other), the RO can foresee the number of needles he wants to implant and the dose he wants to prescribe into the initial target volume. The main tool to perform a good implant adapted to the (residual) tumor after CRT is DRE which allows implantation of the needles precisely in relation to the Gross tumor volume (GTV) and/or Clinical target volume (CTV). A fiducial marker is implanted (under fluoroscopy) to localize the distal end of the CTV. The first needle can be implanted under finger guidance few millimeters under the anal canal mucosa. The template is then positioned (on the first implanted needle) and it helps to perform a good parallel implant of the other needles. Imaging (with dummy source) is taken after implant completion. CT scan of the implant with appropriate TPS will allow to delineate the GTV-CTV, to calculate the dwelling time of each source to achieve and optimize the dose distribution. A good implant in this situation is **mainly finger guided**. Imaging is mandatory for time/dose calculation, quality assurance and comparison between different cohorts.

Rectum and Endoluminal HDR

It is an ambulatory treatment performed in the supine position. Fiducial markers have been previouly positioned by endoscopist/ radiation oncologist to accurately define the upper and lower end of the tumor (or CTV in case of cCR after CRT). The clockwise location of the tumor is also accurately determined. The endoluminal applicator is positioned under fluoroscopic guidance. CT scan of application (often coupled with MRI) is used for quality assurance and to delineate the GTV and CTV. The number of channels is then determined and dwelling time is calculated according to the prescribed dose (usually 10 Gy at the deepest part of the CTV). In this situation the quality of the implant is **mainly image guided**.

Rectum and Contact XB 50 kVp

A good clinical practice of rigid rectoscopy is needed to perform CXB. The definition of GTV is done in real time using direct vision of the tumor. Accurate targeting of the tumor with the rectal applicator is made under direct eye guidance. The dose (often close to 30 Gy prescribed and reported at the exit surface of the X-ray tube) is then delivered in 1 or 2 minutes. Photos of the tumor and of the applicator positioning are taken during CXB session for reporting. With CXB application is **mainly eye guided.**

Take home message

There is not only one way to perform brachytherapy for anal or rectal cancer. The winner is the one who tailor and adapt its approach to the patient, the tumor and the brachytherapy technique.

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3 Gerard JP, Eur J Cancer 2019; 108: 1-16
4 Gerard JP, J Clin Oncol 2004; 22: 2404 2011
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SP-0124 Gallbladder: status of the art

P.Devlin
USA

Abstract not received

SP-0125 Oesophagus: An orphan topic?

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Abstract Text

The increase of life expectancy over the last two decades has led to an increase in the number of older patients with esophageal cancer (EC) not suitable for surgery or chemotherapy. These patients can be treated with external irradiation plus endoesophageal brachytherapy (EBT) with intention to cure, with fewer complications and with good results. Moreover, 90-95% of patients with EC require palliative treatment for dysphagia that causes weight loss and affects the quality of life. EBT is a quick and effective treatment offering a long interval free of dysphagia with fewer complications compared to other palliative techniques, even in previously irradiated patients. The first successful treatment with EBT was performed in 1909. However, since then the lack of experience in EBT and the low number of professionals that perform this technique have hindered the utilization of EBT throughout the world. At present, EBT seems to be an orphan topic, despite the good results achieved when indicated. The past and present status of EBT is commented on with possible strategies to increase its use.

Symposium: Brachytherapy physics 2030 – Adaptive dose delivery and planning

SP-0126 Image registration, Automated segmentation, and Dose Summation

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Abstract Text

In this talk, current status and challenges of image registration, automated segmentation and dose summation with specific focus to image guided gynaecological brachytherapy including combination of external beam radiotherapy and brachytherapy will be discussed.
It has been well documented that contour mapping and applicator reconstruction with rigid registration based on the applicator geometry provide good accuracy.

In the recent past, deformable Image registration is being increasingly explored for adaptive radiotherapy both for contour propagation and dose accumulation. Contour propagation between individual fractions can be useful for cervix cancer radiotherapy, however, associated with a lot of uncertainties. Deformable image registration is particularly challenging in the pelvic region, due to the large and complex deformations caused by tumor shrinkage, bladder and rectum filling, insertion of a brachytherapy applicator and presence of packing material. The current generation of deformable image registration algorithms are limited in complexity, and hence not yet robust enough to handle these changes.

Although, deformable image registration is currently acceptable for OARs, with careful evaluation, its use for target volumes, is still not acceptable, especially for tumors, where regression is quite rapid, as the microscopic extension cannot be accounted. DIR for contour propagation may be validated using visual verification; however, dose accumulation lacks robust validation methods and hence remains the most challenging aspect. In deformable dose accumulation it is expected that each voxel irradiated in one image, is matched with the corresponding voxel in another image. This assumption is violated in the presence of complex deformations associated in the pelvic region, which may induce significant uncertainties and implausible registration.

For these reasons, it is currently advised not to use deformable image registration for dose accumulation in clinical brachytherapy practice. The direct addition of doses provides a reasonable estimate of the total absorbed dose. However, in case of significant dose gradients from external beam boosts or midline-shielding adding dose contributions from different radiotherapy modalities and fractions remains subject to uncertainties.

SP-0127 Automation for treatment planning and quality assurance (actual advancements)

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Abstract Text

Radiotherapy is in the midst of an era of automation, where technology is being leveraged to perform processes and procedures with minimal human assistance. The transition away from human-dominated task performance brings several opportunities and risks. The stakes are especially high in the subfield of brachytherapy due to with multispecialty coordination, a compressed treatment timeline, high prescription doses, and high sensitivity to geometric uncertainty. This seminar will review the ways in which automation is changing the field of brachytherapy, including how automation in treatment planning and quality assurance can help to overcome human weaknesses, such as limited vigilance, decision fatigue, and burnout. Highlights: • An introduction to the use of automation for overcoming human weaknesses in brachytherapy, including limited vigilance, decision fatigue, and burnout. • Review of developments in automation for HDR applicator digitization • Review of developments in automation for treatment plan optimization and selection • Review of developments in automation for plan quality assurance and plan documentation

SP-0128 The role of physics, dosimetry, and physicians in an era of automation: how will our practice change?

A.Cunha
USA

Abstract Text

Brachytherapy is constantly evolving. New technologies come online, computing power exponentiates, biological understanding blossoms. But this is nothing new: the same could have been said 10, 20, 30 years ago. Even 2500 years ago Heraclitus inspired the idea that “change is the only constant.” The question is how. How do we evolve and grow over the next 10 years? The brachytherapy team (physics, dosimetry, and physicians) of 2030 could look quite different. Fully embracing a philosophy of early 20th century Futurism is debatably acceptable for literature or art but is wholly irresponsible in medicine. However, don’t we owe it to our patients to not eschew change? As a mentor of mine once mused, “getting the clinical practice of brachytherapy to adopt new ideas and technology is like dragging a brontosaurus.” How will our practice change as we enter an age of brachytherapy automation?

SP-0129 What is this thing called AI and how can it help brachytherapy?

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Abstract Text

Artificial Intelligence (AI) increasingly pervades the daily news, showcasing self-driving cars, robots, and face recognition even on smart phones. The reason for this revolution is threefold: 1) several AI techniques have matured algorithmically, 2) there have been spectacular advances in computing hardware (e.g., GPUs), and 3) digitizing and storing large amounts of data has become common practice. AI will increasingly be a key driver of automation, including in radiation oncology.

Yet, for many people it is still quite unclear what AI is, really. In this talk, I will sketch, from my perspective, some of the key methods and techniques that are typically considered to be AI (research) and what their use cases are. I will then in particular focus on some key opportunities of AI in brachytherapy and include some of the efforts by my own research group in collaboration with academic hospitals (in particular Amsterdam UMC and Leiden UMC) that predominantly focuses on a particular subfield of AI: that of Evolutionary Algorithms (EAs).

Proffered papers: Dosimetry and quality assurance

OC-0130 Comprehensive 192Ir HDR QA using a pixel segmented ionization chamber

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Purpose or Objective
Quality control within the context of HDR brachytherapy quality assurance (QA) programs is currently fragmented. Different methods are used for testing each parameter (source strength, source positioning, irradiation timer, transit time), increasing cost and workload. This work reports on the potential of using a Pixel Segmented Ionization Chamber (PIXSIC) as a comprehensive QA tool.

Materials and Methods
A MatriXX Evolution PIXSIC (IBA Dosimetry GmbH) was calibrated in terms of dose to water per unit reading using 6MV photons. An explicit PIXSIC model was prepared for Monte Carlo (MC) simulations with EGSnrc to obtain a calibration conversion factor to air kerma per unit reading for each of the 1020 PIXSIC elements. This factor was obtained for 5 irradiation setups of a Flexisource Ir-192 HDR source centered over the PIXSIC at Source-to-Detector plane Distances (SDD) of 0.062, 1, 2, 3, and 5 cm. These single dwell position irradiations were performed using a plastic catheter. Another irradiation was performed employing 15 Flexisource dwell positions of 5 s (spaced 2 cm apart for the first and last 3, and 1 cm for the rest) using a plastic catheter fixed on the PIXSIC and a frame (reading integration) rate 10 s^{-1}. The source position on the PIXSIC plane was determined using the centroid of the recorded reading distribution. The SDD was determined from a linear fit of SDD versus the half width at half maximum (HWHM) of the reading distribution obtained from a 2D Lorentz fit to corresponding MC results.

Results
Experimental source localization uncertainty using the centroid and SDD versus HWHM fit (Fig. 1) was <1.38%. Air kerma strength results, obtained after applying the calibration conversion factor and correcting for irradiation time and SDD, agreed with source certificate and well chamber results within 2.5%. Analysis of PIXSIC results for the multi-source dwell position irradiation (Fig. 2) yielded excellent agreement with programmed step sizes, and an average source dwell time 4.72± 0.04 s. The latter is lower than programmed, probably due to transit dose correction. Initial estimate of average transit speed was 9 and 12.5 cm s^{-1} between dwells spaced 1 and 2 cm apart.

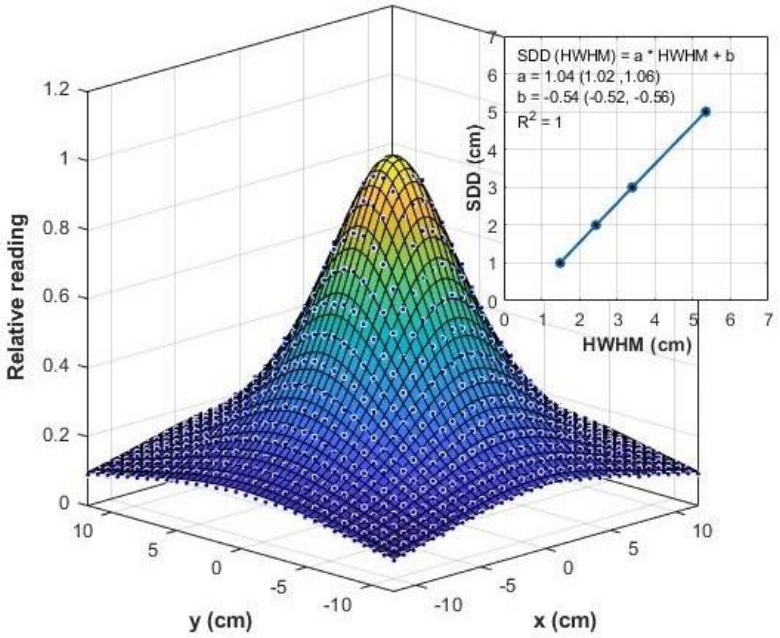

Figure 1. A 2D Lorentz fit applied to MC results for the relative MatriXX reading distribution from measurement with the Flexisource centered at SDD = 5 cm. The inset presents the fit of SDD versus the HWHM of the corresponding MC dose distributions.

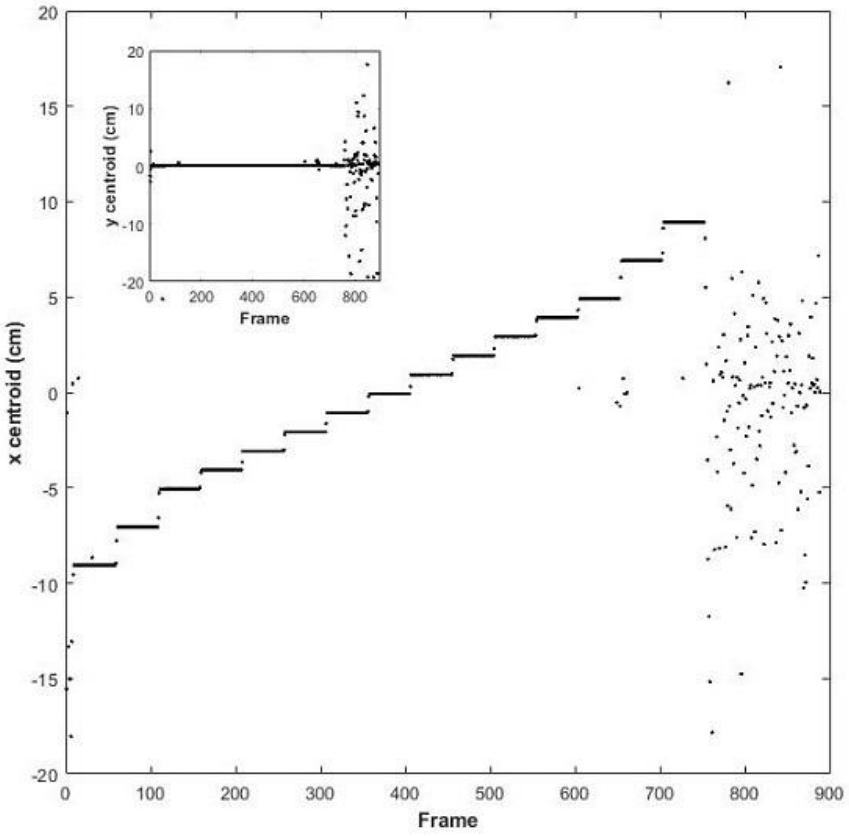

Figure 2. The centroid coordinates obtained from the MatriXX reading distributions in the multi-source dwell irradiation, plotted versus frame number. X runs along the catheter while Y (presented in the inset) runs across the catheter.

Conclusion

PIXSICs can be calibrated to serve as secondary equipment for air kerma strength measurement and have potential for supporting a comprehensive HDR brachytherapy QA procedure in a single irradiation. Work is ongoing for analysis

optimization, automation, and uncertainty characterization. These conclusions support further investigation into the use of PIXSICs in real time dose verification.

Acknowledgements
Research co-financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme "Human Resources Development, Education and Lifelong Learning 2014- 2020". Detector modelling information provided by IBA Dosimetry GmbH. Access to ARIS national high performance computing system by the National Infrastructures for Research and Technology (GRNET).

OC-0131 WP21 BRAPHYQS survey of differences in 192Ir and 60Co brachytherapy RAKR determinations

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Purpose or Objective
The reference quantity for brachytherapy (BT) source strength in Europe is the reference air-kerma rate (*RAKR*). Standards for such quantity are maintained within the international metrology community and requirements on traceability to such standards apply to BT similar as to other radiotherapy modalities. Specifically, source vendors issue certificates of BT source strengths using measuring equipment with traceability to such standards and experimental verification of these certificates at the hospital level is regulated in most countries. This way, experimental determination of *RAKR* constitutes the BT equivalent of reference dosimetry. This work presents the results of a survey designed by the GEC-ESTRO BRAPHYQS WP21 to assess the current level of agreement between *RAKR* values as issued on vendor certificates and verified through measurements at hospitals for HDR-PDR ^{192}Ir and ^{60}Co BT sources. This would provide a realistic picture of the differences existing between measured and certified source strength values in clinical practice in Europe. Existing recommendations state that hospitals should take action whenever differences with the value stated on vendor certificates is >5%.

Materials and Methods
18 hospitals where BT is routinely used from 8 different European countries were contacted to acquire as much data as possible and to avoid any possible bias due to the use of a particular methodology, clinical practice, or national regulations. Data was reported together with information about the clinical practice followed. Contributing hospitals were asked to submit values of their measured value of *RAKR* together with corresponding values on vendor certificates. Percentage differences between these were reported. The number of data points in this study were 832 for ^{192}Ir and 62 for ^{60}Co, corresponding to the period 2005-2020. The interval where more than 99% (k=3 for a normal distribution) of data points resided was considered a conservative estimate of differences expected between *RAKR* from clinical user measurements and vendor certificates.

Results
Figures 1 and 2 present histograms of *RAKR* differences for ^{192}Ir and ^{60}Co respectively. In the case of ^{192}Ir, the number of values obtained was large enough to recover the expected normal distribution. Hence a Gaussian fit was performed, resulting in a mean value for the differences of -0.2% and a standard deviation of 1.0%. Values outside of ±3.0% (k=3) would correspond to less than 1% of the reported values. For ^{60}Co, it was evident that the reduced number of measurements precluded use of statistic-based techniques. Nevertheless, all measurements reported fell within the ±3.0% interval.

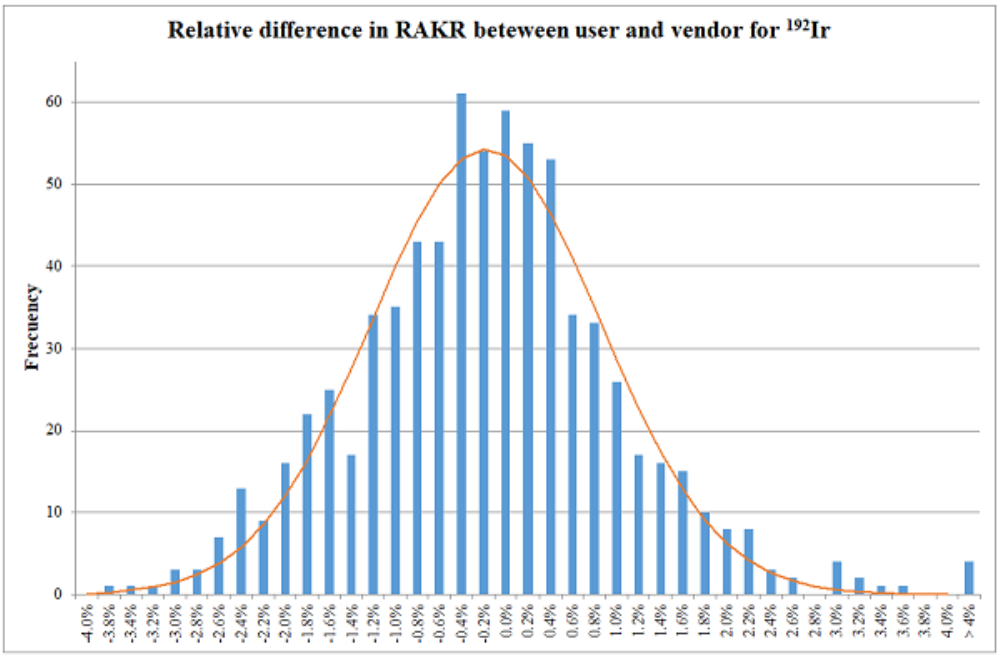

Fig 1. Histogram of *RAKR* differences for ^{192}Ir (n=832).

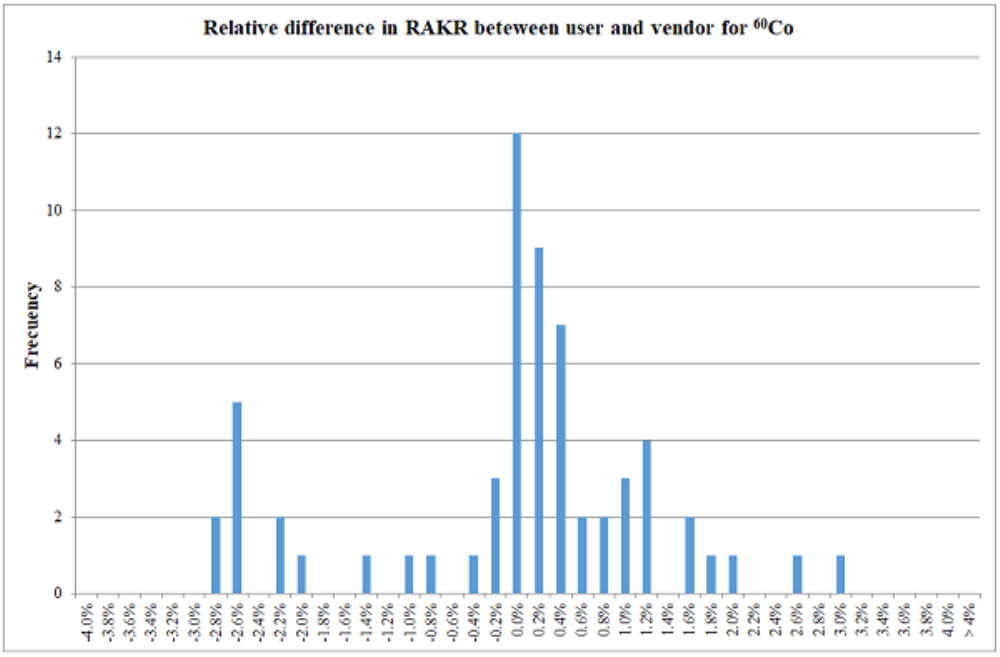

Fig 2. Histogram of *RAKR* differences for ^{60}Co (n=62).

Conclusion

This survey found that differences between hospitals and vendors in determination of *RAKR* were within 3% (*k*=3). This information will be incorporated in future recommendations currently in preparation by GEC-ESTRO.

OC-0132 Brachytherapy TG-43 dosimetry characterization of the INTRABEAM source

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Purpose or Objective

The INTRABEAM system (Carl Zeiss Meditec AG) is an electronic brachytherapy device designed for intraoperative radiotherapy (IORT) applications. Despite its benefits and extended use for common diseases as brain and breast cancers, the INTRABEAM x-ray source has not been characterized according to the AAPM TG-43 specifications for brachytherapy sources. This restricts its modeling in commercial treatment planning systems (TPSs), with the consequence that the doses to organs at risk (OARs) are unknown. Knowledge of these doses is typically important when dose distributions need to be compared and combined with external beam dose distributions. The aim of this work is to characterize the INTRABEAM source according to the TG-43 brachytherapy dosimetry protocol.

Materials and Methods

The dose distribution in water around the INTRABEAM source was determined with Monte Carlo (MC) calculations using egs_brachy, a user code of EGSnrc. MC statistical uncertainties were in the range 0.1% to 0.4% at 1 to 5 cm from the source tip in its longitudinal axis. For the validation of the MC model, depth dose calculations in water along the source longitudinal axis were compared with measurements in two different setups: (1) using a water phantom provided by the source manufacturer and a soft x-ray ionization chamber (PTW 34013) and (2) with a customized setup using a Wellhöfer water tank and synthetic diamond detectors (microDiamond PTW TN60019), with low volume averaging effects and uncertainties from the detector geometry. The calculated radial dose function for the INTRABEAM is compared with published data for the Xoft Axxent® (a subsidiary of iCAD, Inc. Nashua, NH) source, and several commonly used HDR and LDR brachytherapy sources.

Results

Measurements in water with the ionization chamber agreed with the MC model calculations within uncertainties. These combined uncertainties vary with depth in water and have an approximate value of 3.1% at 1 cm from the source tip. The use of the microDiamond yielded local percent differences within uncertainties in points of steeper dose gradients. The radial dose function (Figure 1) presents a steep fall-off close to the INTRABEAM source (< 1 cm) with a gradient higher than that of conventional brachytherapy radionuclides (^{192}Ir, ^{103}Pd, and ^{125}I), but it is partially flattened at larger distances with a similar fall-off as the Xoft source. The simulated 2D anisotropy values (Figure 2) were mainly uniform along $\theta = 0^\circ$ for $r >$ 1 cm, and gradually decreased towards $\theta \approx 120^\circ$. For regions close to the source, the behavior was strongly affected by the beam attenuation in the elements of the source walls.

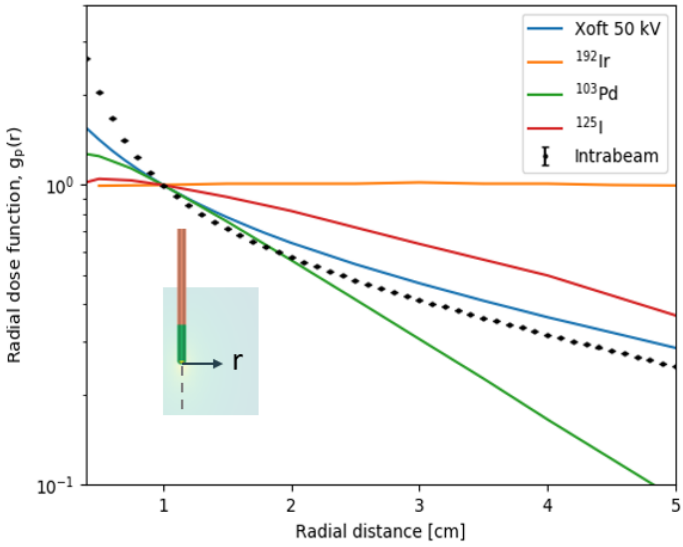

Figure 1: Radial dose function for the INTRABEAM is compared with results for the Xoft source operated at 50 kV and common brachytherapy sources ^{192}Ir, ^{103}Pd and ^{125}I.

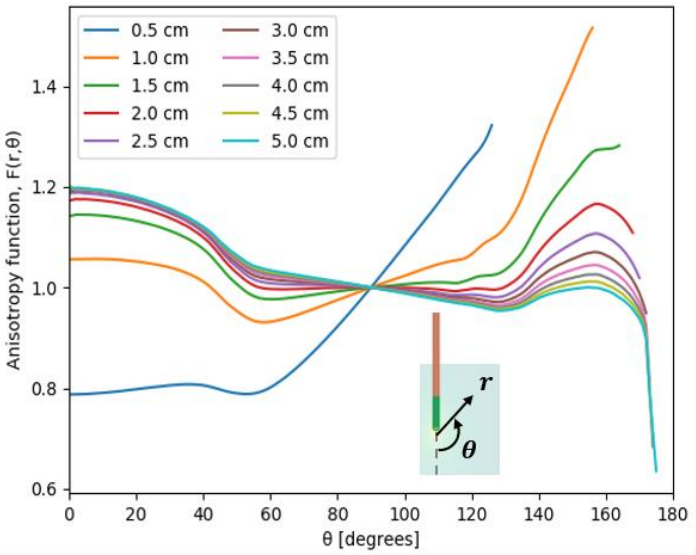

Figure 2: Anisotropy function for the INTRABEAM in the range $\theta = [0°, 180°]$ at different distances from the source tip.

Conclusion
This work presents the MC calculated TG-43 parameters for the INTRABEAM, which constitute the necessary data required by conventional brachytherapy TPSs. In the proximity of the source, the dose distribution exhibits a higher gradient than other sources and the 2D anisotropy function is strongly affected by the wall materials.

OC-0133 Dosimetric characterizations of a novel inorganic scintillating detector - HDR brachytherapy

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Purpose or Objective
Inorganic scintillating dosimetry is the most recent promising technique with a small size scintillating detector that allows it to be potentially used in high dose rate brachytherapy (HDR-BT). Despite several advantages, the major issue of using scintillating detectors is the stem effect, induced in the fiber, when a large core plastic fiber is irradiated. Hence, the purpose of this study is to evaluate the performance of a novel point size miniature inorganic scintillator detector (ISD) in terms of HDR-BT treatment to ensure the best matches between the delivered and prescribed doses.

Materials and Methods
A prototype of the dose verification system has been developed based on (Zn.Cd)S:Ag material used in the proposed novel ISD to measure a wide range of dose rates under ^{192}Ir brachytherapy (BT) source. The scintillating volume used ~ $2x10^{-6}$ mm^3, and the fiber core and cladding were 50 µm, 125 µm, respectively. The associated dose rate was measured in count rate using a highly sensitive photon counter (sensitivity ~20ph/s). Overall measurements were performed both in solid water phantoms and IBA™ water tank phantoms to realize the measurement accuracy. Dose measurements were performed by ISD at 0.1 cm between two measurements following TG43U1 recommendations. The planned dwell times were measured from the difference of two adjacent times of transit. Dosimetric parameters such as linearity, repeatability, and scintillator stability were studied. STEM signal was measured employing a bare fiber at the identical position of the ISD detector. Finally, a comparison was shown between ISD measurements and results obtained from Monte Carlo (MC) simulations based on the TG-43 protocol.

Results
The detection efficiency of ISD was verified through measuring the planned dwell times that agree within 0.09% and 0.03% accuracy for varying and non-varying dwell times, respectively. Measurements demonstrated that ISD has superlinear behavior with dose rate (R^2=1) at 1 cm far from the source. Standard deviation (1σ) of the scintillating signal remains within 0.02%, while afterglow stays less than 0.8% in all the irradiation. STEM characterizations at 0.5 cm from the source catheter shows almost no STEM effect, while at 0.1 cm distance from the source catheter shows a maximum of 0.01% STEM signal relative to the total signal. A proper symmetrical behavior of dose rate was observed at different radiation planes. Finally, a comparison with MC simulations show that considering energy dependency, measurement agrees within 0.8% till 0.2 cm source to detector distance.

Conclusion
The proposed scintillating dosimetry system in this study shows a negligible STEM effect and efficient performances for several BT parameters. Therefore, it is anticipated that the system can be promoted to validate with direct clinical investigations, such as appropriate dose verification and source tracking in BT during patient treatment.

OC-0134 Replacing TG-43U1 by TG-186 in HDR liver brachytherapy has a dosimetric impact on treatment plans

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Purpose or Objective
Single fraction high dose rate (HDR) liver brachytherapy using computed tomography (CT) guided catheter implantation is a standard treatment option for liver mestastases and hepatocellular carcinoma (HCC) under the guideline of the European Society For Medical Oncology (ESMO). At our department, 196 patients were treated with liver brachytherapy in 2019 alone. We investigated the dosimetric impact of replacing TG-43U1 dose calculations with model-based TG-186 dose calculations using Monte Carlo (MC) simulations and the collapsed cone (CC) algorithm.

Materials and Methods
Treatment plans for 10 cases were retrospectively recalculated with MC simulations using Monte Carlo n-Particle Transport Code (MCNP) 6 and the CC algorithm of Oncentra ACE. All patients were diagnosed with either HCC or metastatic colorectal cancer and treated with image-guided interstitial brachytherapy at the University Hospital of the Ludwig-Maximilians-Universität (LMU) Munich. CT tissue segmentation was performed using the dedicated brachytherapy platform AmigoBrachy, assigning reference tissues from TG-186 to Hounsfield unit ranges and using organs contours previously delineated by physicians. MC simulations calculated on a CT-based geometry (Dmm-MC) were compared to simulations on a pure water geometry (Dww-MC) as a surrogate for TG-43U1. ACE calculations (Dmm-ACE) were compared to Dmm-MC. The dosimetric impact was assessed by analysing DVH parameters for liver (V5Gy, V10Gy), OARs (D1cc) and target coverage (V150, V100, V95, V95, D95 and D90).

Results

Fig. 1 shows the isodose lines of Dww-MC, Dmm-MC and Dmm-ACE for four cases. Deviations between Dww-MC and Dmm-MC are visible at lower doses, near low-density interfaces and between dose maxima. Dmm-ACE is very similar to Dmm-MC, except at bone structures and gas cavities. Fig. 2 contains an overview over the range of deviations between Dww-MC and Dmm-MC for all DVH parameters. We found a general overestimation of DVH parameters by TG-43U1. Highest deviations in absolute terms between Dmm-MC and Dww-MC were found in the dose limiting liver V5Gy-parameter with up to -7.0% of the total liver volume. The median difference of this parameter was -1.1%. Large deviations of Dww-MC and Dmm-MC are also visible in the separation of the 5~Gy-isodose lines in fig. 1. For OARs and CTVs, differences between TG-43U1 and TG-186 were in general smaller (see fig. 2). When comparing Dmm-MC and Dmm-ACE, median parameter deviations were all within ±0.2% for liver and CTV parameters, and smaller than 0.2 Gy for OAR D1cc.

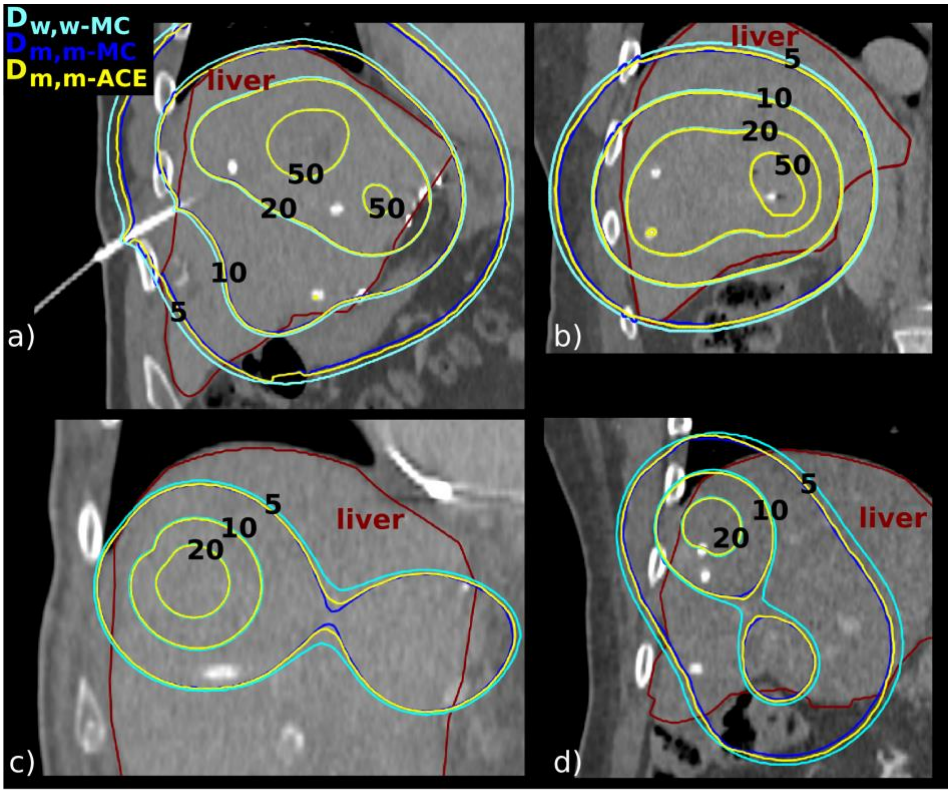

Fig. 1: Coronal CT slices of four patients with isodose lines of MC-calculated TG-43U1 results (Dww-MC), MC-calculated TG-186 results (Dmm-MC), and ACE-calculated TG-186 results (Dmm-ACE). The liver contour is shown in red, dose values in Gy are shown in black.

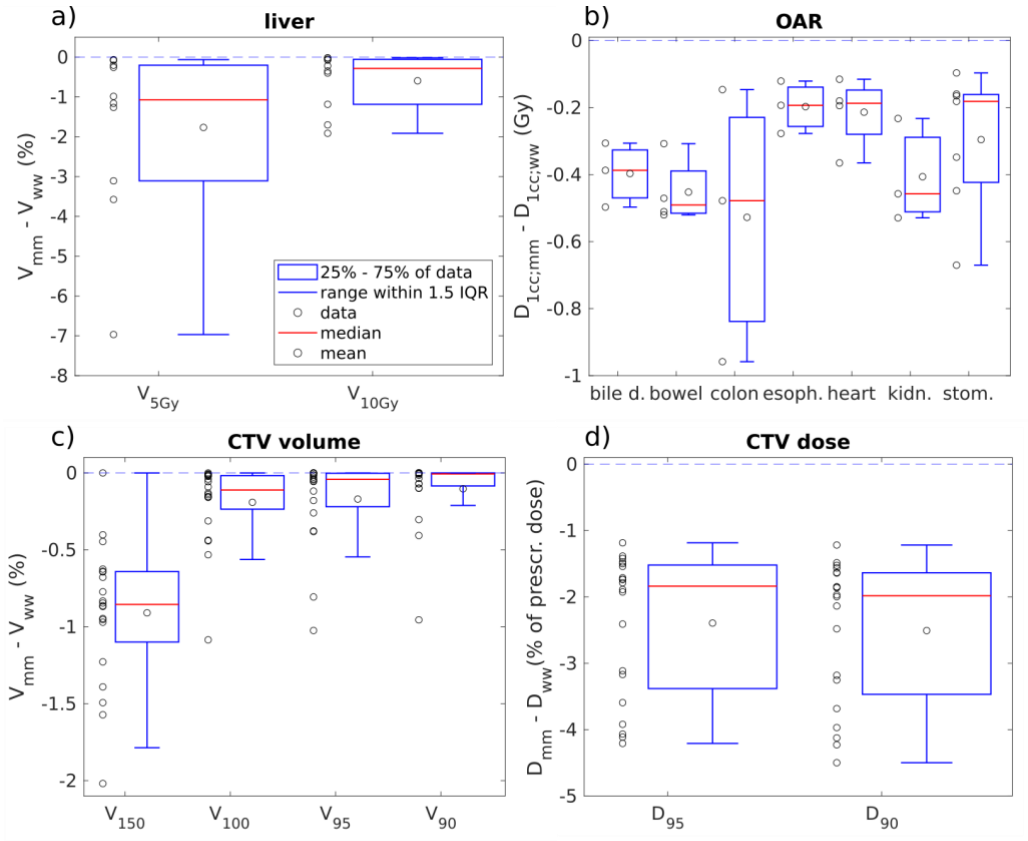

Fig. 2: DVH parameter comparison of MC-calculated dose to medium (TG-186 surrogate, index mm) and MC-calculated dose to water (TG-43U1 surrogate, index ww). a) Liver parameter differences, shown in percentages of the liver volume. b) OAR parameter differences in Gy. c) CTV volume parameter differences, shown in percentages of the CTV volume. d) CTV dose parameters, shown in percentages of the prescribed dose.

Conclusion
Replacing TG-43U1 by TG-186 has a dosimetric impact on liver DVH parameters. This could be of clinical importance for cases where dose to the tumour is limited by sparing of liver volume. Model-based dose calculations with Oncentra ACE are able to replicate MC results to a clinically acceptable degree.

OC-0135 GEC-ESTRO / ACROP recommendations for Quality Assurance of Ultrasound in Brachytherapy

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Purpose or Objective
Ultrasound (US) is an important imaging modality in brachytherapy (BT). In particular for low-dose-rate (LDR) and high-dose-rate (HDR) prostate implants transrectal ultrasound (TRUS) is widespread. Nevertheless, European guidelines on quality assurance (QA) for US in BT are lacking.

Materials and Methods
The BRAPHYQS and UroGEC working groups of GEC-ESTRO worked out guidelines describing QA methods for US in BT. For this, existing literature was studied and experiences of the working group members were collected and structured.

Results
In the guidelines commercial available phantoms for QA in BT US that can be used to follow these guidelines are presented and described. General tests of the US device are shown in the next section. These contain image quality checks like element dropout, penetration depth, high-contrast resolution, and distance measurements. Because the US images are used in the treatment planning system (TPS), some checks must be conducted in the TPS. In particular, geometrical tests

have to be carried out, like volume and scaling measurements of objects with known dimensions. Also offset calibration of biplane probes is covered to prevent systematic errors in the use of biplane probes.
One section is about QA for stepping devices. This is of importance as the in-out and rotational positions of the stepper are often linked with the TPS and have direct impact to the treatment planning process.
Another chapter considers the dedicated use of US in BT prostate treatment. The template calibration is described in detail using adequate water temperature (see figure 1) as well as reconstruction of implant needles. Further chapters characterize US checks of anal and gynecological BT techniques. In the last sections daily checks and a summary QA sheet on test procedures including test frequency and limits is presented.

Conclusion

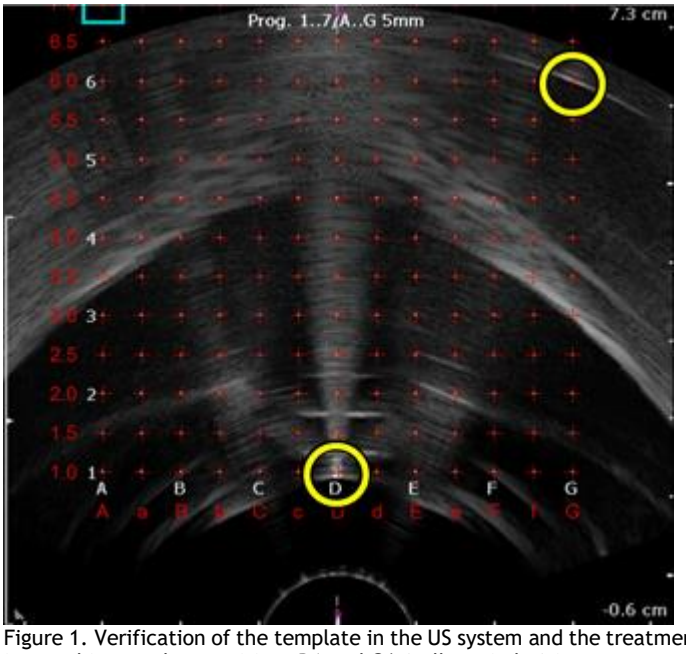

Figure 1. Verification of the template in the US system and the treatment planning system. Two steel implant needles were inserted in template positions D1 and G6 (yellow circles) in a water tank with a temperature of 45° C. The coincidence of US template, the template of the TPS, and the needle positions is visible.

The recommendations explain practical test procedures of US devices in BT. They will help the clinics to perform a high level of quality in the use of US for BT in Europe.

Symposium: Brachytherapy: Strategies to improve utilisation in various sites and settings

SP-0136 GEC-ESTRO viewpoint in strategies to increase brachytherapy utilization

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Abstract Text

Worldwide the incidence of cancer will increase in the coming decades. According to the Global Cancer Observatory by 2025 4,5 million patients will be diagnosed with cancer. This increase in cancer incidence demands an increase in radiotherapy services including brachytherapy. Worrisome is the observed decline in brachytherapy that doesn't show a similar trend as the increase in cancer.
To stimulate the use of radiation therapy there is a need for increasing awareness about the importance and need of it and in particular brachytherapy.
In 2019 ESTRO formulated its new vision for 2030 resulting in the new vision statement, built around 4 concepts of core importance: "Radiation Oncology. Optimal Health FOR ALL, Together". ESTRO is committed to increase the awareness and importance of radiation oncology including brachytherapy. The overlaps between the concept areas highlight how they relate to the new vision statement and actions that need to be taken to increase brachytherapy utilization.
"Strengthening Partnerships" is needed to guarantee radiation oncology for all, inclusive brachytherapy. Closer dialogue with patient's associations will help patients to be more assertive and demanding. Brachy-HERO Working Group activities will be shared with stakeholders to promote brachytherapy. Collaborations with global brachytherapy societies and the industry are important to develop brachytherapy further.
"From Research to Practice" is essential to provide optimal health for all. GEC-ESTRO serves as a platform to facilitate and initiate research projects. Examples of such projects and collaboration are the EMBRACE studies, the GEC-ESTRO APBI study and the Uro-GEC postTURP study. Ultimately, outcome of research needs to be translated into practice by publication of GEC-ESTRO recommendations, educational activities, and participation to the yearly workshops.

One important aspect of “Strengthening the Profession” is to guarantee education to the community. The ESTRO School provides three teaching courses dedicated to brachytherapy with important input from GEC-ESTRO. The GEC-ESTRO Handbook undergoes a first revision with up-to-date chapters on latest developments and practice. Ultimately, more and extensive on-site training need to be provided resulting in a strong society with a guaranteed high-level brachytherapy knowledge to reach for optimal health for those suffering of cancer and other diseases.
The voice of brachytherapy can only be strong and loud by “Strengthening the Society”. GEC-ESTRO is structured with seven working groups representing different treatment sites, physical, and health economy aspects. Leaders and representatives from the GEC-ESTRO group have seats in various committees and consultative bodies within the ESTRO to defend the interest regarding brachytherapy. At the annual ESTRO congresses and the GEC-ESTRO Workshops special sessions about brachytherapy are organized to share knowledge and starting new international collaborations among European delegates and from other continents. The World Congresses of Brachytherapy, being the only global entitled congress within the field of a radiation therapy specialty, highlights the world-wide importance of brachytherapy and brings not only the ESTRO Society together but all brachytherapy societies of the whole world.
These strategic actions, taken together, will result in optimal health for all patients by increased utilization of brachytherapy next to various other treatment modalities.

SP-0137 Brachytherapy: Strategies to improve utilization in various sites and settings (ABS Viewpoint)

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Abstract Text

In the United States there has been a measurable fall in the use of brachytherapy attributable to several factors, but significant is the lack of adequate training to establish a robust brachytherapy practice amongst graduating radiation oncologists. In addition, there is a perceived underestimation of the true value of brachytherapy by practitioners, patients and payers. Recognizing these challenges, the ABS has an established strategy to rectify these underlying obstacles in the settings of training and practice.
To assure adequate training ABS representatives worked with the North American ACGME (Accreditation Council for Graduate Medical Education) for modifications to the brachytherapy requirements effective July 1, 2020. Prior loopholes allowed some residents to graduate without sufficient variety or adequate numbers for confident independent practice. New requirements demand at least seven interstitial and 15 intracavitary procedures. A minimum of 5 of the intracavitary insertions must be tandem-based insertions and no more than 5 can be cylinder insertions. Use of unsealed sources was also increased from 5 to 8 procedures with a minimum of 5 cases of parenteral administration.
The most ambitious effort to target both training and practice was started by a recent ABS president Dr. Dan Petereit. The initiative is called 300 in 10. The goal is to train 30 competent brachytherapists per year over the next 10 years with a multi-faceted approach. There are six mechanisms in development to establish disease-site specific brachytherapy competency through online training modules, simulation training workshops with phantoms, short-term focused fellowships at designated ABS certified centers, competency evaluation by certified ABS experts, ABS certification and ABS maintenance of certification. To leverage the expertise of experienced providers the ABS launched #NextGenBrachy, which is a pilot program that matches early career radiation oncologists with brachytherapy experts, with a focus on attracting mentees from groups traditionally underrepresented in medicine and radiation oncology.
Targeting active practitioners the ABS partnered with Chartrounds (https://www.chartrounds.com/default.aspx). Chartrounds hosts online case-based discussions in real-time between global members and academic disease-site specialists to discuss patient management and treatment plans for both standard and difficult cases submitted by the members or the host. These discussions can also earn the practitioner necessary credits toward maintaining licensure.
To improve perceived value ABS turned attention to the substitution of advanced external therapies for brachytherapy in the curative treatment of cervical cancer. The ABS collaborated with the Society of Gynecologic Oncology to outline the problem in publications and national talks.
Internationally the ABS continues outreach to both national and international members with web-in-ars and virtual outreach events (https://www.americanbrachytherapy.org/meetings-events/webinars-and-virtual-outreach-events-voes/) on topics relevant to practitioners, including brachytherapy specific topics and other important physician topics such as burnout. In addition, ABS collaborates with multiple international societies - AROI-ICRO, ALATRO, ABS, Canadian Brachytherapy Group, FARO, Indian Brachy Society, GEC-ESTRO, JASTRO, Radiating Hope, and Global RT.
Regular events to engage members includes monthly publication of the BrachyBlast which updates members on standard brachytherapy topics and accepts volunteer member contributions. Practical topics are standard, including changes in regulations, description of medical events and quality assurance issues. BrachyNews is published quarterly and includes goals and updates by the current president, notifications of upcoming meetings and social media events and other news relevant to brachytherapists. The ABS also established the journal *Brachytherapy*, which is an international multidisciplinary journal that publishes original peer-reviewed articles and reviews on all aspects of brachytherapy. In addition, consensus statements in select disease sites are crafted and updated regularly to keep members current. Regular meetings are hosted for education, net-working and product investigation. These include the annual meeting, the every-four-year collaboration with GEC ESTRO for the world congress of brachytherapy, the yearly prostate simulation workshop and the gynecologic brachytherapy school. Recordings from prior meetings available on the ABS website. ABS also supports fellowships and scholarships to interested early career members to allow them to increase their skill sets or career radiation oncologists seeking skill expansion.

SP-0138 Brachytherapy: Strategies to improve utilization in various sites and settings: (IBS Viewpoint)

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Abstract Text

Brachytherapy is highly conformal form of RT and provides better dose distribution as compared to most modern EBRT techniques like IMRT, SBRT and proton beam therapy. Significant developments over the past three decades have renewed the interest in brachytherapy practice. The advent of artificial radioisotopes and remote afterloading techniques have reduced the radiation exposure hazards. Innovative imaging modalities (CT Scan, MR imaging, transrectal ultrasound and PET scan) and sophisticated computerized treatment planning systems have helped to achieve an increased positional accuracy and superior, optimized dose distribution and excellent clinical outcome. Compared to the 1990s, the use of brachytherapy has increased substantially and it is expected to continue growing in the future as it becomes ever more precise and efficient. The common diseases treated with brachytherapy include prostate cancer, cervical cancer, head and neck cancer, gynecological cancers, breast cancer and many other tumors. Most of these cancers are common in India and several developing countries. Therefore, India need to expand the role of brachytherapy as this will benefit large chunk of cancer patients. Following are some of the factors related to improved utilization of brachytherapy in India. **1**. Rising incidence of early stage cancers: Due to growing cancer awareness and improved health care structure, number of cancer patients presenting in early stages is rising. It is well known fact that brachytherapy is more useful when the tumors are small in size and have not spread beyond their site of origin. Early breast cancer in India is gradually rising. Brachytherapy is used for these patients in the form of boost therapy and accelerated partial breast irradiation (APBI). Cancers of the oral cavity and prostate are also rising in early stages where brachytherapy is clinically very effective. **2**. Short treatment duration in brachytherapy: Most brachytherapy treatments are prompt and have a shorter course. Usually, definitive brachytherapy treatments last for about a week as compared to 5-7 weeks in case of external beam radiation therapy (EBRT). Short duration treatments are suitable for Indian circumstances due to limited resources and infrastructures. **3**. Cost effectiveness: Since the installation and maintenance of brachytherapy facility does not require huge investment unlike EBRT facility, it suits Indian economy. Most centers in India can afford to procure and run brachytherapy equipments. The quality assurance is also not stringent as in EBRT machines. **4**. Spectrum of cancer cases: The commonly occurring cancers cases in India are treatable by brachytherapy. In females, cervical cancer is the leading cancer where intracavitary radiation therapy in the form of brachytherapy plays an important role. Head and neck cancer is common in males and brachytherapy is often used either as monotherapy or as boost therapy in combination with EBRT. Due to abovementioned factors, utilization of brachytherapy in India should be encouraged. Indian Brachytherapy Society (IBS) is planning to publish guidelines for using brachytherapy in various malignancies. It has already published for cervical cancer. IBS has been organizing regular workshops and teaching courses to impart the skills of brachytherapy. Use of seed brachytherapy is extremely sparse in India and its use needs to be expanded. This is also a cost effective treatment since it is a one-time procedure and does not require prolonged hospitalization. The use of brachytherapy may further be increased by widening the indications in certain rare sites brain tumors, lung and liver malignancies.

SP-0139 Brachytherapy: Strategies to improve utilization in various sites and settings (ALATRO viewpoint)

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Abstract Text

Along the years, communicable diseases have represented the main health problem in low- and middle-income countries (LMIC). With the improvement of health care systems in many of these countries, the prioritization of health problems has increased and noncommunicable diseases, including cancer, are at the forefront of health care priorities. The main purpose of this presentation is to show the Latin American (LATAM) needs today and projected up to 2030 for radiation oncology systems, focused in brachytherapy. This analysis intents helping to overcome this gap knowledge in order to promote creating public policies that could help to narrow the cancer treatment burden for LATAM in this field. We identified the number of megavoltage machines (MVMs), brachytherapy facilities, simulators, and computed tomography (CT) simulators in each country in Latin America/Caribbean, as stated in the International Atomic Energy Agency (IAEA) Directory of Radiotherapy Centres, vendors, and a survey was created to address the questions needed for the inform and sent to different radiation oncology societies in LATAM. The absolute number of most common cancers cases treated with brachytherapy in each state was obtained by multiplying the age-specific incidence rates with the respective age subgroups of the population, and an incidence map was generated. A rate of RT use of 80% was estimated based on available data on incidence of cervical cancer, 60% for prostate cancer and 50% for breast cancer, also the External Beam Radiation therapy fractions needed were calculated on the basis of 25 common fraction schedules as follows: total number of fractions needed for each state for example = cervical cancers in the state *— 0.80 *— 25. Presuming that patients also will need four fractions of BT, the overall BT fractions needed were estimated as: cervical cancer cases in state 0.80— 4. On the basis of proportionate incidence of cervical cancer and use of external RT machine space across various departments. As a result of this analysis a total of 653 RT centers exist in 31 countries, with 1047 MVMs, 370 brachytherapy facilities, 230 CT simulators, and 155 conventional simulators. Telecobalt machines represent 19.24% of total MV units. Around half of the centers, MVMs, and brachytherapy facilities are located in 2 upper-middle-income countries (Brazil and Mexico), which together constitute 52.5% of the whole population. Of 28 Latin American countries possessing MVMs, 2 high-income countries (Martinique and Antigua/ Barbuda) lack brachytherapy equipment. The distribution of MVM and brachytherapy facilities. A total of 18 small countries (1 million population) exist in Latin America (11 high income and 7 upper-middle income). Only 7 small countries possess teletherapy machines, and only 5 countries have brachytherapy facilities as well.

In Latin America, half of the 265 brachytherapy facilities are located in Brazil and Mexico. In 2008 and 2009, the IAEA collected online surveys about the availability and use of brachytherapy facilities in 17 Latin American countries. Around

half of the responders reported available brachytherapy facilities, which were mainly used for malignancies, with rare use in prostate, breast, or other cancers. In Africa, only 79 brachytherapy machines exist to date, with over 70% present in only 6 countries. The shortage of RT facilities, including brachytherapy, in LMIC is multifactorial and can be attributed to the difficulty of providing specialized staff, training, and specific infrastructure for optimal treatment delivery. The expenses related to infrastructure and frequent radioactive source changes, as well as the need for a reliable power supply, play a major role in hindering brachytherapy development in LMIC. In addition, its narrower range of treatment indications compared with teletherapy might discourage health care authorities from investing in such facilities. Most (95%) of the brachytherapy procedures in Latin America are performed for gynecological cancers; no other site exceeds 1%. This observation is surprising because brachytherapy is indicated in many common cancers, such as prostate, breast, and esophageal cancers. To effectively meet the burgeoning need for RT in LMIC, it is projected that training of 30,000 radiation oncologists, 22,100 medical physicists, and 78,300 radiation therapists will be required by the year 2030.

In conclusion If no action is taken, by 2030, each year, 14.5 million patients are predicted to die of cancer. With optimal access to radiotherapy worldwide, we can annually prevent 1 million of these cancer deaths. Let’s work together to make the global impact of radiotherapy a reality.

POSTER PRESEN-TATIONS

Poster presentation: Poster Presentation: Gynaecology

PP-0141 Assessment of interstitial needles with 3D-TRUS in cervical cancer brachytherapy

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Purpose or Objective
To quantitatively and qualitatively evaluate the visibility of interstitial needles in cervical cancer patients with combined intracavitary/interstitial (IC/IS) applications ("Vienna"-type) using 3D-transrectal ultrasound images (3D-TRUS).

Materials and Methods
This study comprised image data sets from two previous prospective trials on 3D-TRUS in cervical cancer brachytherapy. Only patients with IC/IS applications and availability of T2-weighted MRI and 3D-TRUS on the same day with applicators in place were considered for analysis. 3D-TRUS image acquisition was done with a customized TRUS stepper device and software (Medcom, Germany; Elekta, Sweden; ACMIT, Austria). For qualitative assessment, the visibility of each needle was rated on 3D-TRUS with the following scoring system: 0: no visibility, 1: poor discrimination, margin blurred 2: fair discrimination, margin indistinct, 3: excellent discrimination, margin distinct. For quantitative assessment, the distance between tandem and each needle was measured separately in axial slices 2cm above the ring and compared to the respective measurement on MRI. Intraobserver variability was examined by measuring three randomly chosen patients twice. Descriptive statistics were used for data analysis.

Results
In total, 24 patients with FIGO stage IB3-IIIB with 29 applications and a total of 188 needles (132 straight through the ring, 35 oblique through the ring, 21 free-handed) were available. Tandem and ring were always visible. Overall 149/188 needles (79.3%) were visible, mean visibility score was 1.4 ± 0.5 for all visible needles. Characteristics for the non-detectable needles are summarized in table 1.
Distance of the visible needles to tandem was maximum (max) 51mm, minimum (min) 8mm, mean ± standard deviation (SD) 21.3mm ± 6.5mm on MRI and 49mm, 10mm, 21.0mm ± 6.4mm on TRUS, respectively. Difference between MRI and TRUS was max 14mm, mean ± SD -0.3mm ± 2.6mm. 16/149 needles (10.7%) had a difference of more than 3mm.
Max and mean ± SD intraobserver variability was: 2mm and -0.1mm ± 1.0mm on MRI and 2mm and 0.3mm ± 1.1mm on TRUS, respectively.

	Straight needles (n=132)	Oblique needles (n=35)	Free-handed needles (n=21)	Total (n=188)
Not visible inside FOV	2/132 (1.5%)	8/35 (22.9%)	2/21 (9.5%)	12/188 (6.4%)
Outside FOV	6/132 (4.6%)	3/35 (8.6%)	0/21 (0.0%)	9/188 (4.8%)
Masked by myoma (one patient)	5/132 (3.8%)	4/35 (11.4%)	2/21 (9.5%)	11/188 (5.9%)
TRUS probe inserted <2cm above the ring (one patient)	4/132 (3.0%)	2/35 (5.7%)	1/21 (4.8%)	7/188 (3.7%)
Total	17/132 (12.9%)	17/35 (48.6%)	5/21 (23.8%)	39/188 (20.7%)

Table 1: All non-detectable needles allocated to route of insertion (top line) and reason for non-detectability (left column) in total numbers and percent. (FOV= field of view).

Conclusion
Most of the needles were visible with 3D-TRUS (79%). Straight needles were better detectable than oblique needles (87% vs. 51%). Detectability was impaired by insufficient rotation angle of the TRUS probe, poor image quality or anatomical variation. Assessment of applicator geometry was comparable between MRI and TRUS. However, needles show a rather indistinct signal on TRUS. Therefore, online detection with a standardized imaging protocol in combination with optimized needle material or needle tracking should be investigated, aiming at the development of real time needle guidance and online treatment planning.

PP-0142 Vaginal dose de-escalation in cervix brachytherapy

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Purpose or Objective
Vaginal toxicity post cervix brachytherapy is well documented [1]. The EMBRACE 2 protocol specifies dose points which can be used to measure dose to the vagina. The vaginal TRAK gives the percentage of dwell time being delivered via the ring/ovoids and can also be used to measure vaginal dose. This study aims to reduce the dose to the vaginal dose points and TRAK through changes to our plan optimisation process, whilst keeping changes to target and OAR doses minimal, as reported by S. Mohamed et al [2].
Since Feb 2018, we have had the option of using the Venezia applicator with interstitial needles. This may help to reduce the vaginal dose in patients with larger tumours, as dose can be delivered laterally via the needles rather than the ovoids. However, significantly larger CTV volumes are now being referred for brachytherapy rather than external beam boosts. Prior to Feb 2018, 6.2% of brachytherapy patients had a HR-CTV >30cm^3. Since then, 41.8% of patients have had an HR-CTV > 30cm^3. This is likely to have an effect on the outcome of this study as larger volumes may require higher vaginal TRAK to achieve coverage.

Materials and Methods
Twenty plans using either Rotterdam or Venezia applicators (with or without interstitial needles) were retrospectively replanned with the aim of reducing the vaginal TRAK whilst maintaining original EQD2 doses to targets and OAR. The vaginal TRAK and vaginal dose points were compared between the original plans and the new plans.

Results
The vaginal TRAK was reduced by an average of 18%. This resulted in a reduction to the PIBS point doses of between 22% and 31% and a reduction in the RV point dose of 24%. Target doses remained within 5% of the original plans and OAR doses were reduced apart from bowel which increased by an average of 1.4%.

Conclusion
Reduction of vaginal TRAK during plan optimisation results in a reduction to vaginal point doses. This has been shown to reduce vaginal side effects [3], therefore vaginal TRAK should be minimised in the optimisation process whilst meeting target and OAR dose limits. The current planning protocol limits vaginal TRAK to the EMBRACE recommendations of 30-40%, however much lower values can be easily achieved in most cases.
References

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2. S. Mohamed et al, Radiotherapy and Oncology 120 (2016) 480–485.
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PP-0143 Hybrid Tandem & Ovoids Brachytherapy in Locally Advanced Cervical Cancer:Dose & Tumor Volume Metrics

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Purpose or Objective
To report the impact of dose and tumor volume metrics at brachytherapy on outcomes for locally advanced cervical cancer (LACC) treated with tandem and ovoids intracavitary/interstitial brachytherapy (IC/IS BT).

Materials and Methods
FIGO Stage IB1-IIIB LACCs treated with IC/IS BT via a tandem and ovoids hybrid applicator were analyzed. Median HR-CTV volume (mHR-CTV), rate of tumor volume reduction, EQD2 D90, organ at risk doses and outcomes were recorded. Univariable and multivariable Cox regression was used for survival analysis and logistic regression was used for toxicity analysis.

Results
Seventy-one patients were identified. Median follow up was 24.9 months with a 2-year local control (LC) of 83.6%, loco-regional control (LRC) of 72.0%, and overall survival (OS) of 88.6%. The mHR-CTV D90 was 87.4 Gy (IQR: 85.7-90.2). HR-CTV D90 >90 Gy $_{10}$ showed a trend toward improved LC (p=0.19). The mHR-CTV was 37.9 cm^3 and median V100 was 86.5%. A mHR-CTV of ≥40 cm^3 demonstrated worse LRC (p=0.018), and progression free survival (p=0.021). Two-year LC and LRC for Stage IIB patients with a mHR-CTV <40 cm ^{3} were significantly improved as compared to ≥40 cm ^{3} at 100% and 71.8%, respectively (p=0.019) and 100% and 56.5%, respectively (p=0.001). However, this trend was not statistically significant for Stage IIIB patients. Higher percent per day reduction in HR-CTV during BT showed improved LRC (p=0.045). Four percent of patients experienced acute grade 3 GU toxicity, 1% late grade 3 GU, and 1% late grade 3 GI.

Conclusion
Tandem and ovoids IC/IS BT provides satisfactory outcomes with modest toxicity. Higher HR-CTV D90 coverage demonstrated a trend toward improved tumor control. Tumor volume based on mHR-CTV ≥40 cm^3 at brachytherapy was prognostic for poor outcomes even within initial FIGO stage groups warranting caution.

PP-0144 Intensity modulated HDR GYN cervix brachytherapy

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Purpose or Objective

The purpose of this study is to determine if the use of middle-energy brachytherapy sources, such as Se-75 and Yb-169, used in combination with a shielded ring applicator in High Dose Rate (HDR) gynecological (GYN) cervix brachytherapy can achieve the prescribed dose to the cervix while reducing the dose to the bladder, sigmoid, and rectum relative to current treatment techniques. Current HDR GYN cervix brachytherapy is performed using Iridium-192 (or Cobalt-60) coupled with a tandem and ring applicator. Because of the high photon energies of these sources, localized shielding is ineffective resulting in high doses to the bladder, sigmoid, and rectum. The proposed Se-75 and Yb-169 sources with a shielded applicator therefore could enable better medical outcomes by modulating the dose distribution around the cervix to avoid the critical structures.

Materials and Methods

A MCNP6 Monte Carlo study was performed to evaluate the dose distributions obtained in a typical GYN cervix geometry using a standard ring applicator with the currently used Iridium-192 source and with the proposed lower-energy Se-75 and Yb-169 sources coupled with a partially shielded ring applicator. Simulations for the partially shielded ring applicator used gold as the radiation shield. Dose distributions of various thicknesses of shielding were calculated based on each isotope's tenth value layer (Se^{75}_{TVL}= 3 mm gold, Yb^{169}_{TVL}= 1 mm gold). Simulations were also performed for various conical openings of the applicator directed toward the cervix. The ICRU 38 reference points were used to model the geometry.

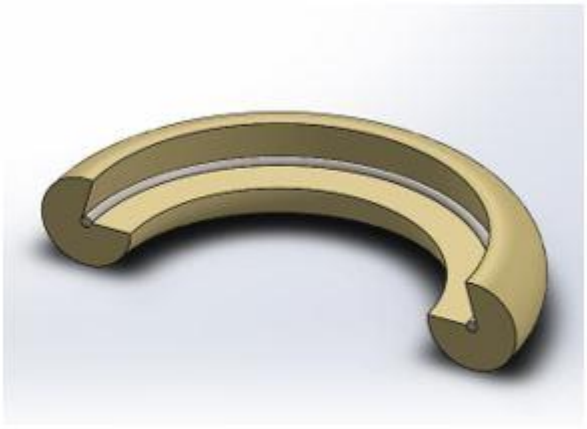

Figure 1: GYN ring applicator 26 mm in diameter and shielded with 3 mm of gold.

Results

The Monte Carlo calculation results show significant dose reductions to the bladder, sigmoid, and rectum when using small thicknesses of shielding relative to the Iridium-192 source applicator. When using 3 mm thick gold shielding with Se-75, dose reductions of 45% were observed to the bladder while achieving the prescribed dose to the cervix. Similar results were found for the sigmoid (60%) and rectum (89.6%). When using 1 mm thick gold shielding with Yb-169, dose reductions of 27% were observed to the bladder, 48% to the sigmoid, and 78% to the rectum. Figure 2 shows the comparative dose distributions of Ir-192 with no shielding and Se-75 and Yb-169 with various thicknesses of gold shielding.

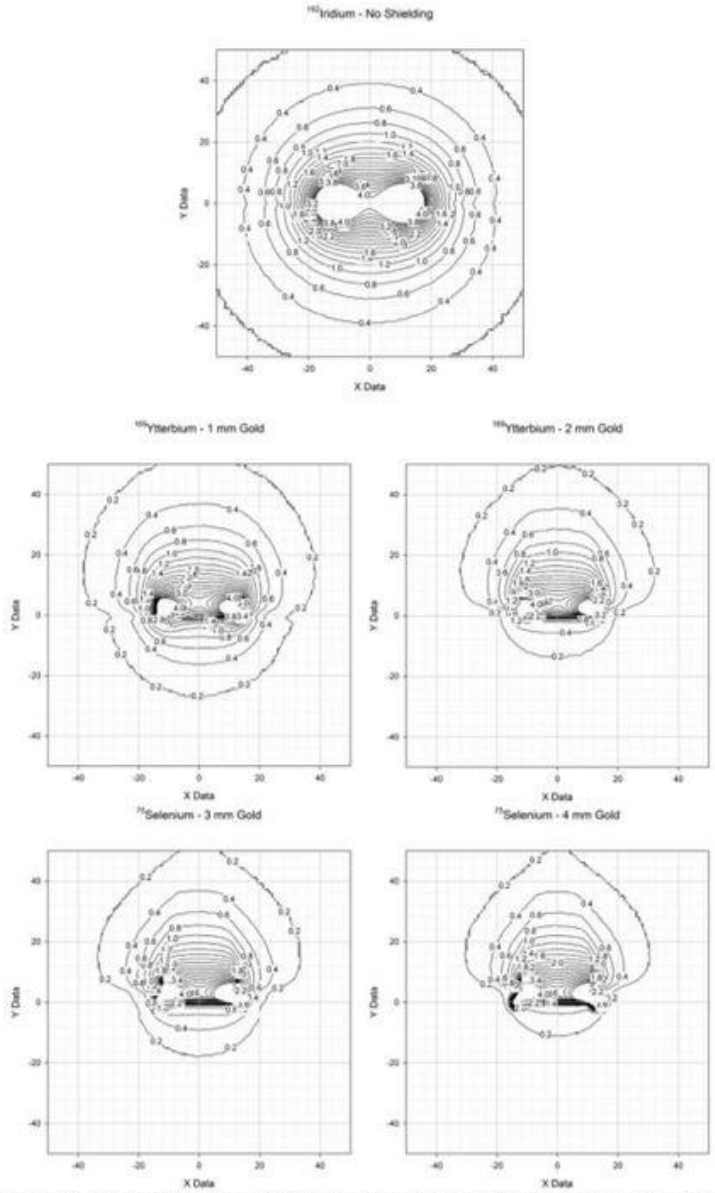

Figure 2: Comparative dose distributions in the XZ plane including the axis of a 26 mm diameter applicator ring that results from using an Ir-192 source. Dose distributions are also shown from the same ring surrounded by 1 and 2 mm of gold for Yb-169 and 3 and 4 mm of gold for Se-75 when using a 75-degree conical opening.

Conclusion

The results show the feasibility of achieving dose reductions to the bladder, sigmoid, and rectum during GYN HDR brachytherapy using Se-75 or Yb-169 while also achieving the desired dose to the target cervix; the use of a partially shielded applicator coupled with Se-75 or Yb-169 therefore can enable oncologists to increase the dose to the cervix without exceeding acceptable limits of dose to the bladder, sigmoid, and rectum. The next phase of the study will be to experimentally verify these calculated results, and to optimize the shielding design to accommodate individual patients.

Poster presentation: Poster Presentation: Physics

PP-0145 Catheter displacements and dosimetric impact in focal salvage high-dose-rate prostate brachytherapy.

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Purpose or Objective
Radiorecurrent prostate cancer is conventionally treated with deferred androgen deprivation therapy (ADT) which causes significant toxicity and impacts quality of life. MRI-guidance has made focal salvage high dose rate (HDR) brachytherapy possible, which potentially provides a safer salvage treatment in terms of toxicity. Accurate dose delivery is of major importance. The aim of this study was to analyze catheter displacements and dosimetric impact on clinical target volume (CTV) and organs at risk (OAR) in MRI-guided single dose focal salvage HDR brachytherapy for patients with radiorecurrent prostate cancer.

Materials and Methods
17 patients with locally recurrent, non-metastatic prostate cancer after primary radiotherapy were treated and analyzed for catheter displacements. 1x19 Gy was prescribed to 95% of the CTV (CTV_D95, CTV=GTV+5mm margin inside prostate and outside urethra) with constraints to rectum, bladder and urethra: D1cc_r≤12 Gy, D1cc_b≤12 Gy and D10%_u≤17.7 Gy. MRI-compatible Proguide catheters were inserted and fixed with the Martinez template (Elekta, The Netherlands). After US (fused with MRI)-guided catheter insertion, patients underwent MR scanning and a treatment plan was made. Just before irradiation a position verification MR scan (prerad) was made followed by plan adaptation if necessary. After irradiation an MR scan (postrad) was made for analysis of catheter displacements. Catheter insertion, scanning and irradiation were performed on the MR trolley to minimize patient movement. The different MR scans were fused and catheter shifts and dosimetric parameters evaluated.

Results
Based on the plan scans a catheter was retracted in one case and 3 catheters were inserted deeper in another case. In two cases the plan was adapted based on the prerad scans. In total, 167 catheters in 17 patients were evaluated, with average shifts (range) between prerad and plan scans of 0 (-1.0 — 1.5)mm, 0.1 (-1.2 — 1.8)mm and -0.8 (-6.4 — 1.9)mm in the LR-, AP- and CC-direction, respectively. Shifts between postrad and prerad scans were 0 (-1.5 — 1.5)mm, 0.2 (-1.1 — 1.7)mm and -0.4 (-4.9 — 4.7)mm. CTV_D95 amounted 18.6±1.8Gy,18.3±2.0Gy, 18.1±2.1Gy and 17.7±2.2Gy according to plan, prerad evaluation, adapted plan and postrad evaluation, respectively. Doses to OAR's varied less than 0.5 Gy (see table).

Table: average dose and standard deviation for different plans

	CTV_D95 (Gy)	D1cc_b (Gy)	D1cc_r (Gy)	D10%_u (Gy)
plan	18.6±1.8	9.4±3.6	9.8±1.8	13.9±4.3
prerad	18.3±2.0	9.1±3.6	9.9±1.7	14.1±4.5
adapted	18.1±2.1	9.1±3.6	9.8±1.7	14.2±4.4
postrad	17.7±2.2	9.0±3.6	10.1±1.9	13.7±4.2

Conclusion
On average, delivered dose to the CTV was 18 Gy, less than the prescribed dose of 19 Gy, predominantly caused by the dose constraints to the OAR's. The catheters shifted mainly in the CC direction with an average displacement of less than 1 mm, which had small impact on the dose distribution. In individual cases larger displacements were observed which warrants the need for catheter repositioning and plan adaptation as possible in MRI guided brachytherapy in a MRI-HDR treatment room.

PP-0146 Quality assurance of curved catheter paths in interstitial brachytherapy using a constructed phantom

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Purpose or Objective
Electromagnetic tracking systems (EMTS) are explored for quality assurance (QA) in interstitial brachytherapy for implant geometry tracking since a couple of years. The current focus lies on breast and prostate entities. The goal is an extension of the EMTS QA for patients with head and neck (H&N) tumors. The main difference are the curved catheter paths in H&N, implanted as one or two-sided loops. In this work the source path of an afterloader (microSelectron, Elekta, Veenendaal, The Netherlands) and the sensor path of an EMTS (Aurora, NDI, Canada) are determined and compared for curved catheter paths of various radii.

Materials and Methods
For this objective, a phantom was constructed with a straight catheter path as reference and eight curved catheters with variable radii (r = 3 – 30 cm). Using an afterloader prototype (Flexitron, Elekta, Veenendaal, The Netherlands), equipped with a sensor and coupled to the EMTS, the catheter trajectories were tracked. Dwell positions (DP) were defined for each catheter in a step size of 10 mm between the button ends. A dwell time of 1 s for the EMT-DP and of 0.9 s for the source-DP (S-DP) were selected. The S-DPs were measured using radiographic films clamped between two acrylic glass plates of the phantom.

The EMT-DPs were compared to the S-DPs of the radiographic films for all curvatures. Different quality indices were defined for the comparison: i) measured distance between two neighboring DPs (nominal value: 10 mm), ii) fit of a circle through the DPs of each catheter to determine the radius, and iii) the median Euclidean distance ΔDP between two corresponding DPs (EMT-DP and S-DP).

Results
Five measurements were conducted according to the described measurement and evaluation routine. The sensor of the EMTS as well as the capsule of the source of the afterloader were able to pass all curvatures, up to a radius of 3 cm. Two neighboring EMT-DPs had a minimum and maximum median distance of 9.97 mm and 10.08 mm for radii of 5 and 3 cm, respectively. On the film, the S-DPs had a minimum and maximum median distance of 9.83 mm and 10.09 mm for radii of 5 cm and 10 cm, respectively. The best fit circle through the whole DPs of a path varied between 0.04 mm and 0.16 mm for radii of 20 and 7.5 cm, respectively in comparison to the nominal curvatures of the catheters. Higher deviations between 0.18 mm (r=30 cm) and 4.9 mm (r=3 cm) were measured using the scanned radiographic film. The catheter-wise determined ΔDP varied between 0.18 mm (straight catheter) and 0.73 mm (r=5 cm).

Conclusion
The presented evaluation showed that all curved trajectories are accessible for the EMTS as well as the irradiation source. This workflow can be integrated as a weekly QA into clinical routine for a comparison between the sensor and source. Based on these results, the EMTS could be introduced for H&N.

PP-0147 Volumetric dosimetry for eye plaque brachytherapy using 3D treatment planning software

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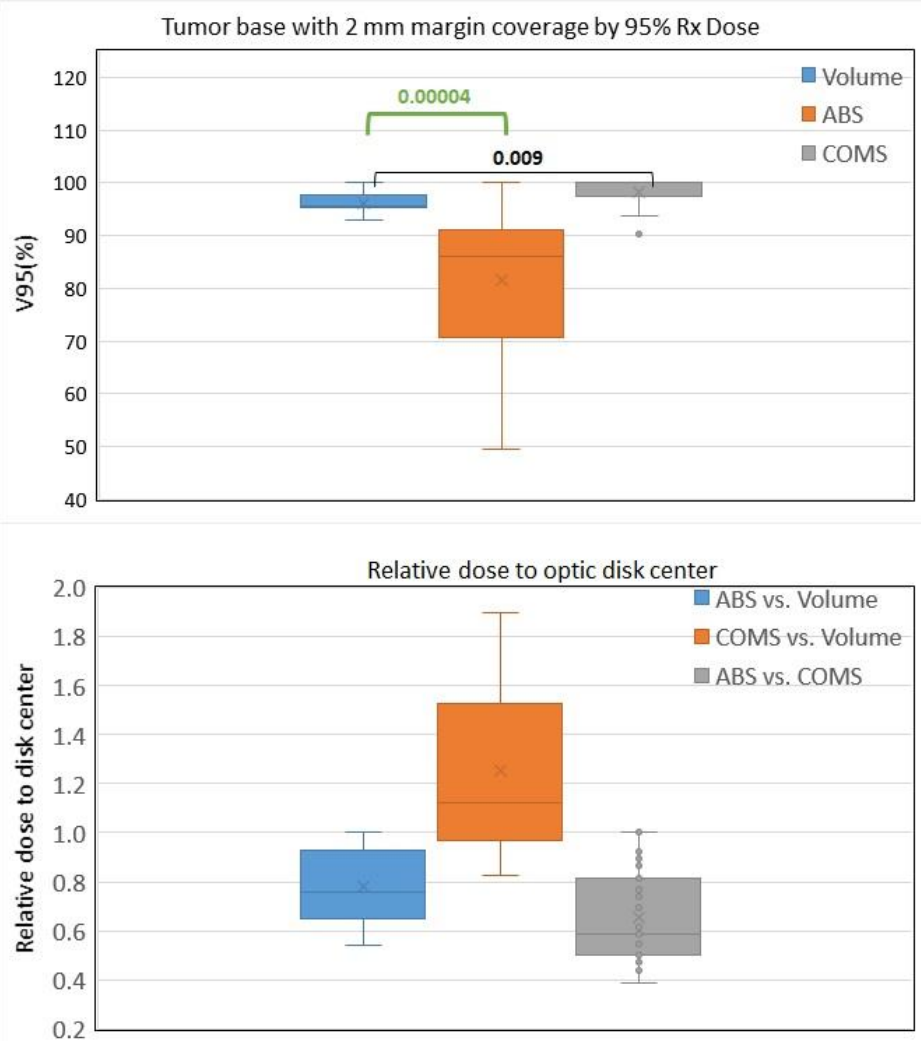
Purpose or Objective
Plaque brachytherapy has been widely used for intraocular tumors over 30 years. However, there is no standard dosimetric criteria for planning and evaluation of dose distribution pattern on target and critical normal structures. ABS and Ophthalmic Oncology recommend the prescription point at the tumor apex and the coverage of entire tumor with prescription dose. COMS recommends the minimum depth of prescription point at 5 mm from inner sclera. Here, we investigate volumetric dosimetry of I-125 plaque brachytherapy using 3D treatment planning system (TPS) and compare its dosimetric parameters with single point dosimetry recommended by ABS and COMS.

Materials and Methods
Plaque Simulator TPS (6.6.9, Eye Physics, LLC) were used to simulate treatment plan for 27 patients with intraocular tumors receiving either COMS or Eye Physics plaques loaded by I-125 seeds. Tumor dosimetric criteria for volumetric dosimetry was prescription dose covering entire tumor volume (V100%) and more than 95% of tumor base area with 2 mm margin (A95%). Dose optimization based on ABS and COMS recommendations was performed by placing prescription point at the tumor apex. For COMS dosimetry, prescription point was kept at the depth of 5 mm for the tumor with less than 5 mm apical height. Dose calculation for homogenous medium was modified by applying correction factors for anisotropy, linear source, silastic carrier attenuation, lip and slot collimation, and shell correction. Dose to center of optic disk, fovea and lens were recorded and compared for the 3 different dosimetric methods.

Results
Prescription points for volumetric dosimetry was, in most cases, deeper than those in ABS dosimetry, while they were shallower compared to COMS dosimetry. COMS dosimetry provided a higher tumor dose coverage, but higher dose to normal structures compared to volumetric and ABS dosimetry. For ABS dosimetry, tumor V100% was in the range of 71.7 to 100% with the mean value of 96.4%. This mean value was 100% for both volumetric and COMS dosimetry. Similar to V100%, tumor base A95% had wider range in ABS dosimetry compared to volumetric and COMS dosimetry. The mean value for A95% were 81.7%, 96.2%, and 98.4% for ABS, volumetric, and COMS dosimetry, respectively. For the shallow tumors (< 5mm depth), ABS dosimetry delivered less doses to normal structures, but poor tumor base coverage compared to other dosimetric methods. For example, optic disk was received, on average, 22% and 34% lower doses by using ABS dosimetry compared to volumetric and COMS dosimetry, respectively.



Conclusion
Single point dosimetry is not sufficient for optimal tumor dose coverage with minimal dose to normal ocular structures, particularly for tumors with small apical height (< 5mm depth). Volumetric dosimetry provides superior dose distribution compared to the recommended point dosimetry methods. By implementing volumetric dose distribution using 3D TPS, it is feasible to enhance therapeutic ratio for intraocular tumors.

PP-0148 A brachytherapy process review and failure mode effect analysis during a system replacement.

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Purpose or Objective
To report on implementation of a brachytherapy process review and failure mode effect analysis, used to develop a prospective quality management program for the treatment of cervical cancer, whilst changing brachytherapy equipment to different vendor.

Materials and Methods
During a change of vendor of brachytherapy equipment, a brachytherapy process review was undertaken, as a multidisciplinary team, using a plan, check, do, act management technique. Using the process map developed, brachytherapy failure modes were identified. Failure modes were scored based on severity, occurrence and detectability. Fault tree analysis was then undertaken for failure modes of higher risk, as per the AAPM TG100 recommendations.

Results
A comprehensive brachytherapy process map was developed, from which 85 failure modes were identified. Risk probability scores ranged from 7 to 500. 39 failure modes were identified for failure mode effect analysis, either due to high risk probably scores or high severity scores. This resulted in documented procedures being developed, roles and responsibilities attributed to different team members and quality management checks being put into place. Prospective quality management techniques were utilized for reviewing the entire brachytherapy commissioning and treatment processes.

Conclusion
Using a process review and failure mode effect analysis enabled a more robust brachytherapy process, with clearer responsibilities defined and enabling prospective quality management to be developed.

PP-0149 Dosimetry of Intraocular Tumors with Small Apical Heights Using I-125 Plaques

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Purpose or Objective
Treatment of small-height intraocular tumors using I-125 plaques is controversial due to the dose coverage of tumor and dose spread in eye. ABS and Ophthalmic Oncology recommend to consider the prescription point at the tumor apex and cover entire tumor with prescription dose. This is hardly achievable for the small-height tumors, particularly for the dose coverage of tumor base with a typical 2 mm retinal margin. Here, we study dose distribution and dosimetric parameters for tumors with different apical heights and basal diameters using volumetric dosimetry of I-125 plaques.

Materials and Methods
Plaque Simulator TPS (6.6.9, Eye Physics, LLC) were used to simulate dose distribution and volumetric dose evaluation. Hypothetical tumors with various apical heights (1.5 - 5.5 mm) and basal diameters (6 – 14 mm) were located temporally on a standard adult eye model in the TPS. COMS plaque at various sizes fully loaded with I-125 seeds were considered to deliver prescription dose to the tumor apex. Tumor dosimetric parameters were tumor volume (V100%) and tumor base area (A100%) with its retinal margin (1 - 2 mm) covered by prescription dose. The results were compared with the dosimetric parameters from 25 patients with small-height tumors. Dose calculation for homogenous medium was modified by applying correction factors for anisotropy, linear source, silastic carrier attenuation, lip collimation, and shell correction.

Results
Tumor dose coverage decreases with shallower apical depths when the dose optimization is based on the prescription point at the tumor apex. This decrease becomes greater for the tumors with larger basal diameters. For a Figure 1 shows At 2 mm tumor height, for example, V100% are 83.2%, 92.5%, and 100% for the tumors with the basal diameters of 12, 10, and 8 mm using COMS plaque with the sizes of 16, 14, and 12 mm, respectively. For the same tumors and plaques, A100% of tumor base with 2 mm retinal margins are 49.2%, 52.0%, and 59.6%, respectively. Tumor dose coverage is improved by using larger plaques and deeper prescription points. Every 0.5 mm increase in the prescription depth or 2 mm increase in plaque diameter can enhance tumor dose coverage by 5 – 20%, depending on the tumor basal diameter and the depth of prescription point. Volumetric dosimetry of patients with small-height apical tumors shows agreement with the theoretical dose distribution and coverage of tumors for selecting different sizes of plaques and depths of prescription points.

Conclusion
Small-height intraocular tumors can be appropriately treated using I-125 plaques by choosing larger plaque size and adjusting the prescription point at slightly deeper than tumor apex. This also limits dose spread outside the tumor in the eye. Special design of plaque can improve conformity of dose distribution for these tumors.

PP-0150 Commissioning of a GPU-based multi-criteria optimisation algorithm for HDR brachytherapy

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Purpose or Objective
In our previous study, we evaluated the impact of combining our graphics processing unit (GPU)-based multi-criteria optimisation (gMCO) algorithm with an interactive graphical user interface (gMCO-GUI) for high-dose-rate (HDR) brachytherapy. gMCO-GUI allows the planner to navigate in real-time through gMCO plans pool of Pareto-optimal plans. In this work, we report on the commissioning of this algorithm using a commercial clinically-validated treatment planning system (TPS) as our baseline.

Materials and Methods
gMCO algorithm implements on GPU the TG43-2D formalism, L-BFGS optimizer, DVH curves and 3D dose matrices computations. Hence, gMCO allows the generation of 1000 Pareto-optimal treatment plans within 10 s. Our MCO workflow was commissioned against Oncentra Prostate v4.2.2 (OcP) (Elekta, Veenendaal, The Netherlands) by using 14 HDR brachytherapy prostate cancer patients. The target, bladder, rectum and urethra structures were delineated from ultrasound images and used for DVH evaluation. For the DVH computations, the random sampling point method as described in the OcP physics manual was implemented in gMCO. In both gMCO and OcP, 50000 points were sampled in each structure, stored in histograms containing 1000 bins with a maximum dose of 400% of the prescribed dose. With gMCO, 1000 plans/case were generated and a single treatment plan (highest target coverage while meeting clinical goals) was selected. The optimized dwell times of the selected plan were exported in the DICOM-RTPLAN format from gMCO-GUI. The final dosimetry of gMCO plans was calculated in OcP. Paired two-sided Wilcoxon signed-ranked tests were used to compare the dosimetric results between gMCO and OcP.

Results

When comparing the TG43 calculations, differences less than 0.1% were observed between gMCO and OcP for different radius (0.1 cm to 10.0 cm) and angles (0, 45, 90, 135, and 180). Furthermore, when comparing the dose to a point with 2 catheters and 2 dwell positions/catheter, a difference less than 0.01% was obtained. Over all gMCO and OcP calculated structure volumes, linear regressions provided a R^2=1 with slopes ranging from 0.99 to 1.00 (mean differences within 0.3%). Fig. 1 illustrates the DVH curves calculated with gMCO and OcP for a random case.

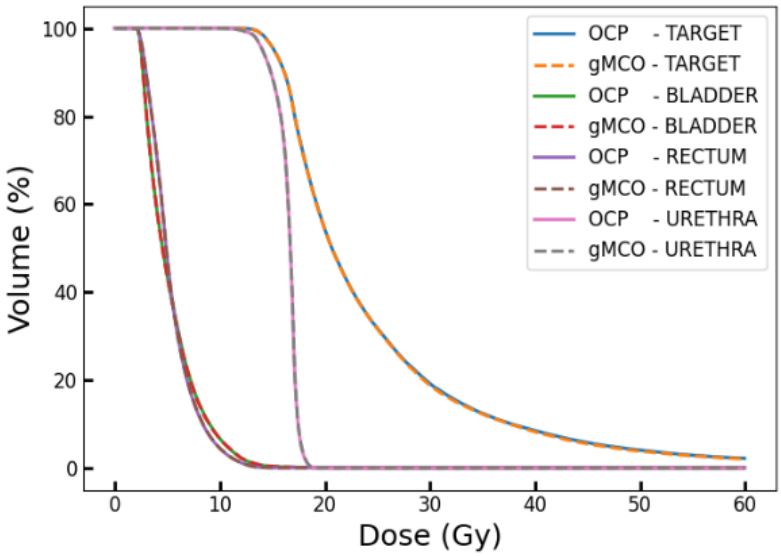

Fig. 1. Comparison of the DVH curves obtained with gMCO and OcP for a random case.

When looking into dosimetric indices, no statistically significant differences ($p>0.05$) were observed in the target V_{100}, the urethra D_{10}, the bladder V_{75} and rectum V_{75}. To validate the 3D dose calculation, a physicist carefully reviewed the isodose lines slice by slice in gMCO and OcP for one case. Fig. 2 illustrates the isodose lines for one gMCO plan imported in OcP.

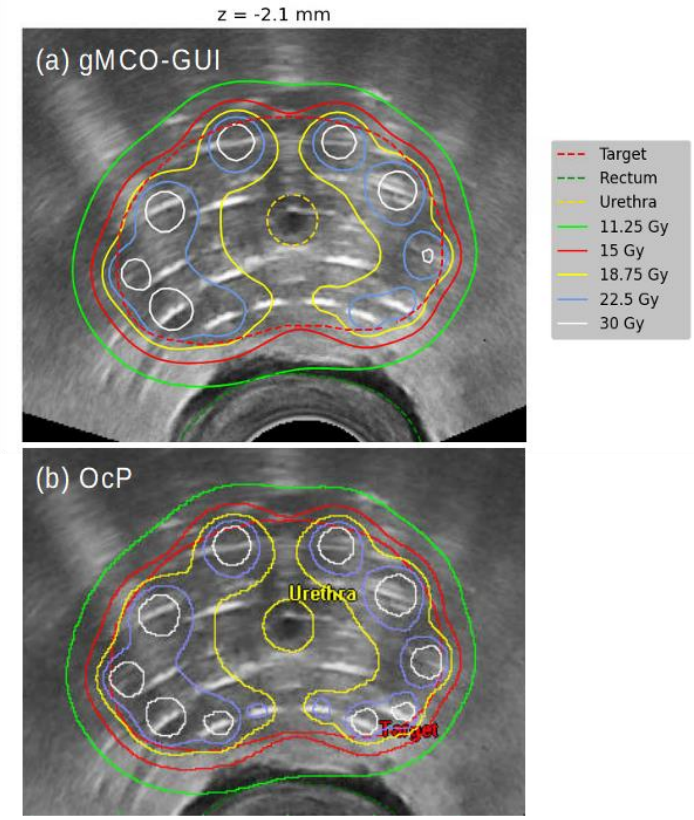

Fig. 2. Comparison of the isodose curves displayed in (a) gMCO-GUI and (b) OcP for a random case.

Conclusion
The GPU-based dose calculation algorithms (TG43, DVH, 3D dose) implemented in gMCO algorithm were evaluated and agreed with the ones integrated in OcP. While slight differences were observed, integrating these tools in the clinical TPS would allow faster calculations for the plan generation and generalize their usage in the clinical workflow by supporting GPU-based MCO algorithms.

PP-0151 A treatment analysis tool for clinical, dosimetric and outcome data reported in the EMBRACE trial

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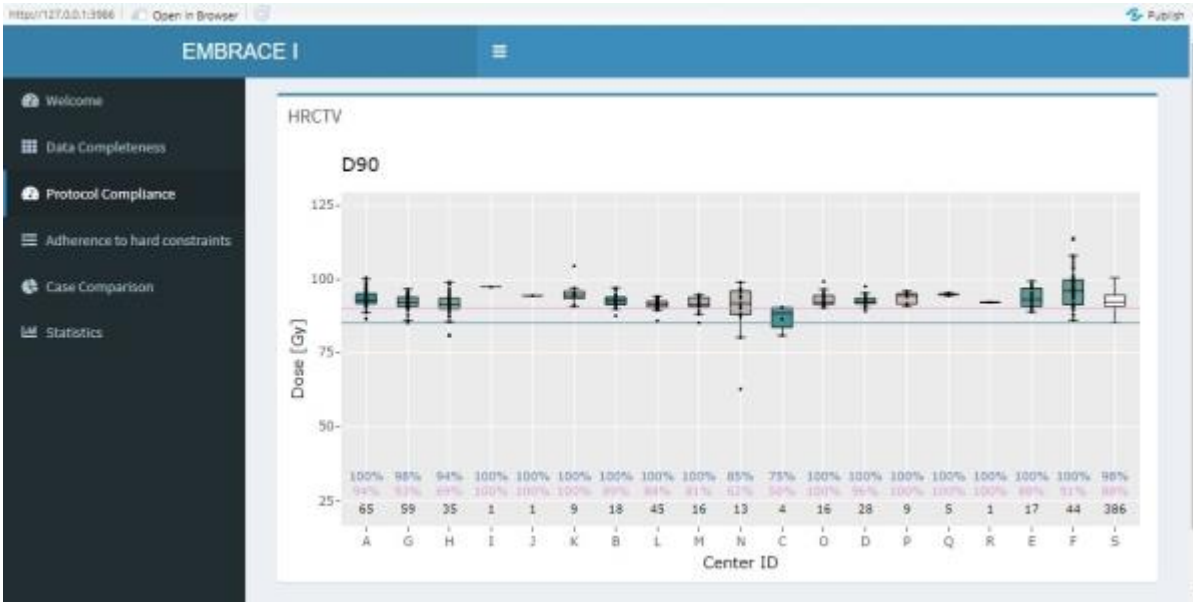
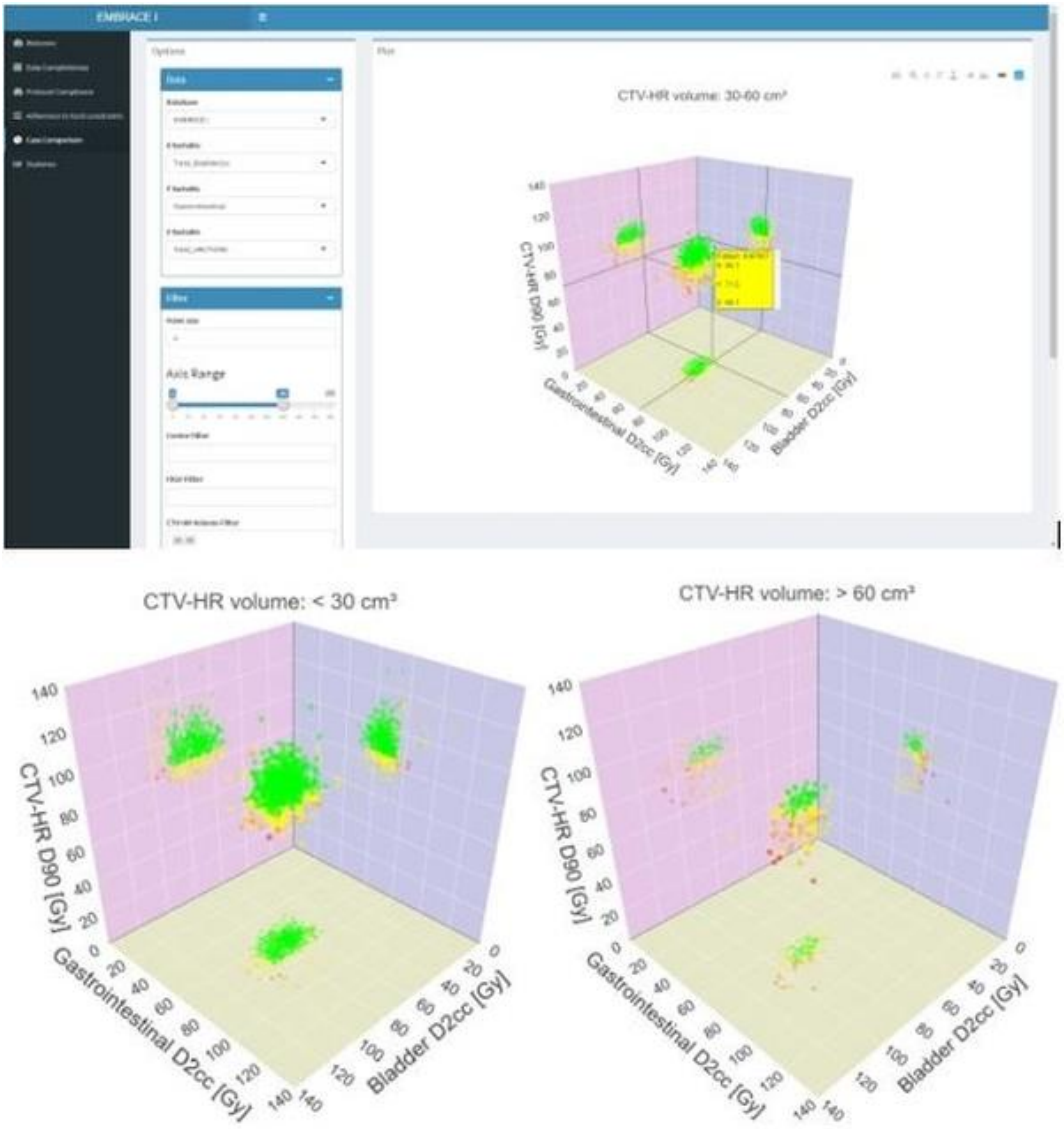
Purpose or Objective
The multi-institutional international study on MRI-guided brachytherapy in locally advanced cervical cancer (EMBRACE) yields an extensive data resource of medical and dosimetric parameters. In order to assist the big data analysis, we present an exploratory software tool which provides dynamic data analysis and visualization utilities for RT databases.

Materials and Methods
The EMBRACE dataset consists of clinical and image-based information at time of diagnosis, time of BT and at a defined follow-up schedule for 1416 patients treated from 2008-2015. A software tool was developed with the programming language R. A graphical user interface enables researchers to use advanced data analysis methods without requiring explicit programming knowledge. To facilitate access and collaboration for authorized users the tool can be hosted online. Users can define and compare subgroups of patients for different treatment parameters and strategies. Multivariate graphics (box plot, histogram, scatter plot) are produced for interactive data exploration.

Results
Treatment datasets for 1341 patients have been processed. The central part of the treatment analysis tool compares individual dose-volume data with dose constraints-based treatment protocols and planning strategies. The comparison includes a comprehensive overview of fractionation schedules, implant types, relations of target vs. OAR doses, and treated volumes. Interactions between these varying factors were analysed for different institutions, treatment strategies and tumor groups. The use of multidimensional graphics allows the visualization of custom datasets in a dynamic and versatile way. Fig.1 shows the graphical user interface (GUI), with an example plot of the variation of CTV_{HR} D_{90} (Gy $EQD2_{10}$) between centers. Fig.2 shows 3D-scatterplots for 3 different CTV_{HR} volume groups (<30cm³, 30-60 cm³, >60cm³), and the GUI for filtering and dose constraint selection. The axes are bladder and maximum of all gastrointestinal organs D_{2cm^3} (Gy $EQD2_3$) dose and CTV_{HR} D_{90} (Gy $EQD2_{10}$) dose. The patients are color-coded according to adherence to the selected dose constraints. Green: all user-defined constraints fulfilled; yellow/orange/red: 1/2/3 dose constraints missed. Interactive labels help to identify the source of each datapoint for further investigation and filtering.





Conclusion
The presented software solution allows to visualize complex relationships between different treatment parameters and groups of patients. It supports researchers in understanding the interplay of treatment data such as dose, volume, tumor stage or techniques, identifying patterns, trends and outliers, and formulating new research questions. The dynamic web-based architecture will help disseminate scientific knowledge to researchers in an efficient manner. It has the potential to be expanded to other radiotherapy applications, where large clinical study data is available, like the ongoing prospective EMBRACEII trial.

PP-0152 Proof of principle measurements for an intensity modulated brachytherapy tandem

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Purpose or Objective
A prototype dynamic rotating intrauterine tandem shield was developed to enable intensity modulated brachytherapy (IMBT) for the treatment of cervical cancer. The purpose of this study was to perform proof of principle measurements for the developed intrauterine tandem shield by delivering dose distributions from the ^{192}Ir HDR brachytherapy source, with clinically acceptable measurement to calculation agreement by using radiochromic films and the Monte Carlo (MC) method.

Materials and Methods
The IMBT delivery system dynamically controls the rotation of a novel tungsten shield placed inside an MR-compatible 6-mm wide tandem. The Geant4-based RapidBrachyMCTPS research treatment planning system was used to calculate absorbed dose in a 30x30x30 cm^3 water phantom composed of 1 mm^3 voxels. The experimental setup consisted of the tandem placed at the center of a solid water phantom with EBT3 Gafchromic films placed at 4, 6 and 16 mm from the surface of the tandem on the side of the emission windows (0°) and a film at 2 mm depth on the shielded side (180°). The ^{192}Ir source was placed half way along the tandem, centered about the central emission window, delivering 30 Gy at a

distance of 4 mm from the emission window. To relate film response to dose, EBT3 Gafchromic film pieces were calibrated using a 6 MV beam up to 40 Gy. An in-house python software using the PyMedPhys library was used to obtain dose difference and gamma evaluation maps using a gamma criterion of 2%, 1 mm. To avoid artificially high gamma pass-rates, film scans were resampled to the resolution of the MC calculated dose maps (1 mm/pixel).

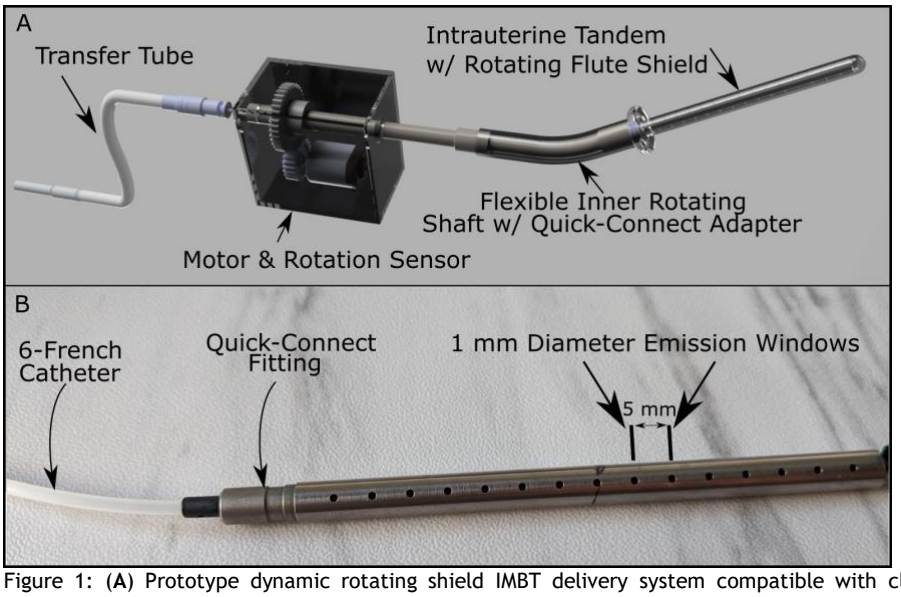

Figure 1: (**A**) Prototype dynamic rotating shield IMBT delivery system compatible with clinical afterloaders. (**B**) MR-compatible tungsten tandem shield.

Results

MC dose distributions were calculated using $2x10^9$ histories, achieving a type-A uncertainty below 0.5% at a distance of 16 mm from the tandem. Gamma (2%, 1mm) pass-rates were 96.7%, 97.3% and 98.9% for dose planes 4, 6 and 16 mm from the surface of the shield emission window. Gamma pass-rate was 95.8% at 2 mm on the shielded side of the tandem.

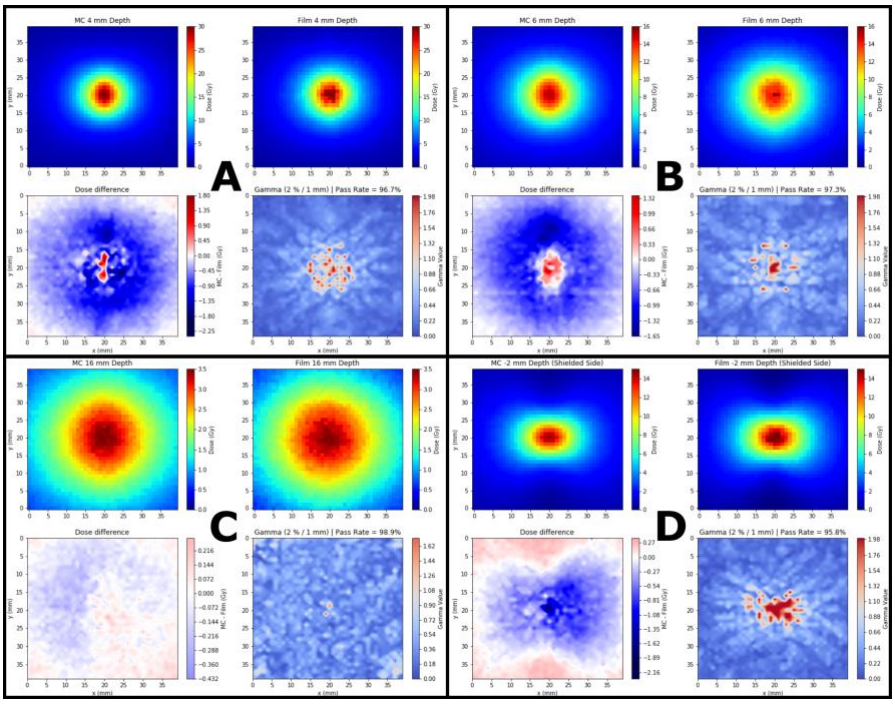

Figure 2: (**Each panel**) Dose distributions for MC (top-left) and film (top-right) are compared using dose difference (bottom-left) and gamma (bottom-right) using a criterion of 2%, 1mm. Panels **A, B** and **C** are for dose planes 4, 6 and 16 mm from the emission window. **D** is evaluated at 2 mm on the shielded side of the tandem.

Conclusion

We have performed proof of principle measurements for a newly developed tandem shield by comparing dose measured with radiochromic film and the MC-based treatment planning software, RapidBrachyMCTPS. We were able to deliver dose distributions with clinically acceptable measurement to calculation agreement. This study will provide the basis for experimental verification of complex IMBT treatment plans produced dynamically by rotating the shield during treatment delivery. Film measurements will in the future be followed up by scintillator-based detector dosimetry.

PP-0153 In Vivo Dosimetry in brachytherapy: A first clinical trial implementation with a mPSD detector

Abstract withdrawn

PP-0154 Knowledge-based Inverse Treatment Planning for Low-Dose-Rate Prostate Brachytherapy

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Purpose or Objective
Permanent low-dose rate brachytherapy is a widely used treatment modality for managing prostate cancer. In such interventions, treatment planning can be a challenging task and requires experience and skills of the planner. We developed a novel knowledge-based (KB) optimization method based on previous treatment plans. The purpose of this method was to generate clinically acceptable plans that do not require extensive manual adjustments in clinical scenarios.

Materials and Methods
Objective functions used in current inverse planning methods are preferably based on spatial invariant dose objectives rather than spatial dose distributions. Therefore, they are prone to return suboptimal plans resulting in time consuming plan adjustments. To overcome this limitation, a KB approach is introduced. The KB model uses the dose distributions of previous clinical plans projected onto a standardized geometry. From those standardized distributions a template plan is generated. An overview of the workflow is shown in Fig.1. The treatment plans were optimized with an in-house developed planning system by solving a constraint inverse optimization problem that mimics the projected template dose plan constraint to DVH metrics. The method is benchmarked under an IRB approved retrospective study by comparing optimization time, dosimetric performance, and clinical acceptability against current clinical practice. The quality of the KB model is evaluated with a Turing test.

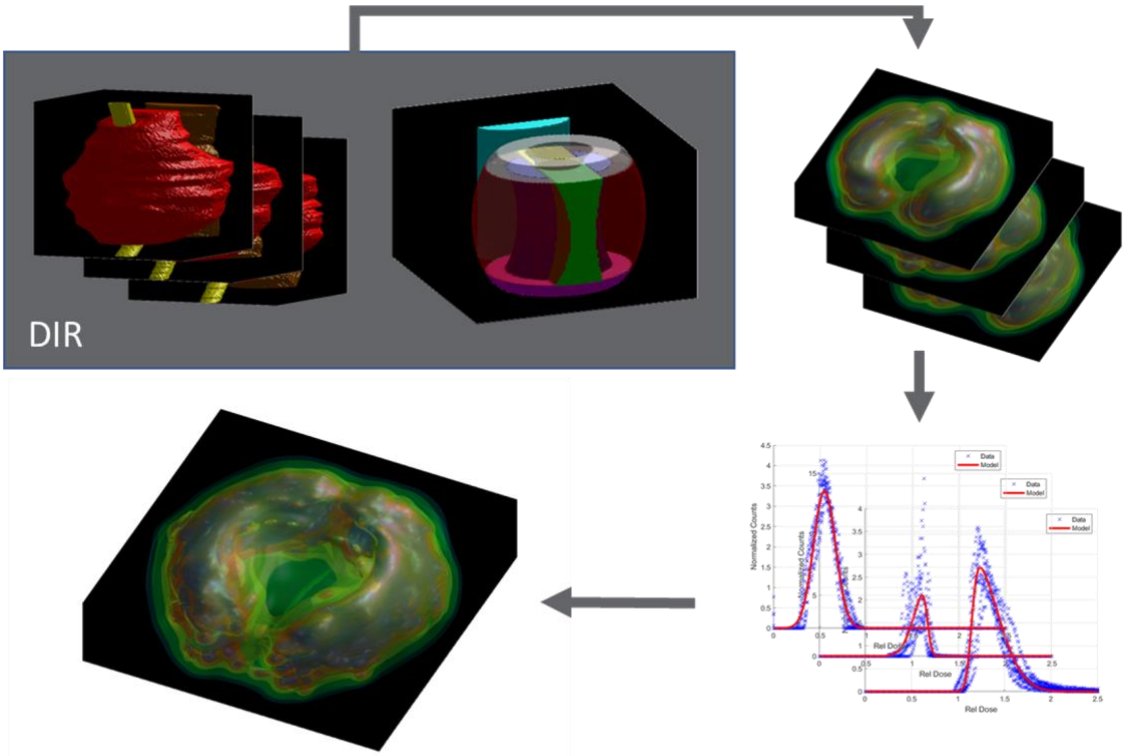

Figure 1. Workflow of the knowledge-based model generation. Each of the plans that form the model are deformed onto the standardized geometry (upper left). Individual dose clouds are deformed with the same transformation as the anatomic DIR (upper right). The dDVHs resulting from the deformed dose clouds are fitted with skew normal distributions (lower right) to obtain the PDF. By mapping the PDF to the torus the final knowledge-based model is obtained (lower left).

Results
The KB model consists of five high quality treatment plans. Those plans were selected by one of our experts and showed all desired dosimetric features. After generating the model treatment plans were created with one run of the optimizer for the remaining 20 patients. The optimization time including needle optimization ranged from 6-29 seconds. Based on a Wilcoxon signed rank test the new plans are dosimetrically equivalent to current clinical practice. A representative slice with achieved isodose lines as well as a summary of achieved metrics for all patients are shown in Fig. 2. The Turing test showed that the proposed method generates plans that are equivalent to current clinical practice and that the dose prediction drives the optimization to achieve high quality treatment plans.

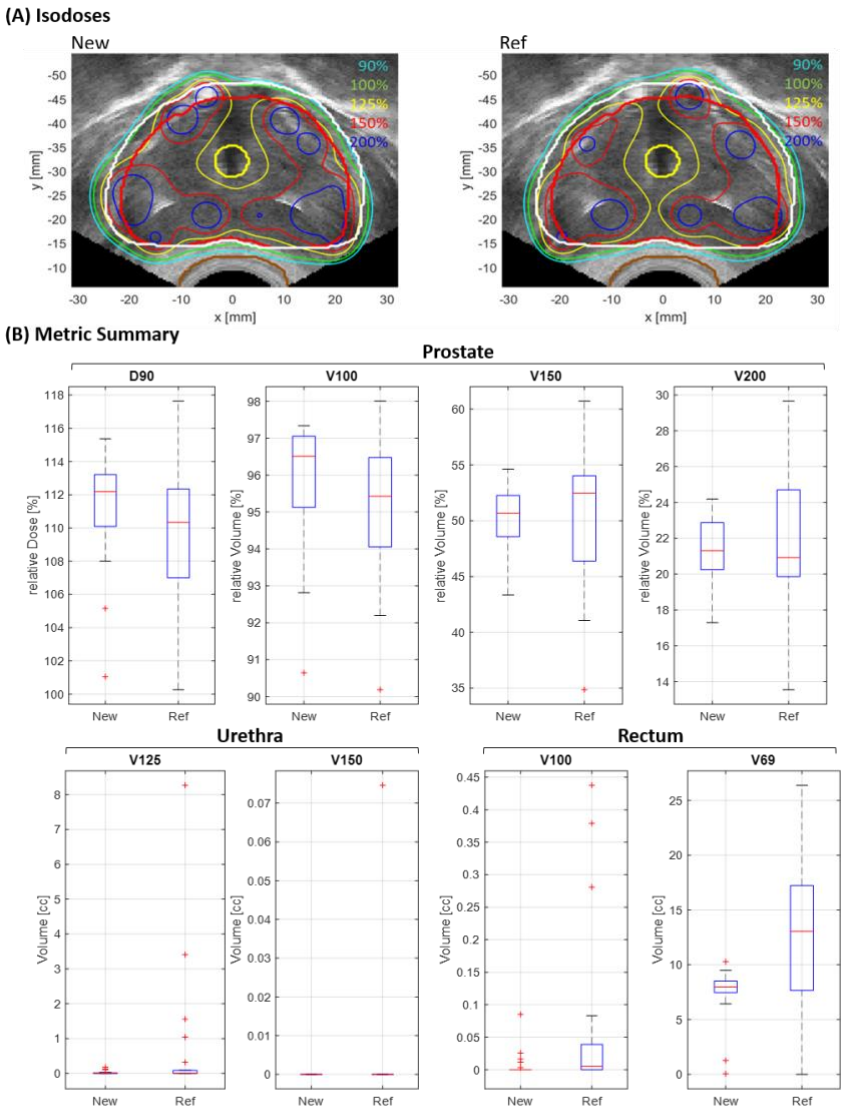

Figure 2. A: Achieved isodose lines (bottom) for the KB generated plans (left column) and the clinical plan (right column) for the central axial slice of a representative patient. B: Box and whisker plot of the achieved DVH metrics. The box represents the range pf the 25th to 75th percentile. The red bar represents the media. And outliers are depicted as "+". The upper row shows metrics for the prostate and the lower row for urethra and rectum.

Conclusion

This study demonstrated that the proposed KB model was able to capture user specific features in isodose lines which can be used to generate acceptable treatment plans with a single run of the optimization engine in under a minute. The presented approach has the potential to accelerate planning time by more than two orders of magnitude. It can be used for pre-planning and real time intra-operative treatment planning. For the intra-operative planning approach, a reduction in planning time may translate into reduced time in the operating room and the time a patient is under anesthesia. The KB approach can encapsulate user specific preferences which can be transferred across institutions.

Poster presentation: Poster Presentation: Prostate

PP-0155 Antibiotic Prophylaxis for Prostate HDR Brachytherapy: Interim Results of a Phase III trial

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Purpose or Objective

Antibiotic prophylaxis is widely used for prostate brachytherapy procedures, mainly based on transrectal prostate biopsy literature. However, for brachytherapy, the technique is a transperineal approach in a sterile environment. Antibiotic prophylaxis comes with other concerns (C. difficile, antibiotic resistance, etc.). The main objective of this study is to evaluate the rate of urinary tract contaminations and infections following prostate HDR brachytherapy.

Materials and Methods
This trial (BRP-30, NCT03862170) was designed to accrue 255 patients undergoing HDR brachytherapy boost randomized between 3 arms: no antibiotic prophylaxis, Ciprofloxacin (Cipro) 400 mg IV 120 minutes pre-operative, and Cefazolin (Cefa) 2g IV 60 minutes pre-operative. An interim analysis was planned. Therefore, we present here the results for the first 128 patients recruited. Serial urine analysis and culture were done: at baseline (the morning of the brachytherapy procedure), one-day, 1 week, 2 weeks, and 1 month post-procedure. 2 patients had contaminated baseline cultures and were excluded from the analysis. Chi-square and Fisher exact test were used to analyze the association between infection rates between arms.

Results
35%, 30%, and 35% were allocated respectively to no antibiotic, Cipro, and Cefa arms. Positive urine culture rates were 26%, 19%, and 19%, presenting no difference between arms (p=0.677) no antibiotics, Cipro and Cefa, respectively. Confirmed infection rates (patients presenting positive cultures, symptoms and treated with antibiotics) were 14%, 8%, and 7%, respectively, presenting no statistically significant difference between arms (p=0.557). 14 patients presented positive urine cultures, but had no symptoms. 8 did not receive antibiotics and cleared the infection in the following analysis by themselves, and 6 received antibiotics.

Conclusion
No difference between antibiotic prophylaxis (Cipro or Cefa) and no antibiotic prophylaxis for post-BT urinary tract infections rates were observed at the study interim results. However, these results still lacks power to safely determine that infection rates are similar between arms. We have to wait for our study's final results to conclude that omitting antibiotic prophylaxis is safe in the prostate brachytherapy sterile setting.

PP-0156 HDR and LDR comparison as monotherapy in localized prostate cancer: PSA kinetic and late toxicity

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Purpose or Objective
The Prostatic Specific Antigen (PSA) is an important predictor of survival post radiation treatment. The PSA nadir and PSA value <0.4 ng/ml have been correlated with biochemical failure and prostate cancer mortality. We previously conducted a multi-institutional phase 2 randomized trial evaluating the differences of health related quality of life (HRQOL) of high dose rate brachytherapy (HDRB) versus low dose rate brachytherapy (LDRB) for localized prostate cancer. HDRB monotherapy was associated with a lower acute urinary toxicity profile and higher HRQOL in the first 12 months compared with LDRB. The aim of this study is to report the PSA kinetics and the late HRQOL in the urinary, gastro-intestinal and sexual domains

Materials and Methods
Men with low and favorable intermediate risk prostate cancer from 3 academic centres were randomized between monotherapy brachytherapy with either Iodine125 LDRB to 144 Gy or single-fraction Iridium192 HDRB to 19 Gy. Serial PSA levels were recorded every 3 months and PSA nadir and PSA value <0.4 ng/ml were evaluated. Biochemical relapse using the Phoenix definition was also reported. Toxicities were recorded according CTCAE 4.0. HRQOL were reported at 24- and 36-months using the Expanded Cancer Index Composite (EPIC)-26 and the International Prostate Symptom Score (IPSS).

Results
Between December 2015 and December 2016, 31 patients met the eligibility criteria and were randomized, 15 in the LDR Brachytherapy and 16 patients in the HDR Brachytherapy arm, respectively. The patients were comparable in term of clinical stage, PSA and Gleason score (Table 1). The median follow-up was 45 months. Three patients experienced a biochemical failure according Phoenix definition, all in the HDR Brachytherapy group (p=0.092). Single fraction HDR Brachytherapy is associated with significant higher PSA nadir compared to LDR Brachytherapy (p=0.00047). Moreover, a significantly larger proportion of patients in the LDRB group had a PSA <0.4 ng / mL (13/15 versus 2/16, p=0.000036). There was no significant difference between HDR Brachytherapy and LDR Brachytherapy in late Genito-Urinary, Gastro-Intestinal, and sexual toxicities at 24 and 36 months. Regarding HRQOL, IPSS and EPIC-26 irritative score were significantly better for patients treated with HDR over the first 36 months post-treatment (p=0.001 and p=0.01, respectively).

Conclusion
Our results suggest that LDR Brachytherapy is superior to HDR Brachytherapy 19 Gy monotherapy in terms of PSA biochemical control. In fact, LDRB resulted in a significant lower PSA nadir and a higher proportion of patients achieving a PSA <0.4 ng/mL at 36 months. There was no significant difference between HDR Brachytherapy and LDR Brachytherapy in late toxicity at 24 and 36 months. HRQOL was better for patients treated with HDR Brachytherapy, with less decline in the EPIC-26 urinary irritative domain compared to patients treated with LDRB patients over the first 36 months.

PP-0157 Long-term Outcomes of Prostate Cancer Patients treated with Low Dose Rate Brachytherapy

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Purpose or Objective

The aim of this project was to report the clinical outcomes of prostate cancer patients treated with LDR Brachytherapy at our centre using post-implant dosimetry, 5 &10-year overall survival (OS), 5 &10-year biochemical relapse-free survival (bRFS), disease-specific survival (DSS), and prostate-specific antigen (PSA) metrics.

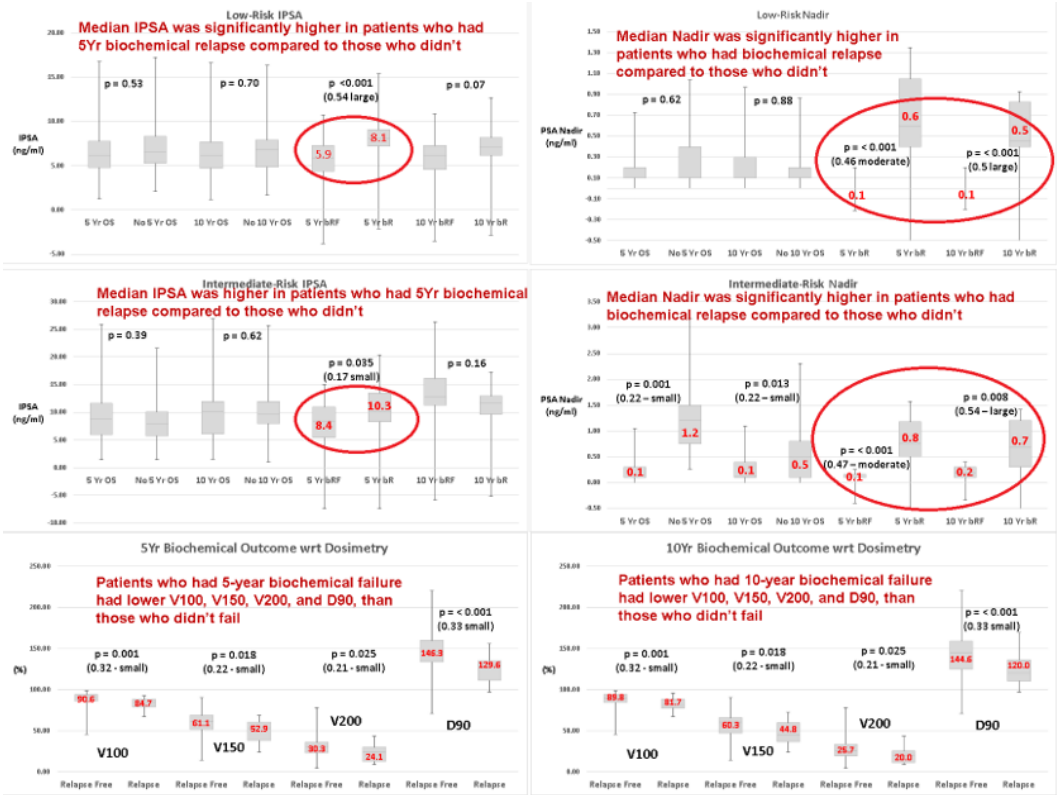
Materials and Methods

A total of 544 patients were treated with LDR Brachytherapy up to December 2012, excluding 20 high-risk patients and those who had an External Beam Radiotherapy boost, or salvage Brachytherapy. The patient characteristics are summarised in Table 1. Low and intermediate-risk disease stratification followed the European Association of Urology (EAU) guidelines, where low-risk disease was defined as PSA < 10 ng/ml, Gleason grade < 7, and clinical stage T1-2a, and intermediate-risk disease was defined as PSA 10 - 20 ng/ml, or Gleason grade 7, or clinical stage T2b. Biochemical failure was defined as PSA nadir + 2 ng/ml. All patients had Brachytherapy as monotherapy, where the whole prostate volume was treated with a prescribed dose of 145 Gy. All patients had 3-6 monthly interval follow-up for PSA testing, and a CT scan at six weeks, which was used for post-implant dosimetry. The dose to 90% of the prostate volume (D90), and the volume of the prostate receiving 100, 150, and 200% of the prescription dose (V100, V150, \& V200) were recorded from the post-implant dosimetry.

	Low-Risk Disease	Intermediate-Risk Disease
No. of Patients	254 (45%)	290 (51%)
Median age (range)	62 (44 – 77)	64 (45 – 76)
5 Yr bRFS	94%	86%
10 Yr bRFS	91%	81%
5 Yr OS	96%	97%
10 Yr OS	90%	86%
DSS	99%	96%

Results

The 5 & 10-year bRFS, OS, and DSS, outcomes are summarised in Table 2. The box plots in Figure 1 are the results of comparing the median differences in IPSA and nadir in patients who survived at 5 &10 years and those who had biochemical failure at 5 &10 years. Figure 2 shows that intermediate-risk patients who had biochemical failure at 5 and 10 years had lower V100, V150, V200, and D90, than those who didn't fail. On univariate analysis, younger men were more likely to bounce (p = 0.008, low-risk and p < 0.001, intermediate-risk), and the bigger the difference between IPSA and the first PSA measurement following treatment resulted in less biochemical failure in intermediate-risk patients (p < 0.001). On multivariate analysis, IPSA was predictive of being relapse-free; lower IPSA resulted in less biochemical failure (p = 0.005, low-risk and p = 0.012, intermediate-risk). In the post-implant dosimetry data, lower V100, V150, V200, and D90 were shown to result in more 5 and 10-year biochemical failure in intermediate-risk patients.



Conclusion
LDR Brachytherapy offers excellent outcomes in terms of overall survival and biochemical relapse-free survival in low and intermediate-risk prostate cancer patients. The IPSA and nadir are significant predictors for biochemical relapse-free survival, with lower levels being more protective against biochemical failure. Lower dosimetric parameters V100, V150, V200, and D90 were shown to result in more biochemical failure in intermediate-risk patients.

PP-0158 Registration accuracy of an integrated MR -TRUS navigation system for prostate HDR brachytherapy

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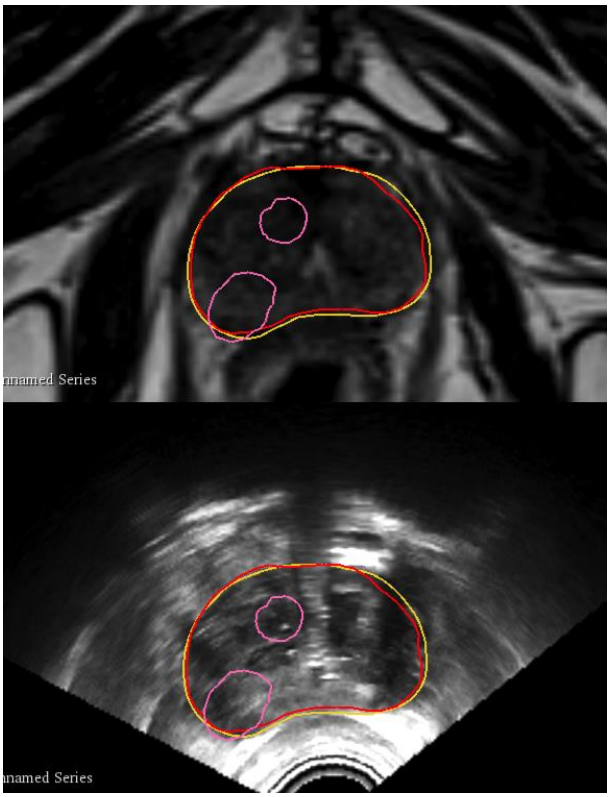
Purpose or Objective
A common treatment for long term disease control for prostate cancer is High-Dose-Rate (HDR) brachytherapy. In conventional HDR, the whole gland is radiated which limits the dose received by the lesion due to risks of radiating the adjacent organs. Therefore a method to locate and incorporate the location of the epicenter of the cancer in treatment planning may improve the outcome of the procedure. Transrectal Ultrasound (TRUS) is a widely used imaging modality for guidance of brachytherapy procedures due to its ease of use, cost efficiency and real-time nature. However, prostate lesions are not clearly visible on TRUS. In order to locate the GTV based on TRUS, a deformable registration between GTV in MRI and TRUS is needed. In this study we aim to evaluate the automated deformable registration performance of a prototype system for focal TRUS guided brachytherapy.

Materials and Methods
The system (Philips Disease Management Systems) was designed with the intent to support prostate tumor targeting through in-room image registration. The registration with this system is done between 3D prostate contours on MRI and TRUS. These contours were exported from the system using the system's software, with the registration being performed live during the intervention. Common anatomical landmarks were identified in 3D on both TRUS and MRI by an experienced physician. These landmarks included the urethra at the apex and base of the prostate, cysts and calcifications. The mean target registration error (mTRE) before and registration is reported. The determinant jacobian matrix (DJM), which is a measure that shows the expansion or reduction of the deformation, was computed as well as the Dice coefficient. For a physically possible deformation, this value is non-negative.

Results
Registration accuracy was evaluated in 37 prostate HDR brachytherapy procedures. Multiparametric MRI (3D T2 SPACE, b2000 DWI, DCE) (n=11) were registered to PSMA-PET/CT (F^{18}DFCPyL) images (n=10) for segmentation (Eclipse, Varian) of the prostate boundary, urethra, and tumor PTVs. Tumor targets ranged from 1.3 to 34.4 cc (mean 8.8), and constituted 3.9-73.5% of prostate gland volumes (mean 17.5). After set-up, baseline interventional 3D TRUS images (BK) were obtained through manual sagittal sweep. Following automated deformable registration, the mTRE was found to 3.4 +/- 1.5 mm. Besides the mean target registration error, the DJM was shown to be positive in all cases, yielding a Dice coefficient above 0.92. Two cases were excluded from the registration evaluation due to significant prostate deformation. An example of a result is shown below.



Conclusion
Registration accuracy of this system was found to be in the clinical acceptable range for existing standard-care environments, and streamlined registration workflow while enabling tumor-targeting approaches. Future work will identify and address potential discrepancies in automated fusion, and report on improvements in navigation accuracy with additional clinical experience.

PP-0159 HDR Brachytherapy Monotherapy in patients with Low/Intermediate-risk Prostate Cancer

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Purpose or Objective
To evaluate the feasibility and toxicity of high-dose-rate (HDR)-brachytherapy (BT) as monotherapy in a prospective clinical trial consisting in two sessions interval 6 hours of a single implant for localized prostate cancer. We report the Acute and Chronic Genitourinary (GU) and Gastrointestinal Toxicity (GI) and Disease Control.

Materials and Methods
Between November 2010 and October 2020 a total of 119 patients were treated. The prescribed dose was 27 Gy in 2 fractions in a day using a single implant. 24 patients (20.1%) was Intermediate risk cancer. 39 patients (33%) received hormonal therapy. Biochemical prostate-specific antigen (PSA) failure was per the Phoenix definition. GU and GI toxicity were evaluated by CTCAE V 4.0. Sexual Function were recorded during follow-up.

Results
Median follow-up was 100 months (range, 33-119). Grade 1-2 acute Toxicity was 26.9%, mainly Frequency/urgency (10%), Dysuria (10%), Dribbling/hesitancy (0.8%). 3 patients required a Foley catheter during 1 week. No acute GI toxicities were recorded. Chronic Genitourinary Toxicities Grade 1-2 were 28.5 %, mainly Dysuria (12.6%), Urinary frequency/urgency (5.8%) and Urinary Incontinence Grade 2 (1.6%); 1 patient had Grade 2 rectal bleeding and 1 patient had Grade 3 GU toxicity requiring RTU. 23.7% of patients without Hormonal therapy reported sexual impotence Grade 1-2 after 2 years therapy. The actuarial Local Control was 99.2%, Biochemical Control 95.8%, Distant Failure 4.2% and Overall Survival was 91.6%.

Conclusion
HDR brachytherapy as monotherapy with longer follow up for localized prostate cancer is an effective treatment with acceptable acute or chronic toxicity. Clinical trials is needed to confirm these encouraging results.

PP-0160 Prostatitis after HDR brachytherapy monotherapy

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Purpose or Objective
Prostatitis is a recurrent toxicity after HDR brachytherapy as monotherapy. The main objective is to determine its occurrence and to investigate how treatment-related and non-treatment-related factors impact prostatitis among patients treated on an HDR brachytherapy Monotherapy protocol.

Materials and Methods
HDR brachytherapy as monotherapy protocol BRP-2 (NCT03424694) recruited 206 patients with low or intermediate-risk prostate cancer. 199 were randomized between one fraction of 19.5Gy and 29 Gy in two fractions. Treatment was delivered in both arms in a single-implant and a one-day schedule. Patients in the 2 fractions are received their treatments 6 hours apart. Each fraction had its own MRI-based dosimetry. Dominant intra prostatic lesion (DIL) boost was allowed. Post-treatment toxicity was evaluated at 1, 3, 6 weeks, 3 months, 6 months and every 6 months subsequently using CTCAE v5.0 and comparing to the patient's baseline. The most frequent acute toxicity were dysuria, pollakiuria/urgency, painful urination all of which improved within the first 6 months after treatment. However, in the late toxicity phase some more symptoms occurred. We defined prostatitis as a combination of dysuria, pollakiuria/urgency, painful urination accompanied by a painful rectal examination, with or without positive urinary culture. Although, CTCAE v5.0 does not have a specific category for prostatitis, we used the category: Renal and urinary disorders - Other, specify. We considered all grade 1 or greater toxicity as prostatitis for this analysis. Logistic regression models were used to evaluate predictive factors of prostatitis. Statistical significance was 0.05.

Results
Prostatitis was graded as: grade 1, none or oral medications indicated to control symptoms; grade 2, oral antibiotic and/or Gabapentin; grade 3, IV antibiotic; grade 4, life-threatening consequences, urgent intervention indicated; grade 5, death. 24% of patients presented prostatitis as a late urinary toxicity post HDR brachytherapy.
Mean follow-up time was 46 (8.9-64.9) months. Prostatitis was present in 20% of the 19.5Gy arm, and 27% of the 29 Gy arm. Patients presented 1 or 2 episodes of prostatitis, with a mean duration of 7.4 months (1-18 months) in the 19.5Gy arm, and 7.2 months (0.1-17.6 months) in the 29 Gy arm, respectively. Clinical Inclusion criteria and dosimetry characteristics were tested as predictive factors for prostatitis. On univariate analyses, only a higher maximum dose for the urethra showed statistical significance (p=0.038). iUrethra presented a tendency (p=0.051) towards significance.

Conclusion
Prostatitis is a frequent although undescribed late toxicity of HDR brachytherapy monotherapy. Dosimetry characteristics can present predictive factors, although further exploration of multivariate models are needed to better understand this issue.

PP-0161 mpMRI-guided dose escalation to DIL with US-planned HDR prostate brachytherapy: a phase II study

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Purpose or Objective
Dose escalation for prostate cancer improves biochemical recurrence free survival. We aimed to evaluate the long-term outcomes and toxicities of 25% dose escalation to the dominant intraprostatic lesions (DILs) using high dose rate (HDR) brachytherapy and multiparametric magnetic resonance imaging (mpMRI) guidance.

Materials and Methods
26 patients with predominantly unilateral intermediate or high risk prostate cancer were recruited to this IRB-approved phase II prospective trial. Prior to treatment, mpMRI (1.5T with endorectal coil) was performed to identify and contour the DIL(s), which was then registered with the pre-brachytherapy ultrasound for transfer of the DIL contour(s). This was in turn registered with the intraoperative ultrasound at the time of brachytherapy. Planned DIL dose escalation was >125% of prescription dose, while respecting critical organ and homogeneity constraints. Treatment consisted of HDR brachytherapy in 2 fractions of 10 Gy and pelvic external beam radiotherapy (EBRT) 46 Gy in 23 fractions with or without androgen deprivation therapy (ADT). The first HDR fraction was delivered 5 days prior to EBRT and the second was delivered 1 week into EBRT. We compared results for this cohort to a previous cohort of 25 patients treated identically but without DIL identification or dose escalation. Toxicity was graded using CTCAE v3.0. Descriptive and inferential statistics were used.

Results
51 patients were analyzed. Median follow-up was 77 months (range 59-98). Median age at diagnosis was 65. 92% were intermediate risk with predominantly Gleason 7 (92%) and median PSA 9.3ng/mL (range 1.3-20.0). ADT was used in 29% for a median duration of 6 months (range 2-12, 80% 6-12 months). Baseline characteristics between the two cohorts were similar, including age, percent pattern 4 or 5, PSA, baseline IPSS, and prostate volume. Mean DIL D90% was 132% (SD 10%) of prescription dose. There were a total of 7 failures (3 distant, 2 regional, 1 local which was biopsy-proven, 1 biochemical only) with no significant difference between cohorts. In those without biochemical failure or previous ADT, the mean PSA nadir was not significantly different with a value of 0.06; however, time to PSA nadir was significantly shorter in the DIL dose escalation cohort (55 vs. 67 months, $p<0.04$). Late grade 3 GU toxicity was 6% and late grade 3 GI toxicity was 2%, all occurring in the non-DIL cohort.

Conclusion
Focal dose escalation to the DIL(s) using ultrasound-planned mpMRI-guided HDR prostate brachytherapy is feasible, with minimal late toxicity. Compared to no dose escalation, it appears to significantly shorten the time to PSA nadir, which has previously been shown to be an early prognostic marker.

PP-0162 MR-assisted whole salvage HDR prostate brachytherapy with intra-prostatic boost: a prospective study

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Purpose or Objective
Salvage options for those with local recurrence after external-beam radiotherapy (XRT) include surgery, brachytherapy, cryotherapy or high-frequency ultrasound. However, the risk of significant complications (e.g. fistula, incontinence, bladder neck contracture) is not insignificant. The sensitivity of multiparametric MRI in detecting viable cancer within the prostate is more than 70%. To reduce complications, we sought to investigate whether whole gland salvage HDR brachytherapy with intra-prostatic boost in patients with MRI-visible biopsy-confirmed local recurrence was tolerable and effective. Herein, we present preliminary toxicity, IPSS and efficacy results.

Materials and Methods
Eligible patients included: multiparametric 3T MRI visible biopsy confirmed local recurrence >30 months after XRT, negative metastatic workup, IPSS <15, post-XRT PSA <10ng/mL. Ultrasound-based HDR brachytherapy with the Oncentra Prostate planning system was used. Intraoperative deformable registration between the multiparametric MRI and ultrasound images were done in 13 of 15 patients, and cognitive fusion in the remaining 2 patients. The prescription dose was 21Gy to the entire prostate and 27Gy to the MR-defined intraprostatic target volume (TV) divided over two implants separated by 1 week with dose constraints to the urethra and rectum. Follow-up PSA, IPSS and CTCAE v4.0 toxicities were collected.

Results
15 patients (median age 73 years) were enrolled in the study. Median follow up from salvage HDR was 24 months (12-54). At initial presentation, there were 3, 8 and 4 low-, intermediate- and high-risk disease. The initial XRT dose was 70-78Gy with conventional fractionation in 13 patients and SBRT in 2 patients (35Gy/5F and 50Gy/15F). The Gleason score of the local recurrence was 6, 7 and 8-10 in 1, 10 and 4, respectively. The pre-HDR median PSA was 2.61ng/mL (0.63–8.30). The median size of the prostate was 35.7 mL (15.9-55.2) and TV was 4.4mL (0.4-11.9). The median dosimetric endpoints were: prostate V10.5Gy 96.8% (94.2-98.7), prostate D90 11.4Gy (10.9-12.0), TV V13.5Gy 95.9% (83.5-100), TV D90 18.6Gy (16.8-22.2), urethral D10% 12.0Gy (11.9-12.6), urethral Dmax 12.6Gy (12.2-13.5) and rectal V8.4Gy 0mL (0-0.5). Three patients

(20%) required temporary urinary catheterization. There were no acute/late GU/GI grade 3-5 toxicities. The most common acute toxicity was frequency, dysuria and urgency. Mean IPSS at baseline, 1.5-, 3-, 6-, 9-, 12-, 18-, 24-months was 5, 16, 10, 9, 10, 12, 10 and 15 (p=0.11). Two and three-year PSA failure free rate was 72% and 60% respectively. Of the 12 patients who had a post-HDR MRI (median 432 days), 9 (75%) patients had a complete response and 3 had persistent disease in the TV. No patients recurred elsewhere in the prostate.

Conclusion
Early toxicity, IPSS and PSA failure-free data suggests that whole gland salvage HDR brachytherapy with intra-prostatic boost is well tolerated and effective.

PP-0163 Very long-term biochemical and dosimetric outcomes of LDR boost in intermediate-risk prostate cancer

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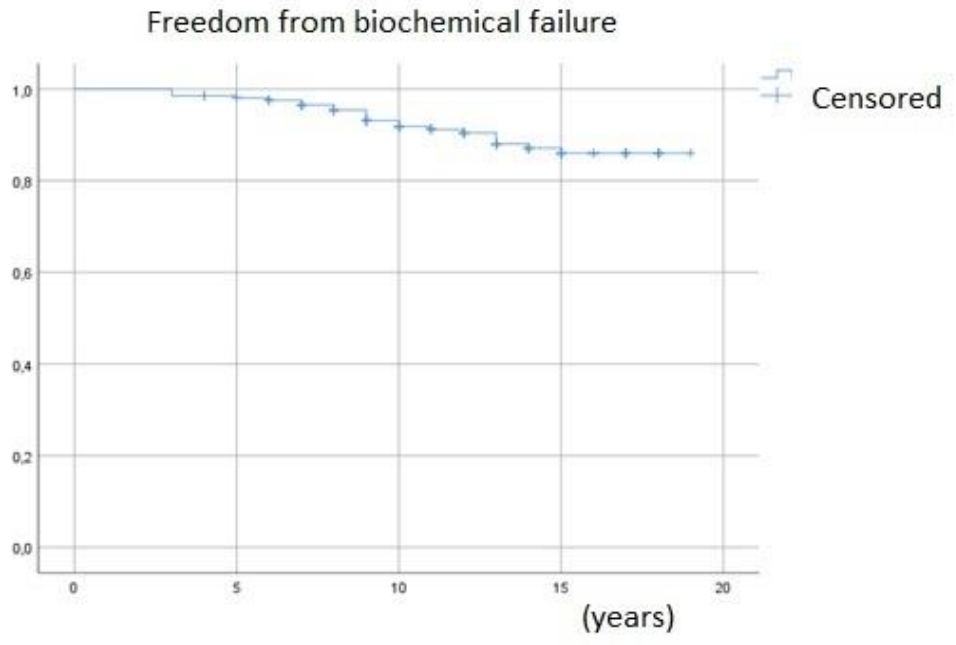
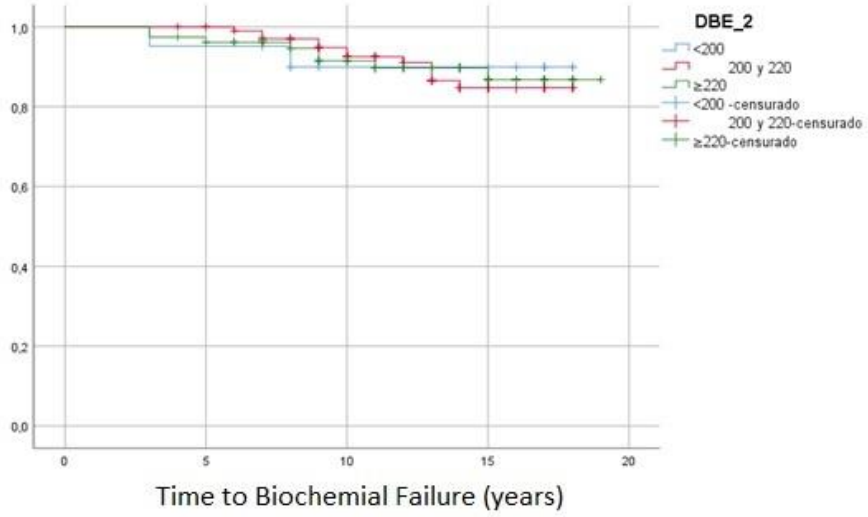
Purpose or Objective
To report very long-term biochemical and dosimetric outcomes in patients undergoing low-dose-rate (LDR) brachytherapy (BT) boost after external beam radiotherapy (EBRT) and analyze the effect of biologically effective dose (BED) on prostate-specific antigen (PSA) failure.

Materials and Methods
Consecutive patients with diagnosis of primary intermediate prostate cancer undergoing LDR boost with I-125 after EBRT (between June-2001 through December-2006) were examined. All patients received 46Gy in 23 fractions of pelvic irradiation encompassing the prostate and first third of seminal vesicles. Four weeks after irradiation, subjects received a low-dose-rate 125I brachytherapy boost of 108Gy. All patients underwent CT-based postimplant dosimetry a month after BT. Those with less than 4 year follow-up and less than four post brachytherapy PSA were excluded from the study.

Results
About 204 patients satisfied inclusion criteria. The median age of patients was 67 years. Median PSA was 10 ng/mL. Twenty-six patients had clinical T2c classification and 86 subjects Gleason 7 score. A total of 18 of the 204 patients received androgenic deprivation therapy (ADT) for prostate cytoreduction. The median postimplant D90 was 119,39Gy and the v100 93,56%. The median of seeds implanted was 78. Median follow-up was 13.3 years (range 4 – 19) for entire cohort and 15.4 years (5 – 19) for patients alive at the moment of the study. Biochemical failure occurred in 22 patients. Freedom from biochemical failure (FFBF) as defined by the Phoenix Criterion was 98.5%, 91.8%, 86% and 86% at 5, 10, 15 and 19 years, respectively. Freedom from metastases was 99,5% at 5 years, 96.7% at 10 years, 93.9% at 15 years and 92.6% at 19 years. No difference in dosimetric outcome was observed. The 15-year FFBF for v100 ≤90 and >90 was 8.4% and 89.1%, respectively. Similarly, 15-year FFBF for those patients with D90 ≤115Gy was 91,7% and 82.9% for those with D90 ≥115. The 15-year FFPF for BED (α/β=2) <200, 200-220 and >200 were 89,9%, 84,7% and 86,8%, respectively.





Conclusion
LDR boost after EBRT provided excellent very long-term outcomes in patients with intermediate risk prostate cancer. FFBF at 15 years was as low as 86%. BED achieved with the I-125 boost is enough for an optimal local control in this type of disease, despite a suboptimal BT implant.

PP-0164 focal treatment of prostate cancer with 169Yb-based high dose rate intensity modulated brachytherapy

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Purpose or Objective
By means of a retrospective dosimetry study, to investigate the difference between conventional ^{192}Ir based high dose rate (HDR) brachytherapy and ^{169}Yb based intensity modulated brachytherapy (IMBT) for focal treatment of prostate cancer. IMBT is a solution to the critical limitation with brachytherapy, which is the rotationally symmetric dose distribution provided by brachytherapy sources, delivering high absorbed dose to the tumour but often with poor tumour conformity due to the non-symmetrical shape of the tumours resulting in dose spillage to surrounding healthy tissues. By incorporating rotating metallic shields inside brachytherapy catheters, IMBT opens the possibility to escalate the dose to the tumours while more effectively shielding the surrounding healthy tissues by dynamically directing the radiation towards the tumours and away from the healthy tissues. Increased dose-to-tumour conformity may provide a means to reduce number of catheters used, thus allowing for a less invasive treatment.

Materials and Methods
Postimplant dosimetry was performed by using ultrasound images in DICOM format for a cohort of 13 patients with prostate cancer treated with HDR brachytherapy. Dose calculations were performed using RapidBrachyMCTPS, an in-house Monte Carlo treatment planning system. Distinct non-IMBT treatment plans were optimized and simulated using ^{192}Ir and ^{169}Yb each as the active core of a microSelectron V2 (Elekta Brachytherapy, Veenendaal, The Netherlands) source model, while IMBT plans were optimized and simulated using ^{192}Ir and ^{169}Yb as the active core of a custom-modeled source combined with 0.8 mm thick platinum shields. For IMBT plans, 16 shield angles were considered per dwell position. Fast mixed integer optimization was used. 1 mm^3 voxel size was used. 10^7 decay events were simulated to ensure Type A statistical uncertainty of 0.4% on the 100% isodose line. Dosimetric indices from dose volume histograms were imported and evaluated for planning target volume (PTV) and organs at risk.

Results
Results evaluated for one patient show that, for the same source model, same number of catheters, and equal PTV D_{90} coverage, IMBT performed with ^{169}Yb reduces the urethral D_{10} by 30.6% and the rectum D_{2cc} by 9.70%. Maintaining the PTV D_{90} coverage, ^{169}Yb based IMBT also allows for a decrease in number of interstitial catheters from 5 to 3 with a urethral D_{10} reduction of 33.8%. In both cases, urethral sparing results at the cost of PTV V_{150} and V_{200} increases as presented in Table 1. Decreasing the catheter number down to 2 created drastic hot spots in the PTV as shown in the last column of the Table 1.

Conclusion
Dynamic-shield IMBT with ^{169}Yb for focal treatment of prostate cancer has the potential to improve tumour coverage while decreasing the dose to organs at risk and number of catheters required, allowing for a more efficient and less invasive treatment, albeit more heterogeneous.

			# Catheters: 5			4	3	2
		Clinical Plan Ir-192 (%)	HDR-BT Ir-192 (%)	HDR-BT Yb-169 (%)	IMBT Yb-169 (%)	IMBT Yb-169 (%) -C5	IMBT Yb-169 (%) -C2,5	IMBT Yb-169 (%) -C1,2,5
PTV	D90	116.0	116.0	116.1	116.1	116.0	116.0	116.1
	V100	98.8	97.4	97.3	97.0	96.8	96.6	96.3
	V150	53.9	58.6	58.7	60.7	61.0	62.2	70.4
	V200	20.2	23.5	21.9	31.9	32.2	33.7	42.1
Rectum	V75	0.5	0.4	0.0	0.0	0.0	0.0	0.0
	D2cc	34.9	34.4	35.0	31.6	31.9	34.1	33.3
Urethra	D10	85.7	87.3	87.0	60.4	59.2	57.6	63.3
	D0.1cc	90.8	90.7	90.8	63.7	62.9	61.7	66.4
	V150	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 1: Dosimetric metrics for one patient treated by using 5 catheters with ^{192}Ir HDR brachytherapy. The yellow column presents the dosimetric indices retracted from the clinical treatment plan. The plan was reoptimized using RapidBrachyMCTPS to yield a ^{192}Ir HDR brachytherapy plan for consistency. The HDR plan was also reoptimized using ^{169}Yb. IMBT plans were then generated using 5, 4, 3, or 2 of the original 5 catheters with the ^{169}Yb source.

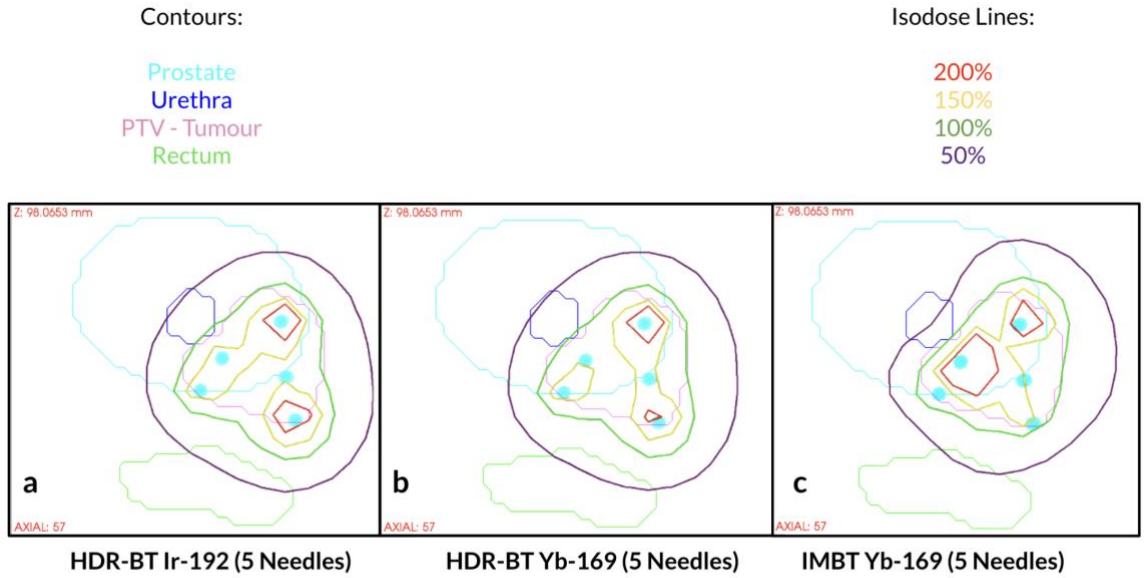

Figure 1: Isodose lines of simulated dose distributions in the axial plane of the patient geometry for a 5 catheter (a) conventional HDR-BT plan using ^{192}Ir, (b) conventional HDR-BT plan using ^{169}Yb, (c) intensity-modulated brachytherapy plan using ^{169}Yb shielded with 0.8 mm thick platinum shields.

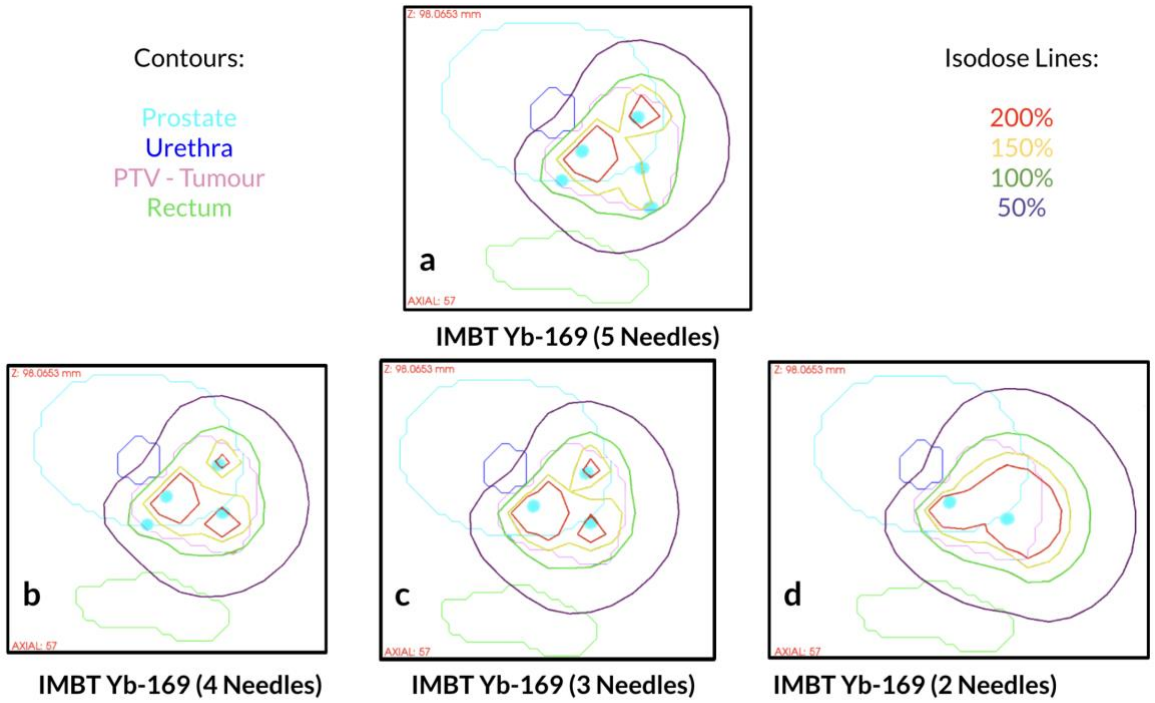

Figure 2: Isodose lines of simulated dose distributions for IMBT treatment plans using (a) 5, (b) 4, (c) 3, and (d) 2 catheters with a ^{169}Yb source using 0.8 mm thick platinum shields placed in the axial plane of the patient geometry.

Poster presentation: Poster Presentation: Skin

PP-0165 Contact X-Ray Brachytherapy for eyelid carcinoma: Efficacy and toxicity in 69 patients

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Purpose or Objective
To assess the tolerance and efficacy of eyelid carcinomas treated using contact X-ray brachytherapy (CXB) 50 kVp.

Materials and Methods
A cohort of 69 consecutive patients was treated between June 2009 and December 2018 with 2 CXB machines (Philips RT 50 and since 2011 Papillon 50). In 26 patients CXB was for a local recurrence. The median age was 79 years. Gender ratio was 1/1. The eyelid carcinoma site was upper lid for 9 patients, external canthus for 6, lower lid for 23 and internal canthus for 31. The carcinoma pathology was basal cell: 52, squamous cell: 10, melanoma: 2, others: 5. CBX treatment was used alone for 12 patients and as adjuvant post resection treatment for 57 patients (R0: 21, R1: 25, R2: 11). Two CXB protocols were used, 42 Gy in 6 fractions over 4 weeks or for R0: 35 Gy in 5 fractions over 3 weeks.

Results
Median survival time was 36 months. Local control was 97% (local failure: 2 patients). Among patients with acute toxicity, 60% had erythema grade 1, 29% erythema grade 2, 25% had conjunctivitis grade 1, 3% conjunctivitis grade and 23% had tear drop grade 1. Late toxicity was seen in 37 patients, 7 of which had persistent eyelid loss, 2 with telangiectasia grade 2, 14 with tear drop grade 1:, 13 with skin whitening and1 with visual acuity decrease: 1. No lens opacity was observed.

Conclusion
CXB for eyelid carcinomas is safe, simple, fully ambulatory and provides high rate of local control with low toxicity in selected patients.

PP-0166 Failure modes and effects analysis guided implementation of 3D printed bolus for skin brachytherapy

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Purpose or Objective
The objective of this study was to determine the risk associated with various steps in skin brachytherapy using failure modes and effect analysis (FMEA). This analysis has previously been conducted for the use of a Valencia applicator which informed our current clinical quality management practices. The department is commissioning the use of custom 3D printed bolus for skin brachytherapy. Repeating and expanding the FMEA will be used to establish novel processes for this new technique which currently do not exist in the literature.

Materials and Methods
The method outlined in the report of task group 100 of the AAPM 2016 (TG100) guidelines was followed with input from a multidisciplinary team including Radiation Oncologists, Physicists, Radiation Therapists and 3D printing experts. The risk priority number (RPN) was determined for each step and fault tree analysis (FTA) was used to determine the root cause of Failure modes related to 3D printed bolus.
The Occurrence (O), Severity (S) and Detection (D) scores were determined for each failure mode. Each score is on a scale between 1 and 10 as done in TG100, with 1 being the lowest risk potential and 10 being the highest.
The potential causes of failure modes were sorted into different categories for the initial tabulation and determination of RPM scores. All the failure modes identified had the potential to cause patient harm and those with the highest RPM underwent a complete fault tree analysis.

Results
Fifteen failure modes associated with the expansion of the current skin brachytherapy service using 3D printed bolus were identified and are shown table 1. The failure modes with highest RPNs were related to a variety of causes most commonly human error and poor documentation.

Table 1
Failure Modes and Effects Analysis (FMEA) for skin HDR brachytherapy steps including 3D printing moulds

Step	Failure Modes	Causes[a]	Effects	O[b]	S[b]	D[b]	RPN[b]
Patient plan created in Mosaiq	Incorrect 3D bolus used in planning	E, PD, S	Major dosimetric and/or geometric error	3	8	7	168
Applicator setup on patient	Incorrect orientation of applicator	E, PD	Major dosimetric and/or geometric error	3	8	7	168
3D Printing	Incorrect patient's mould used	E, PD	Major dosimetric and/or geometric error	3	8	6	144
Independent dose calculation	Incorrect material density used in calculations	S, H	Major/Minor dosimetric error	2	8	9	144
3D Printing	Inhomogeneity in printing	H	Major/Minor dosimetric error	2	8	8	128
3D Printing	Catheter entry/exit holes on wrong side	E, PD	Treatment delayed, geometric error, exposure to contralateral body	5	8	3	120
3D Printing	Incorrect printing material used	E	Major/Minor dosimetric error	2	7	8	112
3D Printing	Multiple channels printed with obstruction	S, H	Major dosimetric and/or geometric error, treatment delayed	4	9	2	72
Scan data transfer/selection	Incorrect file selected	S	Major dosimetric and/or geometric error, treatment delayed	4	8	2	64
3D Printing	Individual channel printed with obstruction	S, H	Partial geometric miss, incomplete treatment delivery	5	6	2	60
Patient Examination	Unintended overlap with previous treatment	PD	Increased toxicity to overlap areas	3	6	3	54
3D Printing	Scaffolding print not removed	E	Major dosimetric error	2	8	2	32
Surface scan	Scan data un-useable	S, E	Delayed treatment, rescan required	5	5	1	25
Surface scan	Scan of incorrect site taken	E, PD	Major geometric error	1	9	1	9
Determination of applicator/mould type	3D printing used where inappropriate	E, PD	Increased workload, increased risk of errors	2	2	2	8

[a] Human/user error (E), software related (S), hardware related (H), plan documentation/instructions (PD)
[b] Occurrence (O), severity (S), detectability (D), risk priority number (RPN), RPN = O x S x D

Conclusion
The fault tree analysis and process maps were used to create the checklists and work instructions for the 3D printing bolus process. By using the RPN for each failure mode, the quality control processes could be designed such that the resources were allocated to minimise patient harm and optimise staff resources. The absence of prior processes allowed for a complete design of all processes without interference from historic tests or checklists.
Using these new processes clinically will allow for a reflection and analysis of the study once patient treatment begins. Having quantitative data used to drive the creation of the initial process will allow for adjustments to be made easily and effectively when limitations are found and RPNs are adjusted to reflect reality.

PP-0167 what about post-operative high-dose-rate brachytherapy in the management of keloids? 5-year outcomes

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Purpose or Objective
Keloid scars are a particularly challenging clinical entity. There is a large variety of management approaches described in the literature. Surgery appears inefficient when underwent exclusively with 45 to 100% of recurrence rate reported. Till now, keloid resection followed by adjuvant radiotherapy appears to be the most efficacious treatment for keloids. However, an optimal protocol for the technique, total dose and fractions of adjuvant radiation for earlobe keloids has not yet been established. We propose to report our experience of immediate monofractionated high-dose-rate (HDR) brachytherapy (BT) after surgery in earlobe keloids.

Materials and Methods
From 2015 to 2020, 8 patients with 10 earlobe keloids were treated with immediate post-operative monofractionated HDR Brachytherapy. Five patients were females, and 3 were males. The mean age was 35-year-old. Four primary keloids and 6 recurrent keloids were examined in this study. The mean length was 3 cm (range 2- 5 cm). keloid tissues were removed before HDR BT treatment. A flexible plastic tube was put in place during the surgical procedure, and the surgical wound was repaired by absorbable suture. BT was prescribed in 5-mm tissue depth and covered the scar in total. Treatment was

optimized using AAPM TG 43. BT was given, within 1 -3 hours of surgery, in a 1 fraction single dose of 8 Gy for the 6 patients treated in 2015 and 10 Gy for the 2 patients treated in 2020. Follow up visits were scheduled at 1 month, 3 months, 6 months, 1 year, and annually thereafter. Therapeutic outcome was assessed in terms of recurrence, acute and late complications, and cosmetic results according to the POSAS scale (Patient and Observer Scar Assessment Scale)

Results
After a follow-up of 5 years and 6 months for those treated, respectively, in 2015 and 2020. No procedure-related complications occurred. No patient was lost to follow-up. No keloid recurrences were detected. Improvement of keloid-related symptoms was noticed in all patients after treatment. Cosmetic results were considered to be good or excellent in all patients according to POSAS scale. Skin pigmentation changes were observed in only 1 patient. No late effects were observed during the 5 years of follow-up.

Conclusion
Our results suggest that immediate post-operative BT may be advantageous in the management of keloids, which is in line with several studies. however, the radiation therapy community is, still, not in total agreement about the optimal dose, time and fractionation. A 8-Gy in a single fraction appears to be a safe and effective protocol for the treatment of earlobe keloids and it is also more convenient and cost effective, but many other studies concluded that this dose regimen is considered suboptimal and discouraged in practice that's why we are conducting a large prospective study with 10 Gy in a single fraction (BED= 20Gy). Thus, this single dose regimen is of utmost importance for the management of keloid scars in developing countries with limited resource like ours.

POSTERS

Poster: Breast

PO-0168 External beam radiotherapy and brachytherapy for partial breast irradiation: dosimetric comparison.

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Purpose or Objective
to compare doses that are absorbed by adjacent organs at risk during the course of adjuvant breast irradiation using interstitial high dose rate brachytherapy (HDRB) or external beam radiotherapy (EBRT).

Materials and Methods
Forty-six women with stage IA-IIA breast cancer were treated in our center by breast conserving surgery with subsequent breast irradiation using HDRB. Preimplantation CT examination was performed to plan catheter geometry. Subsequently, this CT images were used for virtual planning of EBRT.

Results
Both methods were equally effective in delivering the dose to the tumor bed. In comparison with EBRT, the HDRB induces higher doses to organs at risk. In 23 women with left-sided breast cancer HDRB decreased radiation dose to the heart: for EBRT mean (Dmean cor) dose was 0.45% of prescribed dose whereas for HDRB Dmean cor decreased to 0.11%. For left coronary artery Dmean Cat reduced from 1.22% (EBRT) to 0.2% (HDRB); for left anterior descending coronary artery – from 2.8% to 0.39%.

In comparison with external beam radiotherapy, HDRB dramatically reduce radiation exposure to the breast (Dmean decreased from 34% to 0.55%), to the skin and subcutaneous tissues (16.5% vs 0.35%).

Difference for ipsilateral lung Dmean was also in favor of brachytherapy – 1.02% vs 0.14%.

Conclusion
dosimetric comparison of two techniques demonstrated that HDRB outperformed EBRT in terms of radiation doses to organs at risk.

PO-0169 Effects of uncertainty with Strut Adjusted Volume Implant applicator in Japan.

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Purpose or Objective
We started accelerated partial breast irradiation (APBI) after breast conservation surgery using Strut Adjusted Volume Implant (SAVI®) from March 2014. We performed that investigated the dose constraint achievement of the region of interest from the dosimetric index of DVH. Further We examined changes in the interfraction uncertainty.

Materials and Methods
In this study, we examined 50 patients. The DVH parameter was calculated for the initial treatment plan of patients who underwent APBI by SAVI®. We calculated the uncertainty due to displacement of the applicator between fractions from daily CTs. For details, the contouring the object to CT, imprinting of the initial plan was performed, and the change of the DVH parameter due to the interfraction uncertainty of the applicator was calculated. The region of interest to be evaluated is a PTV = "PTV_EVAL" for dose assessment excluding the SAVI catheter, adding 2 mm from the skin side and 0 mm from the chest wall, adding a 3-dimensional margin of 10 mm to the SAVI catheter, Skin = "SKIN", chest wall = "CHESTWALL".

Results
The degree of achievement was "PTV_EVAL" V 90%: 100%, V 150%: 100%, V 200%: 95.3%, "SKIN" D 1 cm^3: 100%, "CHEST WALL" D 1 cm^3: 99.6%. Dose constraints were achievable for "PTV_EVAL" V 90%, V 150%, "SKIN" D 1 cm^3in all cases. The average coefficient of variation in daily CT was "PTV_EVAL" V 90%: 1.0%, V 150%: 7.2%, V 200%: 8.1%, "SKIN" D 1 cm^3: 5.6%, "CHEST WALL" D 1 cm^3: 4.1%. In "PTV_EVAL", the variation of V90% is small, and the influence by interfraction uncertainty is considered to be small. However, the variation was increased at a higher dose region. "SKIN" was more variant than "CHESTWALL".

Conclusion
From this study, deviations in dose constraints were observed in several cases, but it is suggested that the achievement of dose constraint in SAVI was good in most cases. The interfraction uncertainty in daily fluctuation of applicator was estimated to be about 4% for PTV and about 3% for OARs.
Therefore, it is considered that effects of interfraction uncertainty with SAVI®applicator can be estimated to be about 5%.

PO-0170 Impact of risk factors for long-term breast recurrence of APBI with interstitial HDR brachytherapy

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Purpose or Objective
Accelerated Partial Breast Irradiation (APBI) with multicatheter interstitial brachytherapy (MIBT) is a standard treatment for early invasive breast carcinoma. Five-year results are excellent. But few papers arrive at ten-year of follow-up. We review our experience at long-term to know if some risk factors influence the recurrence rate in the breast.Accelerated Partial Breast Irradiation (APBI) with multicatheter interstitial brachytherapy (MIBT) is a standard treatment for early invasive breast carcinoma. Five-year results are excellent. But few papers arrive at ten-year of follow-up. We review our experience at long-term to know if some risk factors influence the recurrence rate in the breast.

Materials and Methods
We have reviewed 66 women treated with conserving surgery and APBI between 2003 and 2013. Median age was 70 years old (46-92). Six cases (9%) were pT2, 11% pT1a, 38% pT1b y 42% pT1c. Four cases had lymph node involvement, pN1a (3), pN1mi (1). 80% had invasive ductal carcinoma and 13.6% invasive lobular carcinoma. Positive hormonal receptors (HR) were 88%, 8 cases with negative receptors (12%), 5 triples negatives (7.5%) y 12 c-ErbB2+ (18%), but no FISH confirmation was available. Implants were ultrasound guided with a median of 12 plastic tubes (7-17) in three planes. CT scan was used for planning. A dose of 4 Gy x 8 fractions was the most common scheme (86%), and 4.3Gy x 7, during 4-5 days, with HDR brachytherapy. Adjuvant chemotherapy was used in 9%, and hormonal treatment in 84%. Transtuzumab was not available. Kaplan–Meier curves were used for survival.

Results
With a median follow-up of 121 months (35-197), 6 patients suffered a recurrence in the breast, 3 in the same quadrant and 3 in other quadrants, due to second malignancies. One of them was treated with a second APBI. Breast recurrence at 10 and 12 years was 3% and 6.2%. For 63 low-risk cases (excluding 3 cases of extensive intraductal carcinoma not suitable for APBI), breast recurrence was 1.6% at 10 and 12 years. The difference between positive hormonal receptors vs negative was significant (p= 0.002), 0 and 3.6% for positive HR vs 25% for negative HR at 10 and 12 years. Triple negative cases had 20% of recurrences. Two cases out of 6 of pT2 recurred with breast recurrence rate of 16.7% at 10 and 12 years (p=0.04). Only one case luminal A recurred at 13 years. Cases with axillar positive nodes, or G3 had no relapse. Cosmetic results were good or excellent in 87,7% with local fibrosis as the most frequent late complication.

Conclusion
Interstitial APBI is effective at long-term of follow-up with very low rate of breast relapse. In our experience, EIC+, negative HR, and pT2 should not be managed with APBI. Patients with C-erbB2 cannot be evaluated as long as the current anti-HER2 treatment was not used at that time. Luminal A cases have 100% breast control at 12 years.

Poster: Gynaecology

PO-0171 Intraoperative Brachytherapy (HDR-IOBT) in advanced or recurrence gynecologic cancer.

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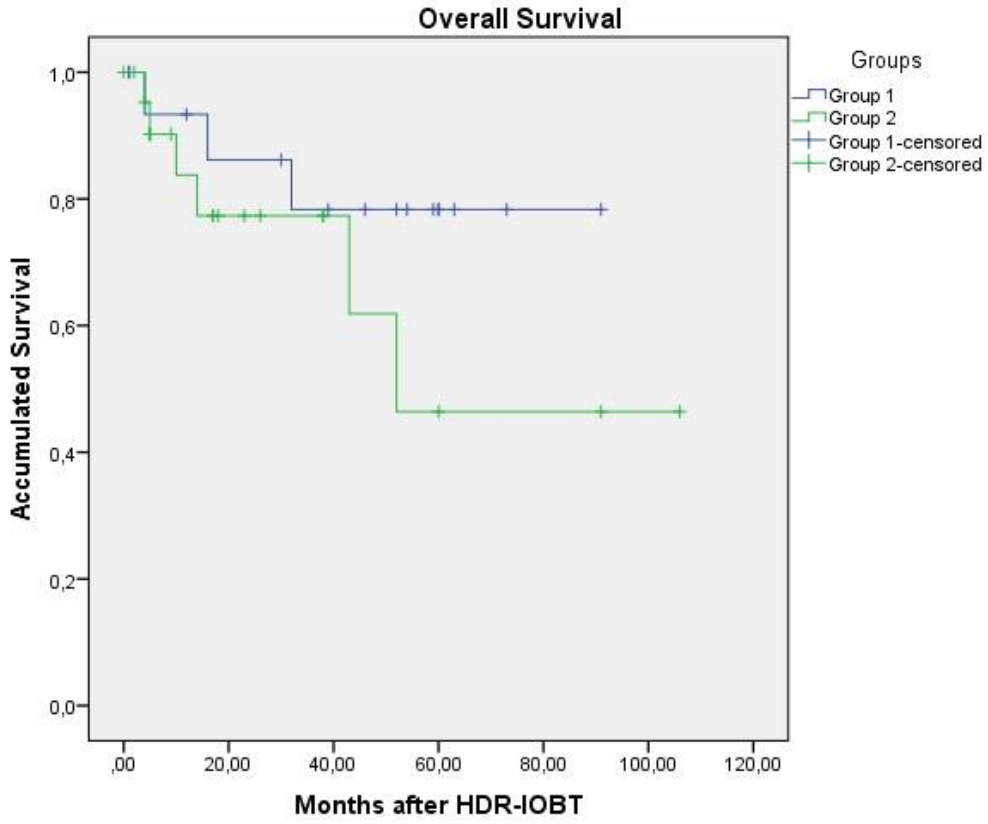
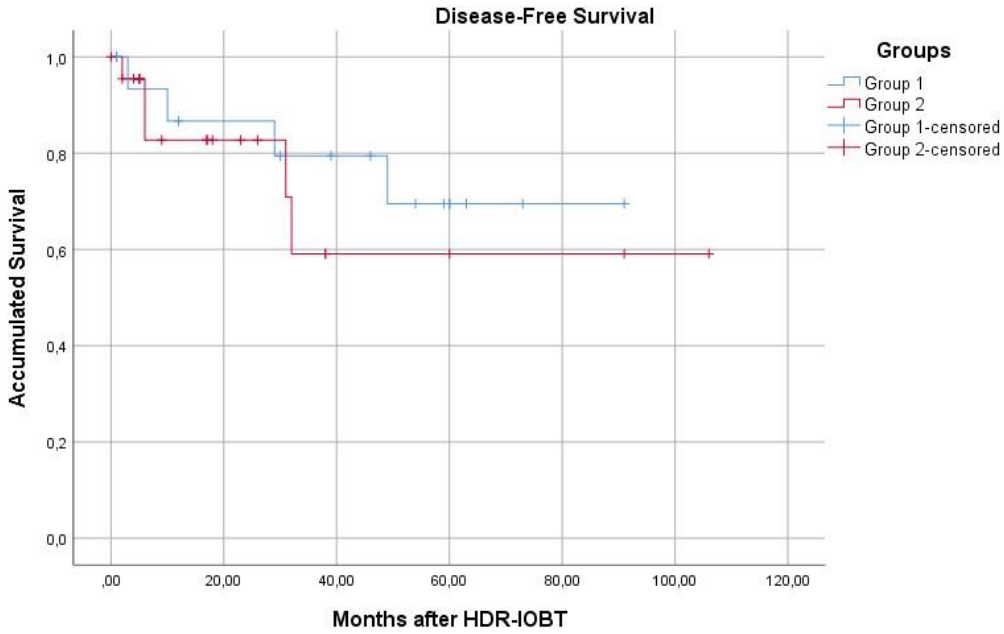
Purpose or Objective
Review of our results in the treatment with surgery and Intraoperative Brachytherapy (HDR-IOBT) in advanced or recurrence gynecologic cancer.

Materials and Methods
This protocol was designed in 2011 and all cases have been approved in the Committee on Gynecologic Tumors. They included two patient groups: Group 1: patients with advanced cervical or endometrial cancer with poor response to Radiation and chemotherapy; group 2: patients with pelvic recurrence of gynecological tumors of any origin. In all CT and MRI was performed, in recurrences also PET to exclude metastatic disease.
The surgical procedure was pelvic exenteration, enlarged cystectomy or rectal resection or both depending on the extent of disease. After extraction of the surgical specimen was confirmed in all cases with intraoperative biopsy the absence of macroscopic residual disease. We put clips in the surgical bed. Subsequently an applicator Fleipbrup Flap® (Elekta) was placed, with an appropriate number of channels to the extension of the bed. After intraoperative planning, a dose of 10 Gy prescribed at 0.5 cm bed depth was administered.
Since Dec 2018, Intraoperative CT was used for 3D-treatment planning.

Results
In the period between October 2011 and May 2020, 40 patients have been included. In group 1, there were 17 patients with cervical or endometrial cancer; in group 2 were 23 recurrences.With a median follow-up of 53 months, disease-free survival (DFS) at 5 years was 64.3%; Group 1: 69.5%; Group 2: 59.1%; 5 years Overall Survival (OS)was 65.5%: Group 1: 78.3%,

Group 2: 46.4%. Grade 3-5 complications were fistula in 3 patients (7.5%): 2 intestinal infections (5%). There were 2 sigmoid stenosis (5%), pubic osteitis in 1patient (2.5%) and Ureteral stenosis in 5 patients (12.5%).





Conclusion

HDR-IOBT associated with pelvic exenteration offers good results of pelvic control and overall survival in patients with gynecologic cancer with a poor prognosis, which usually palliative treatments are offered, although further monitoring is required. However the number of complications, especially fistulas has been important, so we must take it into account for prevention. These results are possible thanks to the multidisciplinary approach to these patients.

PO-0172 Towards real-world quality cervical brachytherapy: how convergence met complexity, taxing capacity

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Purpose or Objective
To assess uptake of curative brachytherapy (BT) practice improvements, in an era of rapid incremental advances for locally advanced cervical cancer (CC), at a large multiteam publicly-funded site, sole provider of CC BT services to a vast Canadian catchment.

Materials and Methods
We reviewed 36-month BT practice trends at our site, distally (01/2013–12/2015; cohort C1) and proximally (06/2017–05/2020; C2). Medical records were mined for patient, disease, and treatment analytics. Cases treated in part elsewhere (C2: 1) and multifraction PDR (C1: 5; C2: 3) or HDR (C1: 1; C2: 5) were excluded. Descriptive statistics were contextualized.

Results
N=80 (median age 51 y [24–83]) were classified to C1; N=98 (median 50 y [25–95]), C2. This unexpected +22.5% caseload increase, step-wise and sustained over 7 y, was coincident with greater clinical stage IIB presentations (+19 cases, p=0.05). With concurrent drop in IB (-30.9%) and stability at higher stages (Table 1), C2 had more “early” locally advanced disease. N+ rates, overall similar, spread differentially: 65% in C1 (30.8% pelvic+para-aortic (PA)) and 69.4% in C2 (19.1% PA, 38.2% pelvic+PA). All had pelvic±PA external beam radiotherapy (EBRT), heterogeneous in C1. Among N+ in C1, only 60% had nodal EBRT boost (51.6% via SIB), 100% in C2 (all SIB). Chemotherapy was given to >90% in both groups, mostly concurrent weekly cisplatin (median 5 cycles [1–6]; >93% had 3+]. By time of BT, CTV-HR volumes were similar (Fig 1). Single PDR BT boost (58 hourly pulses) was mostly MRI-based and volumetrically planned. Majority (80% in C1) intracavitary flipped in C2 to 84.7% added interstitial (IS) component. How IS was utilized did not change (median 3 channels loaded) despite added oblique and freehand IS options in C2. Across time, ring was the preferred (68%) intravaginal accessory over ovoids, multichannel cylinder and lunoids, yet vaginal TRAK (p=0.02) improved in C2. Better attention to this, and other dosimetric parameters (not shown) was expected after release of international guidance recommendations in 2016. CTV-HR D90 and overall treatment time (OTT) did not change.

			Cohort 1	Cohort 2
Patients				
	Median age	*(years [range])*	51 [24 - 83]	50 [25 - 95]
	Clinical stage	*(%)*		
		IB	32.5	22.4
		IIA	10.0	13.3
		IIB	38.8	51.0
		IIIA	1.3	1.0
		IIIB	13.8	10.2
		IVA	3.8	2.0
	N+ location	*(%, among N+)*		
		pelvic-only	69.2	42.6
		PA only	0	19.1
		Pelvic+PA	30.8	38.2
Treatment				
EBRT	Dose fractionation		45 – 50 Gy equivalent, in 1.8 – 2 Gy/fraction	45 Gy, in 1.8 Gy/fraction
	Technique	3DCRT	48.8	0
		IMRT	10.0	0
		tomotherapy	5.0	0
		VMAT	36.3	100
Chemotherapy	Concurrent weekly cisplatin *(%)*		91.3	83.7
	Median # cycles *[range]*		5 [1 - 6]	5 [1 - 6]
BT	MRI-based planning *(%)*		90	100
	Volumetric planning *(%)*		99	100
	IS usage *(%)*		20	85
	Median # of needles loaded *[range]*		3 [1 - 4]	3 [1 - 11]
	Most used intravaginal component *(%)*			
		Ring	68.8	68.4
		Ovoids (conventional)	18.8	20.4
	Mean CTV-HR Vol *(cc)*		39.3 ±28.7	33.0 ±23.0
	Median CTV-HR D90 *(Gy_{10})*		89.6 [55.6 - 122.1]	91.1 [50.3 - 94.9]
	Mean (SD) TRAK *(cGy)*		2.242 ±0.584	2.027 ±0.593
	TRAK in Vaginal component *(%)*		41.4	35.9
	TRAK in IS catheters *(%)*		10.9	13.2
	Median OTT *(days [range])*		45 [38 - 81]	45 [37 - 60]

Table 1. Patient and treatment characteristics of cohorts 1 and 2.

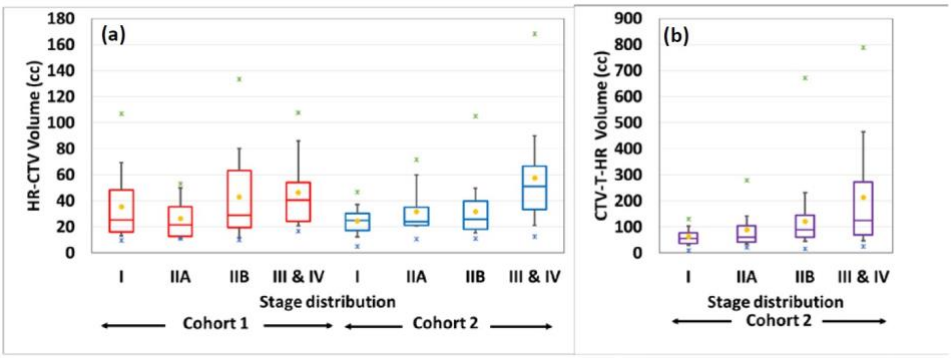

Figure 1. (a) CTV-HR target volume at time of BT (a) for both cohorts, by stage; (b) CTV-T-HR volume at EBRT for cohort 2, by stage (data unavailable for cohort 1, inconsistent guideline-informed contouring at that time). Across time periods there is sustained clustering of small CTV-HR volumes at time of BT, with little variance across stages IB through IIB. Regression from CTV-T-HR to CTV-HR is suggested.
The lower boundary of the box indicates the 25th percentile and the upper boundary, the 75th percentile. The solid line and dot inside the boxes represents the median and mean, respectively. Whisker ends represent the 10th (bottom) and 90th (top) percentiles. Maximum (green) and minimum (blue) values are shown by "✳".

Conclusion
Convergent CC EBRT/BT practices were observed in short time, to align with international standards. Rapid adoption of complex BT techniques was congruent with unexpected change in CC casemix and caseload, with no detriment to target dose nor OTT. Stable clustering of BT target volume across stages suggests pre-BT chemoEBRT to be an equalizer, laying favorable conditions for better-optimized BT, with promise of better outcomes. Quickly devolving pattern of CC presenting to RT, largely predating pandemic-related cancer care disruptions, is concerning in an integrated health system, and requires study.

PO-0173 Needle localization in MRI-guided gynecological brachytherapy using a PETRA sequence

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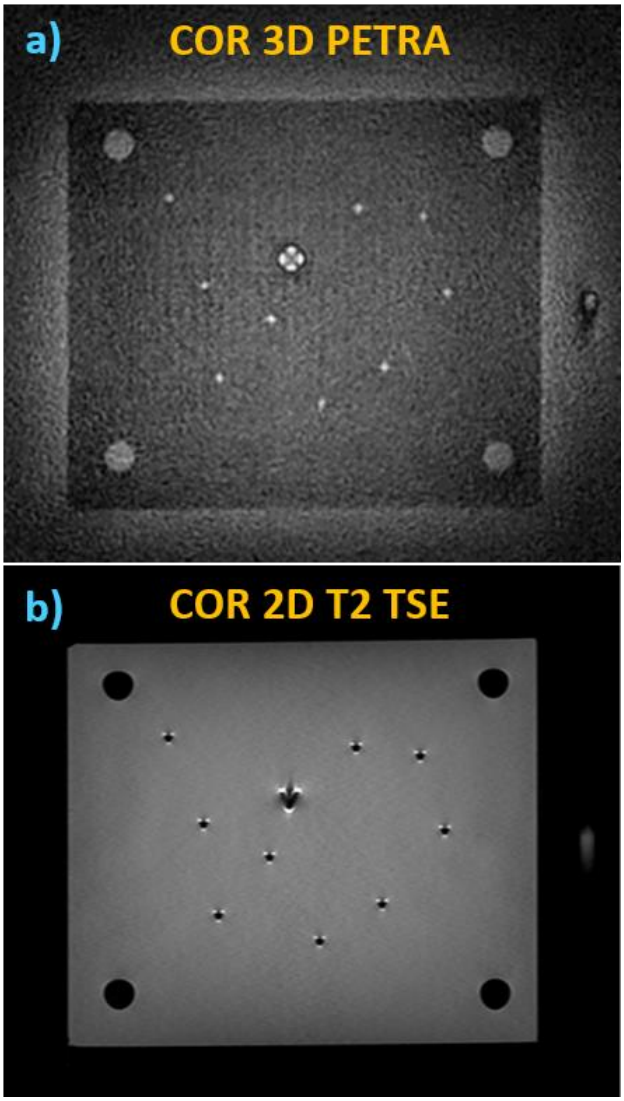
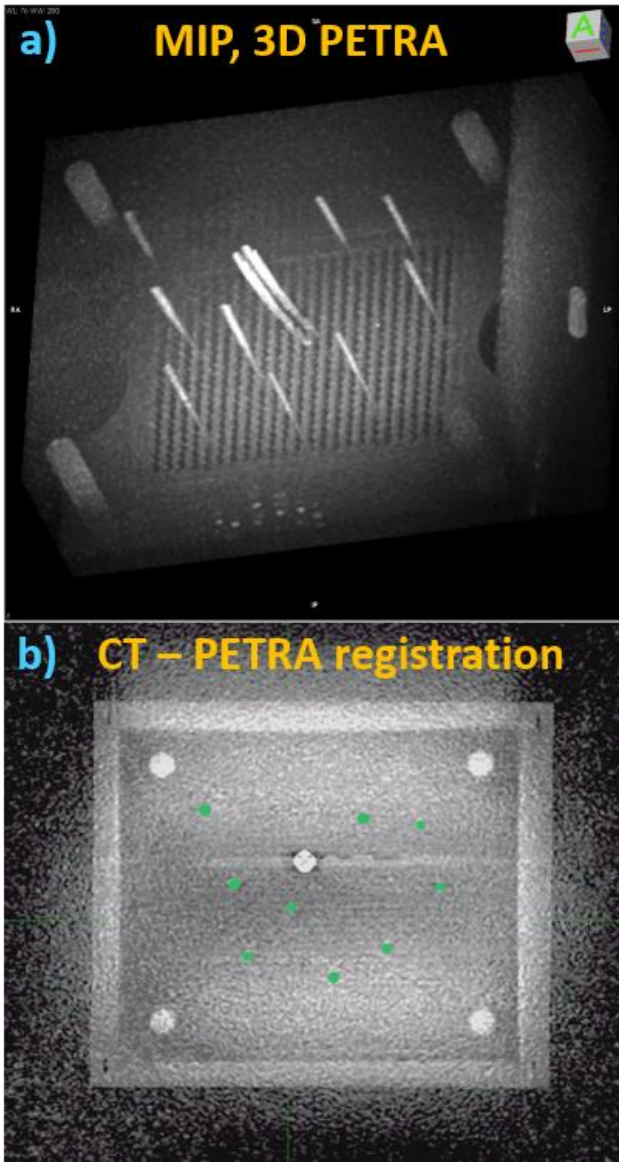
Purpose or Objective
Needle localization in MRI-guided brachytherapy is challenging due to various uncertainties, including lack of signal on standard MRI. Therefore, in the clinical setup CT images are utilized for needle localization, while MR images are used for target and organs at risk delineation. In this phantom study, we used a Pointwise Encoding Time Reduction with Radial Acquisition (PETRA) sequence for needle detection using MRI only. Accuracy of needle localization was assessed by comparison to gold standard CT images.

Materials and Methods
A gelatin-based phantom with 10 parallel plastic ProGuide Sharp Needles 6Fx294mm (Elekta Brachytherapy, Netherlands) was imaged in a 3T SIEMENS Vida simulator using a spine matrix array coil topped with a Qfix Insight board, and a Body 18 long coil. The phantom consisted of a plexiglass box featuring an orientation verification marker and two identical templates with 2mm diameter holes. Nine parallel empty needles and one with a metallic trocar for metal artifact observation were placed in the templates. Isotropic 0.82 mm edge length voxels were acquired with a coronal 3D PETRA (TR\TE\TI 3.32\0.07\100 ms, FOV 289*289 mm^2, BW 400 Hz/px, 100000 radial views). 2mm thick coronal T2-weighted Turbo Spin Echo (TSE) slices (TR\TE 3840\102 ms, FOV 199*199 mm^2, matrix 736*736, BW 200 Hz/px) were acquired for comparison. The phantom with needles was subsequently scanned on a helical CT (250 mA, 120 kV, 1.25 mm slice thickness). Needles were localized in the Oncentra Brachy (Elekta Brachytherapy, Netherlands) treatment planning system using both CT and MRI. CT images were registered to PETRA images, and needle positions were evaluated.

Results
Plastic needles showed positive signal on PETRA (acquisition time 6min 20s) and less distortions than on conventional TSE images (example comparison at a similar slice location on picture below). The metal artifact extended symmetrically around the trocar on PETRA, contrary to its contorted shape on TSE.



Needle localization using PETRA MRI only was uncomplicated (3D representation using Maximum Intensity Projection (MIP) in a) below). The observed position difference in PETRA and CT images was < 1 mm for the needle tip in all 10 needles, and < 0.5° for the deflection angle, making this level of accuracy clinically acceptable. CT to MR registration (example registered slice showing good agreement of needle positions in b) below) did not reveal any deformation of empty needles on PETRA, suggesting that these MRI images can be used for treatment planning.



Conclusion
We demonstrated that plastic needles used in gynecological brachytherapy can be imaged with submillimeter accuracy using a manufacturer provided PETRA sequence in acceptable scanning time. Future clinical workflow would include registration of PETRA with MR sequences of the same session utilized for segmentation. The results of this work reveal the potential to ultimately replace CT for needle localization and treatment planning in MRI-guided brachytherapy.

PO-0174 Cervix cancer treated with PDR brachytherapy boost

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Purpose or Objective
To review the results of patients with cervical carcinoma treated with a PDR brachytherapy boost at a single institution. Outcomes including factors were analysed using the Kaplan-Meyer method and Cox proportional hazard models and t-test. Complication were recorded

Materials and Methods
Retrospective review of all patients with cervix cancer who had PDR brachytherapy between 2014 to 2017

Results
There were 202 patients. All had external beam radiotherapy with concurrent chemotherapy prior to brachytherapy. Staging included CT 202, PET 193, MR 113. PDR alone was used in 186 as a single insertion, and 16 had both PDR and HDR. The brachytherapy applicators used were tandem and ovoids, there were no cases where interstitial insertion was used. Brachytherapy was planned using CT. Outcome At the 3-year endpoint using Kaplan-Meier curves, the survival (OS) was 76%,

disease specific survival (DSS) 77%, and relapse free survival (RFS) 57%, and central pelvis failure free survival was 92%. There was no difference in outcome by histology squamous (163) vs adenocarcinoma (38) or grade. The main factors affecting outcome adversely were M stage, N stage and large primary (advanced T stage, vaginal extension or large diameter). Age was an adverse factor for OS and DSS but not for RFS. The median EBRT dose was 50.4Gy [45-59.4] with median fractions of 28. For those with PDR alone the median PDR dose to point A was 28Gy, with quartiles <24Gy, 28Gy, 33Gy, > 33Gy. Those treated with high PDR dose to point A had a higher RFS which may reflect bulk of disease. Combining EBRT and PDR using biological equivalent EQD2 median dose 82Gy with quartiles <75, 75-<82, 82->90, and >90. The was a significant correlation between EQD2 and OS, DSS, and RFS with the higher dose having a worse tumour outcome, which may be due to the higher dose was used in more advanced disease. The median time between start of EBRT and PDR was 53 days. There was no significant difference in outcome for those >56 days. The presence of disease at the PDR insertion had a worse outcome than those with no macroscopic disease at PDR. Complications There were 2 acute deaths, one massive pulmonary embolism and one had recurrent pelvic abscesses following perforation. Other acute events were uterine perforation 3; 1 with pelvic abscess and 2 with no subsequent adverse effect; displacement of applicator 3, fever 3, severe pain 3. The reasons for multiple insertions with HDR in addition to PDR included pain control during admission, fever, and electively to shorten treatment. There were 16 cases with fistula 5 at diagnosis (of those 2 subsequently had exenteration with no residual malignancy). Subsequent to RT 11 developed a fistula, 8 vesico-vaginal, 2 recto-vaginal and 1 recto-pelvic abscess. Other late effect includes ureteric obstruction requiring stents 5, haematuria 7 (1 severe), rectal bleeding 11, vaginal stenosis 48. Thus 17 (8.4%) had a major late complication and 2 (1%) had major acute complications. There was a correlation between late urological complications and brachytherapy dose.

Conclusion
This is a large series of 202 cases of cervix cancer treated with PDR brachytherapy boost. The main sites of relapse were distant or elsewhere in the pelvis and not in the central pelvis. The major complication (acute and late) rate was 9.4%. The total biological dose EQD2 median of 82Gy is at the lower range of guidelines.

PO-0175 Deformable registration for HDR Cervical case: Dose accumulation for multiple deformation techniques

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Purpose or Objective
Dose specifications to the high risk clinical target volume (HRCTV) and the organs at risk (OAR) are based on summation of dose volume parameters using the equivalent dose in 2Gy fractions (EQD2) methodology for ring and tandem high dose rate (HDR) treatments. A more robust dose accumulation to the OARs requires a practice that involves nonrigid registration of the imaging datasets and dose propagation. The feasibility of deformable registration to assess dose accumulation to the HRCTV and OARs has been studied in this retrospective analysis.

Materials and Methods
Ten sequential patients from a single institution who received HDR treatments to the cervix using the ring and tandem applicator were reviewed retrospectively for dose accumulation to the HRCTV, bladder, rectum and sigmoid. Patients in the study received 5 fractions to deliver a combined external beam and brachy dose of greater than 85Gy EQD2 to the HRCTV while honoring the 2cc OAR dose constraints. The treatment plan was generated for each fraction based on CT images on which the HRCTV and the OARs were contoured. The CT dataset from the first fraction was used as the primary dataset and subsequent treatment planning studies were deformed and registered to the first fraction by two methods. In the first method, the volume of interest that encompassed the OARs was deformed based on the CT densities. In the second method, the deformation was driving by aligning the ring and tandem applicator. The quality of the deformation was assessed visually by tissue overlay methods and deformable warp maps. Additional metrics of Dice Similarity Coefficient to evaluate overlap and Mean Distance to Agreement to evaluate the contour edges were recorded for the applicator, HRCTV and OARs. Dose from each fraction was accumulated on to the CT images from the first fraction and the 2cc dose indices for the OARs calculated.

Results
There was no discernible difference between the two deformation techniques. The average sum dose to the bladder, rectum and sigmoid as compared to the clinical D2cc was 0.95$\pm$0.2, 0.93$\pm$0.2 and 0.98$\pm$0.2, respectively. There was no significant difference in the dose sum from the deformation techniques. Large rectal and bladder changes led to poor Dice Similarity coefficient (0.4-0.9) between the fractions.

Conclusion
The structure mapping of bladder, rectum and sigmoid with deformable registration is acceptable and the dose accumulation show results similar to the clinically determined dose metric. The large dose gradients in brachytherapy results in high doses close to the applicator and the deformation of the datasets is minimal in this region. The larger deformation changes in the OAR occur farther away from the applicator. While this has an effect on the overall volume of the structure, these sections receive less clinically relevant dose and does not contribute to changes in the high doses region. Therefore, dose accumulation with deformable dose propagation yields results similar to clinical summed 2cc EQDs.

PO-0176 Clinical outcomes of cervical cancer with CT-based image-guided brachytherapy

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Purpose or Objective
Three-dimensional image-guided brachytherapy (3D-IGBT) has become the standard therapy for patients with cervical cancer. MRI-based IGBT provides better soft tissue visualisation for accurate delineation of target volumes, but more expensive, logistically difficult and time-consuming, compared with CT-based IGBT.
This retrospective study evaluated the clinical outcomes of cervical cancer patients treated with CT-based IGBT in an university hospital in Hong Kong.
Materials and Methods
Consecutive cervical cancer patients, with stage IB-IVA, treated with external beam radiotherapy (40 Gy/ 20 fractions) then CT-based IGBT at the dose of 7 Gy × 4 fractions to the High-Risk Clinical Target Volume (HR-CTV) in January 2014 to December 2019, were analysed. All patients had pre-brachytherapy MRI. 3-year local control rate (LC), disease-free survival (DFS) and overall survival (OS) were calculated. G3-4 late adverse events (CTCAEv4.0) were reported.
Results
Total 135 patients, median age 56 years old (range 26-83), were included. 110 patients (81.5%) had squamous cells carcinoma. FIGO stage distribution was IB/IIA: 14.8%, IIB: 54.8%, IIIA-IVB: 30.4%. 104 patients (77.0%) received concurrent chemotherapy. 55 patients (40.7%) had pelvic lymph node (PLN) involvement. 3 patients (2.2%) had para-aortic lymph node (PAN) involvement and received extended field radiotherapy. The mean volume of HR-CTV at first-brachytherapy was 41.9cm^3. Mean D90 HR-CTV was 84.31Gy±13Gy. Mean D2cc rectum, sigmoid and bladder were 65.5Gy, 65.6Gy and 82.2Gy respectively.
Median follow-up was 37.2 months. 27 patients (20.0%) had persistent disease at the time of 4th brachytherapy. Only 3 (2.2%) had positive cervical biopsy 8 weeks after completion of IGBT and required salvage surgery.
The 3-year actuarial LC, DFS and OS were 95.7%, 86.2% and 93.8% respectively. 22 patients (16.3%) had either local or distant failure at time of first relapse. 7 patients (5.2%) had local failure; none had only PLN failure; 2 (1.5%) had only PAN recurrence; 19 (14.1%) had distant failure. Of the 19 patients (14.1%) with distant failure, 10 (7.4%) had synchronous local and distant failure. Significant correlations were found between histology and local recurrence, between volume of HR-CTV and distant failure, and between mean D90 HR-CTV and OS.
For G3/4 late adverse events, 3 (2.2%) had proctitis, 1 (0.7%) had cystitis and 1 (0.7%) had pelvic insufficiency fracture.

	No. of patients	Percentage	Median time of onset (month)	Range of time of onset (month)
Local recurrence	7	5.2%	11.4	5.6-18.3
Pelvic LN recurrence	0			
Para-aortic LN recurrence	2	1.5%	9.6	4.7-14.4
Distant recurrence	19	14.1%	11.1	1.4-29.3

Conclusion
CT-based IGBT offered excellent local and regional control rates for cervical cancer patients. Comparable 3-year LC, DFS and OS can be achieved as in other studies with MRI-based IGBT.

PO-0177 A new software for designing patient-specific sleeves for the Montreal split-ring applicator

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Purpose or Objective
To introduce and evaluate a new software for designing patient-specific 3D-printed combined intracavitary/interstitial (IC/IS) brachytherapy applicators by modifying build-up caps (sleeves) of the commercial CT/MR split-ring applicator (Eckert & Ziegler BEBIG).

Materials and Methods
A DICOM dataset was exported from Oncentra TPS (Elekta) containing CT images of the CT/MR split-ring applicator (5mm build-up cap), RT-structure set and RT-plan with 6 additional source-trajectories optimized in straight and oblique directions with respect to the applicator's tandem. The dataset was imported into Adaptiiv's brachytherapy software (Adaptiiv Medical Technologies) where a CAD model of the widened sleeves were co-registered to the original 5mm sleeves. After co-registration was confirmed in all 2D viewing planes, all 6 source-trajectories were subtracted from the CAD model, forming needle tunnels with user-defined diameters. Using the same dataset, the trajectories were also subtracted into notches corresponding to the ''Venezia'' (Elekta) applicator system for needle guiding-tube fixation. The output of the software were two RT-structures and two STL files corresponding to the patient-specific design of the Montreal split-ring sleeves with subtracted needle tunnels and notches respectively. Spatial fidelity of the subtracted tunnels and notches were evaluated on RT-structures and on rendered STL files of the designed sleeves. Angles of the subtracted tunnels and notches were evaluated on the RT-structure of the designed applicator with respect to the reference geometry in the

TPS. CloudCompare software was used to compare surface distances of the applicator RT-structure and its corresponding STL. Time was estimated as necessary to complete the software workflow.

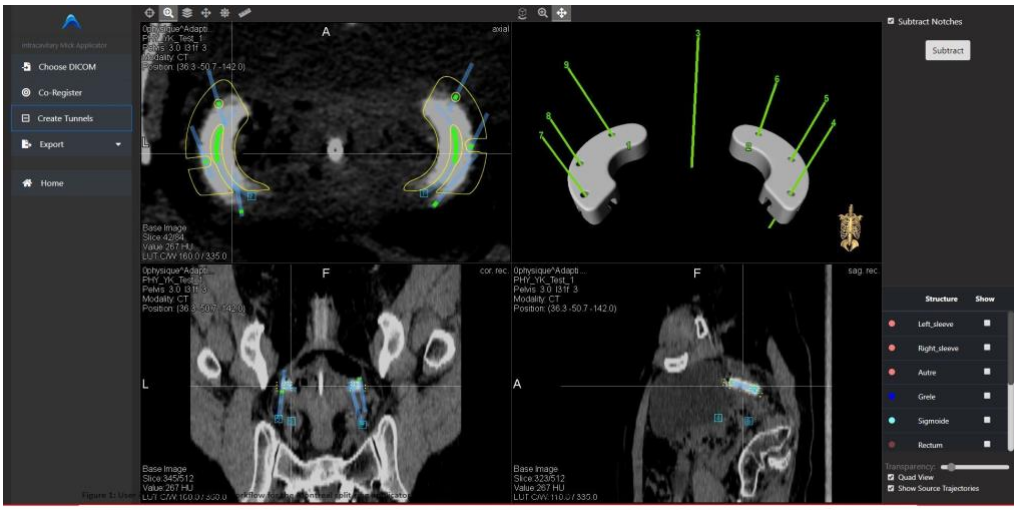

Figure 1: User interface of the design workflow for the Montreal split-ring applicator within Adaptiiv's brachytherapy software.

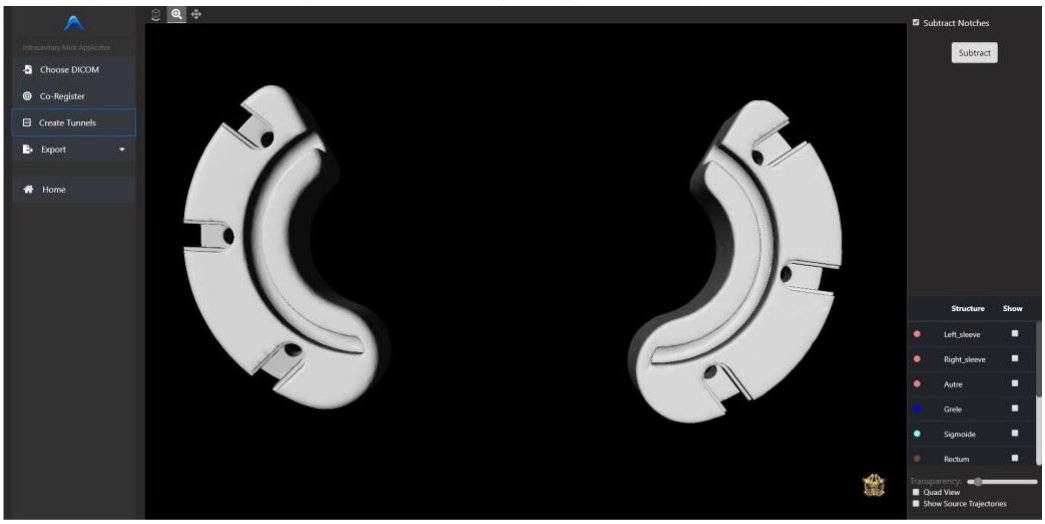

Figure 2: 3D-view of the personalized design of Montreal split-ring sleeves with subtracted needle notches

Results

Diameters and inter-trajectory distances (ITDs) of generated needle tunnels and notches were evaluated on the RT-structure of the designed applicator and found to be within ± 0.1mm with respect to the user input while diameters and ITDs of the needle tunnels and notches corresponding to the STL file were found to be ± 0.2 mm with respect to the user input. CloudCompare software demonstrated submillimeter agreement between surface distances of the DICOM-RT applicator structure and the corresponding STL file. The tunnel angles measured in sagittal and coronal planes on the RT structure of the designed applicator matched the source-trajectory angles created in the TPS within ± 0.2 degrees. The workflow in the Adaptiiv software took approximately 5 minutes to complete and did not require any specialized 3D-modelling skills.

Conclusion

The novel technology and workflow presented provide a practical approach to efficient and accurate design of patient-specific needle tunnels for the novel 3D-printed Montreal split-ring applicator for adaptive IC/IS GYN brachytherapy.

PO-0178 Feasibility and Outcomes for Cervical Cancer Patients Treated with Hybrid Brachytherapy Applicators

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Purpose or Objective

The Vienna and Venezia (Elekta) are hybrid intracavitary/interstitial brachytherapy (BT) applicators for cervical cancers unsuitable for intracavitary BT alone to improve target coverage or reduce critical organ dose. There is limited outcome data with the use of these applicators outside published experience of the EMBRACE group. We report feasibility and early outcomes with the use of these hybrid applicators at our institution.

Materials and Methods
A total of 256 patients with cervical cancer treated with definitive chemoradiation followed by BT boost were identified, of whom 61 patients were treated with BT boost using hybrid BT applicators from November 2011 to December 2019. Indications for hybrid applicator use were involvement of the vagina in 10 patients (16%), residual central or parametrial disease in 46 patients (75%), and a narrow introitus in 5 patients (9%). Toxicities were graded using the CTCAE v4.0. Outcomes were assessed with the Kaplan–Meier method.

Results
Median follow-up was 16 months (IQR 9–32 mos). Median HRCTV volume was 31.6 cm 3 (IQR 25–48 cm 3). Median HRCTV D90 was 86.1 Gy (IQR 84.3–88.0 Gy). In 54 patients with follow-up PET/CT at 3 months, complete initial imaging response locally was seen in 46 patients. Estimated 12-month Kaplan–Meier overall survival, locoregional control, distant control, and recurrence-free survival estimates were 86.9%, 80.6%, 73.8%, and 65.9%, respectively. The 12-month incidence of Grade 3+ GI/GU chronic toxicities was 5.7%, consisting of vesicovaginal fistula, rectovaginal fistula, and ureterovesical fistula.

Conclusion
Our single-institution experience supports the use of the hybrid applicators for definitive treatment of locally advanced cervical cancer as an alternative to traditional BT applicators when clinically warranted based on extension of disease or patient anatomy, while also sparing use of conventional template-based interstitial BT and allowing for MRI-based planning. Use of hybrid applicators is feasible with adequate coverage of disease in the vagina and parametrium, consistent with other published literature. Early clinical outcomes show translation of dosimetric results into favorable responses and additional follow-up will clarify long-term outcomes in these patients.

PO-0179 Hypnosedation for endocavitary uterovaginal applications: a pilot study

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Purpose or Objective
Implantations for uterovaginal brachytherapy are usually performed under general or spinal anesthesia, which are not without risk. As it is a rather short procedure and since post-operative pain is minimal, hypnosedation was proposed to selected patients requiring endocavitary applications as part of their routine treatment. Need for rescheduling to spinal/general anesthesia and patients satisfaction were examined.

Materials and Methods
Consecutive patients requiring intracavitary uterovaginal brachytherapy from January to October 2019 were included if they accepted the procedure. A premedication based on antalgics, antispasmodics and anxiolytics was systematically administered. The procedure was conducted under constant cardiovascular monitoring. Hypnosedation was based on an Eriksonian technique. The procedure was immediately interrupted if the patient requested it, in cases of extreme anxiety or pain. Procedure was in that case rescheduled with a “classical” anesthesia technique.

Results
20 patients were included. 4 patients had to be converted towards a general anesthesia : one because of a fibroma on the probe’s way and three young patients with a very anterverted/retroverted uterus that was painful at every mobilization. Mean and max pain scores during implant were 2.9/10 and 5.1/10 respectively. The most painful manoeuver was cervical dilation for 45% of the patients, followed by mould insertion in 40% of cases. Anxiety scores were low : 2.3/10 and 85% of the patients declared that hypnosis helped them relax. 90% of the patients would recommend the technique to other patients. No procedure-related complication occurred.

Conclusion
With a 80% success rate, one can conclude that uterovaginal brachytherapy implantation under hypnosedation is feasible and received a high satisfaction rate from the patients. This technique may reduce overall treatment time in a context of difficult access to the OR and to anesthesiologists, while reducing anesthetic drugs resort and post-operative nausea.

PO-0180 Impact of hybrid brachytherapy in cervical cancer: A survival and toxicity profile assessment

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Purpose or Objective
Advancements in role of imaging in brachytherapy in treatment of cervical cancers has seen further improvement in therapeutic ratio. We assessed the impact of combined interstitial and intracavitary brachytherapy in locally advanced cervical cancer in relation to survival outcomes and toxicity profile.

Materials and Methods
A total 125 patients, histopathologically diagnosed as cervical cancer and staged as per FIGO staging, were enrolled for the procedure. After completing external beam radiation therapy (Median dose 50Gy), patients were evaluated for brachytherapy which involved CT based hybrid interstitial-intracavitary brachytherapy using Iridium-192 source and a novel template to facilitate therapy. Parametrial extent of the disease in these patients was judged to exceed the coverage limit

of intracavitary brachytherapy alone. Clinical feasibility, treatment outcomes and toxicity profile were assessed. The patients were followed up as per the institution protocol.

Results
There were 57 patients (45.6%) in FIGO stage IIIB and 50 patients (40%) in stage IIB. The median EBRT dose was 50Gy and Brachytherapy dose received was 23Gy. The overall median EQD2 was 85Gy. After a median follow up of 30 months (Range 10 -50 months), local control rate was 95.2% and 11 patients (8.8%) developed distant metastases (9-Lung, 2-brain). Of the distant metastases, 7 were Stage IIIB and 4 had IIB disease. The median total treatment time was 69 days. No adverse events were caused by the procedure. Grade 2 and 3 rectal and bladder toxicities were 7.9% and 2.4% and 5.66% and 2.4% respectively. Disease free survival probability after 1 and 2 years was 94.1% and 93.53%. On multivariate analysis, stage of disease IIB, treatment duration less than 49 days and EQD2 of more than 85Gy were found to improve the rate of local recurrence and distant metastases.

Conclusion
Hybrid brachytherapy with the novel template has shown to improve the therapeutic ratio in LACC by enabling a tumour specific dose escalation leading to improved survival outcomes without adding treatment related late morbidity. The procedure was more conformal with improved dosimetry and clinical outcomes.

PO-0181 Comparison of vaginal doses and toxicities between two brachytherapy applicators in Carcinoma Cervix

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Purpose or Objective
The aim of the study was to compare the dose to vaginal points and vaginal toxicity between two intracavitary tandem and ovoid applicators used for HDR brachytherapy in Carcinoma Cervix

Materials and Methods
Carcinoma cervix patients planned for radical radiotherapy from January 2019 till August 2019 were randomly allocated for brachytherapy treatment with either Manchester style or Fletcher style applicator. All patients received an external beam radiotherapy dose of 50Gy in 25 fractions. HDR Brachytherapy was administered using CT based planning. All patients received a dose of 7Gy to Point A one week apart for a total of three fractions. All patients were treated using fixed bladder and rectum protocol for brachytherapy. For vaginal dose reporting, the PIBS points (PIBS, PIBS+1, PIBS+2, PIBS-1, PIBS-2) and dose to vagina at 3, 6, 9 and 12 o clock position at 5mm from the surface of ovoids was compared between the two applicators. Vaginal toxicity was graded using CTCAE version 4.2

Results
A total of 30 Carcinoma cervix patients were randomly allocated to receive intracavitary brachytherapy with either Manchester style or Fletcher style applicator. All patients received a total Point A dose of 80Gy EQD2. The mean vaginal reference length for patients treated with Manchester style applicator was 4.3 cm and for patients treated with Fletcher style applicator was 4.4 cm. The total median EQD2 doses at PIBS-2cm, PIBS-1cm, PIBS, PIBS+1cm and PIBS+2cm using Manchester style applicator were 10.3Gy (2.3-26), 30Gy (14-37), 58.4Gy (35-69), 86Gy (63-128) and 104.6Gy (82-202) respectively. The total median EQD2 doses at PIBS-2cm, PIBS-1cm, PIBS, PIBS+1cm and PIBS+2cm using Fletcher style applicator were 5.6Gy (2-12), 11.3Gy (5-25), 52Gy (45-61), 62.4Gy (49-69) and 66.2Gy (54-79) respectively. The dose delivered to all vaginal points was significantly higher with Manchester style applicator ($p<0.05$). The median doses to vagina at 3, 6, 9 and 12 o clock position (5mm from ovoid surface) using Manchester style applicator were 98Gy, 106.5Gy, 93.4Gy and 114.8Gy and using Fletcher style applicator were 94.2Gy, 79.6Gy, 89.4Gy and 82Gy respectively. At a median follow up of 18 months (14-22 months), the incidence of Grade 1 and 2 vaginal toxicity in patients treated with Manchester style applicator was 26.6% and with Fletcher style applicator was 20%

Conclusion
Manchester style applicator gives higher dose to the vagina as compared to Fletcher style applicator in Carcinoma Cervix brachytherapy. The choice of using a particular applicator depends on the residual disease at the time of brachytherapy and patient anatomy.

PO-0182 Excellent Outcomes with CT-Based HDR Brachytherapy for Locally Advanced Cervical Cancer

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Purpose or Objective
To report clinical outcomes of CT-based image guided brachytherapy (IGBT) technique for treatment of cervical cancer in a center without available MRI procedure suite. Although MRI-based IGBT is an attractive option to improve tumor delineation, routine use of MRI with each brachytherapy treatment is not feasible due to cost and accessibility for many radiation departments.

Materials and Methods
We reviewed 114 women with FIGO stage IB1 to IVB (updated 2018 staging) cervical carcinoma diagnosed between 2011 and 2019 and treated with definitive EBRT with or without concurrent chemotherapy followed by HDR IGBT. The EBRT dose to the pelvis ranged between 40 and 60 Gy (median 45 Gy). Majority (95%) of patients received concurrent chemotherapy. Transabdominal ultrasound guidance was used for applicator placement. All patients underwent a CT simulation at each implantation. HR-CTV, encompassing visible tumor and entire cervix, and OARs (bladder, rectum, sigmoid) were contoured

on the simulation CT. When available, MRI obtained prior to CT simulation was fused to assist with tumor delineation. The dose was prescribed to HR-CTV to achieve a D90 equal or greater than the prescription dose. Brachytherapy dose was converted to the EBRT/IGBT sum 2-Gy equivalent dose (EQD2) dose using the linear quadratic model (a/b = 10 for HR-CTV and a/b = 3 for OARs). The total combined EBRT and brachytherapy EQD2 was calculated. OS and PFS outcomes were estimated using Kaplan-Meier method with Cox regression analysis. Acute side effects were evaluated using CTCAE v5.0 criteria.

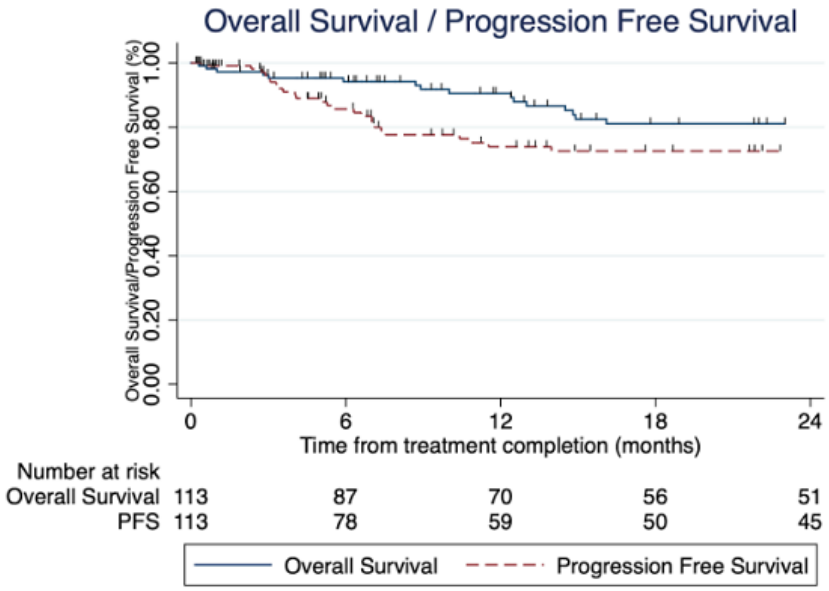
Results

Median follow-up time was 16.8 months (range 0 to 93). The most common histology was squamous cell carcinoma (77%; n=88). Fifty-eight patients (51%) had nodal involvement at presentation. Only a few patients had an MRI fusion prior to brachytherapy planning (19%; n=22; n=19 for stage >=IIB). The median EQD2 delivered to 90% of the volume of the HR-CTV was 84.7 Gy (SD 9.5 Gy). The median maximum EQD2s delivered to 2cc's of the rectum, sigmoid, and bladder were 80.6 Gy (SD 9.3), 61.0 Gy (SD 7.1), and 60.1 Gy (SD 7.1), respectively. Only one patient had local recurrence at 4.1 months. Nine patients had regional recurrence within the pelvis. Eighteen patients recurred distantly. The 2-year progression free survival and overall survival were 72.6% (95% CI; 62.0-80.6) and 81.1% (95% CI; 70.1-88.0), respectively (Figure 1). Acute grade 2 toxicities were nausea (13% n=15), diarrhea (30%; n=34), and cystitis(28%; n=32). Acute grade 3 toxicities requiring hospitalization were intractable nausea (n=3), neutropenic fever (n=1), diarrhea/dehydration (n=1).

Table 1. Patient, tumor, and treatment characteristics (N = 114)

Characteristic	n
Age, y median (range)	50, (26 - 81)
Follow-up time, mo, median (range)	16.8 (0 - 93)
Histology, n (%)	
Squamous cell carcinoma	88 (77)
Adenocarcinoma	19 (17)
Other	7 (6)
FIGO stage, n (%)	
IB1	17 (15)
IB2	7 (6)
IIA	5 (4)
IIB	2 (2)
IIIA	0
IIIB	6 (5)
IIIC1	30 (26)
IIIC2	14 (12)
IVA	6 (5)
IVB	11 (10)
Nodal disease at diagnosis, n (%)	58 (51)
Treatment Duration, d, median (range)	48 (35 - 91)
EBRT dose, Gy, median (range)	45 (40-60)
Brachytherapy prescription dose, Gy (range)	28 (14 - 30)
EBRT/IGBT EQD2 sum, Gy, mean (SD)	
HRCTV D90	84.7 (9.5)
Bladder D2cc	80.6 (9.3)
Rectum D2cc	61.0 (7.1)
Sigmoid colon D2cc	60.1 (7.1)
MRI fusion	
Yes	22 (19)
No	92 (81)
Chemotherapy	
Cisplatin	104 (91)
Other	6 (5)
None	4 (4)
Cycles of chemotherapy, median (range)	6 (1-7)

Figure 1. Kaplan-Meier Overall Survival and Progression Free Survival after completion of treatment of locally advanced cervical cancer with CT-Based HDR Brachytherapy



Conclusion
Although GEC-ESTRO supports MRI-based IGBT, limited evidence is available for CT-based planning. Our institutional experience demonstrates excellent local control and outcomes, and acceptable toxicities with CT-based HDR brachytherapy planning. CT-based IGBT is safe, efficacious, cost effective, and has widespread applicability. One of 5 grade 3 toxicities attributable to radiation.

PO-0183 Intracavitary electronic brachytherapy (e-BT) for gynecological malignancies

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Purpose or Objective
To report a single-center experience in terms of toxicity and the rates of local tumor recurrence after adjuvant electronic brachytherapy (e-BT) for patients with endometrial and other gynecological malignancies (GM).

Materials and Methods
Patients with various newly diagnosed and recurrent GM and an indication for adjuvant brachytherapy with or without external-beam radiotherapy (EBRT) were retrospectively assessed. Fractionated adjuvant intracavitary e-BT was applied using a portable low-energy (50 kV) linear accelerator equipped with a vaginal cylindrical applicator. Depending on histology and variate risk factors e-BT single doses ranged between 4 and 7 Gy (EQD_2 ~ 6 – 12 Gy assuming an α/ß of 10 Gy and a RBE 1.3) and were prescribed to 5 mm depth. Adverse events were graded by CTCAE v.5.0 and considered as "immediate" (occurrence within the first week after treatment), "acute" (1–3 months), "sub-acute" (3–12 months), "late" (12–24 months) or "chronic" (>24 months). Local and distant recurrence-free rates (LFR, DFR) were determined using longitudinal imaging. Overall survival (OS) was estimated using the Kaplan-Meier method.

Results
A total of 38 patients were included in the analysis. The median age was 66 [35 – 86] years. EBRT was added in n=25 (62.8%) patients. The predominant diagnosis was endometrial adenocarcinoma (n=32; 84.2%) with 12.5% staged as T1a, 46.9% as T1b, 21.9% as T2, 6.2% as T3a and 3.1% as T3b. Three patients (9.4%) received e-BT for recurrent disease. Endometrial histology was G3 in 50% (n=16), G2 in 21.9% (n=7) and G1 in 28.1% (n=9). The median follow-up was 44.5 months [5 – 88]. Incidences of grade 1, 2 and 3 toxicity at any time point were 92.1% (n=35), 26.3% (n=10) and 7.9% (n=3) respectively. The three grade 3 events were "acute" pelvic pain as well as one "acute" and one "late" vaginal stricture. No grade 3 cystitis or proctitis nor higher grade toxicities occurred. LFR was 100%, while the DFR was found to be 94.2% after 1 year and 84.8% after 2 years (n = 5 events). Estimated OS rates at 12, 24, 36 and 48 months were 94.6%, 91.8%, 83% and 79.7% respectively.

Conclusion
Despite the retrospective nature of this study our data suggests that intracavitary e-BT is a safe and effective approach, with a very low toxicity profile and a high local control rate.

PO-0184 What do women say about their experiences of brachytherapy for cervical cancer? A qualitative study.

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Purpose or Objective
To explore women's experiences of brachytherapy in UK settings and to find out their ideas for improvements to reduce pain, anxiety and distress caused by brachytherapy.

Materials and Methods
Data were collected in semi-structured interviews with women who had received brachytherapy for locally advanced cervical cancer. Four UK recruitment sites were selected to include a cross section of brachytherapy treatment schedules with different numbers of applicator insertions and procedure duration. Two cohorts of women were recruited: cohort one had recently had brachytherapy and cohort two were a year post brachytherapy. Initial interviews were face to face but changed to remote interviews (video conference or phone) due to the COVID-19 pandemic. Consecutive brachytherapy patients were invited to interview to minimise risk of bias. Participants were invited to retell their brachytherapy story and explore views on their care and ideas for improvement. Interviews were audio-recorded and transcribed. Data were analysed following Braun and Clarke's method for reflexive thematic analysis (2006).

Results
Nineteen interviews were conducted by PH; six face to face, two by telephone and eleven by video. There were 12 participants that had brachytherapy 4 weeks to 6 months prior to interview, and seven were interviewed between 12 and 18 months after brachytherapy. Age ranged from 28 to 77 years. Interview duration ranged from 22 to 78 minutes (median 38 minutes). Women's reports of brachytherapy were variable, with stories of difficult experiences and suggestions for improvements. However, some women described positive experiences, reporting what had gone well. Three themes were developed, each with subthemes:

1. *How I got through it*: Coping strategies (including passing time with music, reading, TV, phone, iPad and relaxation techniques; and personal attitudes and resilience (such as not overthinking it, taking one step at a time, and getting through the final hurdle).
2. *The physical impact of brachytherapy*: positioning/lying flat (causing difficulty eating or drinking, build-up of gas and back ache); medical complications (such as pulmonary emboli, pressure sores and allergic reactions); and side-effects during and after treatment (including severe pain, nausea/vomiting and late effects on bowel and bladder).
3. *The psychological impact of brachytherapy*: trauma associated with loss of fertility and associations with childbirth; privacy and dignity (including embarrassment, wanting a single room and feeling vulnerable); and not being listened to/believed (when experiencing severe pain).

Conclusion
Participants reported widely varying experiences of brachytherapy. The existing themes will be developed through further interviews. Women's ideas for improvements will be explored in further stages of this research to develop strategies for improving services.
This study was funded by the National Institute for Health Research (NIHR) [ICA-CDRF-2017-03-079].

PO-0185 Kelowna GYN template-based high-dose rate interstitial brachytherapy: design and dosimetric results

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Purpose or Objective
The Kelowna GYN template (Varian Medical Systems; Palo Alto, CA) is a perineal template for interstitial GYN brachytherapy designed for compatibility with a single channel vaginal cylinder as the vaginal obturator. We present the first reported series of patients treated with this system and an additional 3D printed modification for utilization of this template with an intrauterine tandem for treatment of locally advanced cervical cancer. Indications included bulky cervical tumor that responds poorly to external beam radiotherapy and/or vaginal involvement (tumor thickness greater than 0.5 cm), or for bladder invasion, and primary vaginal carcinomas and recurrent endometrial carcinomas with depth of invasion >0.5cm per GEC-ESTRO and ABS guidelines.

Materials and Methods
The Kelowna template allows placement of titanium or plastic interstitial needles with straight angled holes to provide coverage of the craniocaudal and lateral extension up to 3 cm from the vaginal cylinder. A modified applicator system using a custom 3D printed adaptor piece allows secure attachment of the tandem to the template for patients with an intact uterus (**Figure 1d**). Transabdominal ultrasound was utilized to guide needle placement. CT treatment planning with stepwise dwell weight adaptation and needle loading to achieve optimal dose coverage and sparing of organs at risk (OARs). Dose constraints were applied for dose-volume histogram parameters per ABS guidelines for HDR brachytherapy. Dosimetric data was evaluated including the D90 and D98 of high risk-clinical target volume (HR-CTV) with total EQD2 including whole pelvis radiotherapy (biologically equivalent to 2 Gy fractionation, alpha/beta = 10). D2cc (Dose to 2cc) of OARs were recorded.

Results
Between October 2018 and June 2019, eleven patients with GYN malignancies were treated using the Kelowna template. Patients with cervical cancer had median HR-CTV volumes of 46 cm3. Mean number of needles utilized was 11 (range 5 to 17). Treatments consisted of 3 or 4 fractions on consecutive days (BID). Dosing was 21 Gy in 3 fractions (n=9), 24 Gy in 4 fx

(n=1) and 28 Gy in 1 fx (n=1). For cervical tumors, the median D90 was 81.9 Gy (range 80.3 - 92.6). For vaginal and recurrent endometrial, the median D90 was 83.1Gy (range 75.8 - 91.1). Individual dosimetric data is displayed in **Table 1**. Interstitial needles allowed dose coverage of heterogenous asymmetric HR-CTV volumes as demonstrated in **Figure 1.** The median dose to OARs was within standard limits for intracavitary brachytherapy alone (EQD2cc for bladder of 72.3 Gy (IQR 67.2 - 77.5 Gy) and rectum of 61.6 Gy (IQR 58.7 - 62.7)). No patients needed adjustment in needle position between treatments. No patients had grade 3 acute toxicities. No patients had recurrence on follow-up.

Table 1. Dosimetric data of patients with gynecologic malignancies treated with Kelowna template. Indications for Kelowna template with interstitial needles listed as below: Tumor greater than 4cm in greatest dimension after external beam radiation (Tumor > 4cm) Parametrial involvement (para); Middle and distal ⅓ vaginal involvement (Vag); Abbreviations: EBRT (external beam dose); Gray (Gy)

Case	Primary Site	Histology	Stage	Indication	EBRT Dose (Gy)	Procedure	Brachy Dose (Gy)	Fractions	# of needles	D90 HRCTV (Gy)	D98 HRCTV (Gy)	D2cc Bladder (Gy)	D2cc Rectum (Gy)
1	Cervix	SCCa	IIIC2	> 4cm; para	45	tandem/ template	21	3	9	80.3	72.8	69.8	59.3
2	cervix	adeno	IIIB	Tumor > 4cm; para	45	tandem/ template	21	3	13	80.7	72.4	71.8	56
3	cervix	SCCa	IVA	Tumor > 4cm; para	45	tandem/ template	21	3	15	83	73	99.4	69.1
4	cervix	SCCa	IIIB	Tumor > 4cm; para	55	tandem/ template	21	3	13	92.6	78.8	77.5	72
5	recurrent endometrial	Adeno	IB	>0.5cm depth	45	cylinder/ template	21	3	10	86.3	77.1	67.2	61.5
6	recurrent endometrial	Adeno	IA	>0.5cm depth	45	cylinder/ template	21	3	11	79.2	65.6	75.6	68
7	recurrent endometrial	adeno	IA	>0.5cm depth; para	54	cylinder/ template	21	3	12	91.1	81.7	70.7	57.8
8	recurrent endometrial	adeno	IIIC2	>0.5cm depth; para; vag	45	tandem/ template	21	3	5	82.9	74	58.1	62.7
9	vaginal	SCCa	III	>0.5cm depth; para; vag	50	cylinder/ template	24	4	13	88.1	77.7	75.1	60.4
10	vaginal	SCCa	III	>0.5cm depth; para; vag	45	cylinder/ template	28	4	17	83.1	72.7	47.7	52.4
11	cervix post-op	adeno	IIB	>0.5cm depth; para	45	cylinder/ template	21	3	10	75.8	69.4	82.2	58.7

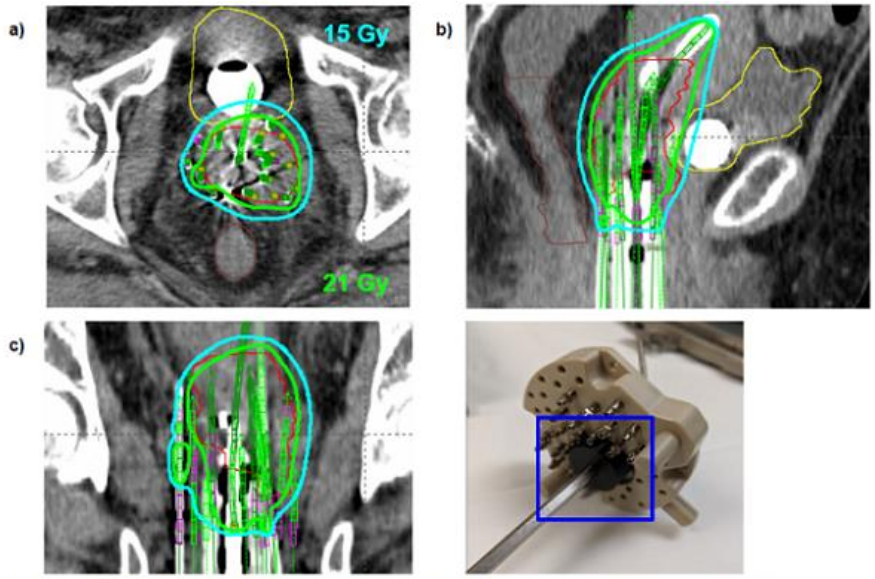

Figure 1. Case 2 indications for template and interstitial needle involving bulky tumor (>4cm) after external beam radiation and parametrial involvement, with prescription dose to 21 Gy over 3 fractions. **a)** axial view of dosimetry, 21 Gy; 100% line in Green, 15 Gy; 70% in cyan, high risk CTV (**red**), rectum (**brown**), bladder (**yellow**) **b)** sagittal view, **c)** coronal view, **d)** 3D printed adaptor piece (**blue box**)

Conclusion

The Kelowna template allows for customized safe, robust, and reproducible implants with combined interstitial-intracavitary applicator for selected cases of bulky, asymmetric cervical, vaginal, and recurrent endometrial cancer.

PO-0186 Analysis of Outcomes and Cost Effectiveness of Inpatient vs. Outpatient Based Interstitial Vaginal Brachytherapy

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Purpose or Objective
Vaginal cancer is a rare gynecological cancer with an estimated 5350 new cases annually. For advanced cases definitive treatment consists of chemoradiation and interstitial brachytherapy. Traditionally, interstitial brachytherapy consisted of one implantation with multiple treatments given over days as an inpatient. Recently there has been a trend toward single fraction outpatient techniques eliminating the need for hospitalization. Inpatient delivery also has a higher incidence of acute and posttraumatic stress disorders. The downside has been the need for more implantations raising concerns about cost-effectiveness. Our objective was to analyze the outcomes as well as cost-effectiveness and resource utilization for both methods at our institution.

Materials and Methods
We reviewed consecutive vaginal cancer patients treated using an inpatient delivery technique from 2018-2019. These patients were then matched to an equivalent cohort treated using an outpatient delivery technique. Patient demographics, disease control and toxicity were collected in addition to data related to cost of services.

Results
A total of 22 treatments over 8 implantations were reviewed for the inpatient cohort. This cohort was matched to an outpatient cohort which received a total of 23 treatments in 23 implantations. At a median follow up period of 9 months, DFS is 90% for both cohorts combined. There was one grade 3+ toxicity noted in the inpatient cohort. The mean monetary cost for inpatient delivery per treatment was significantly higher than outpatient delivery ($33,426 vs $22,300, $p<0.0001$.) Additionally, in the inpatient cohort, patients received more doses of narcotics as well as prolonged procedure time, length of anesthesia and immobilization.

Conclusion
Traditional interstitial brachytherapy for vaginal cancer is a complex procedure requiring significant resources to perform and carrying significant patient related toxicity. Outpatient treatment utilizing less procedure time and anesthetics. There is also a 33% reduction in total cost with outpatient delivery. Taken together, outpatient HDR interstitial brachytherapy has the potential to reduce risk of iatrogenic harm, reduce long term psychological damage for the patient and improve healthcare resource utilization all without compromising disease control.

PO-0187 Vaginal dose reduction by changing the ovoidloading pattern in intracavitary brachytherapy of cervix

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Purpose or Objective
Locally advanced cervical cancer is treated by a combination of external beam radiotherapy and brachytherapy. Vaginal morbidity following radiotherapy is a major problem. The aim of this study is to analyse the changes in dosimetry to CTV, OAR and vagina by changing the ovoid loading pattern in image guided high dose rate brachytherapy of cervix

Materials and Methods
45 CTbased intracavitary brachytherapy plans of 15 patients were analysed. 3 sets of plans were generated for the 45 applications, namely, a standard loading plan (A), reduced ovoid loading plan (B) and tandem only loading plan (C). DVHs were generated and the dose volume parameters were recorded for the 3 sets of plans

Results
The D90 to CTV was not significantly different between the three set of plans ($p=0.20$) (Average D90 for plan A, B and C were 8.15Gy,8.16Gy and 7.4Gy respectively). There was no statistically significant difference between D2cc bladder ($p=0.09$)(average D2cc bladder were 6.7Gy, 6.5Gy and 5.9Gy for plans A,B and C respectively) and D2ccsigmoid ($p=0.43$)(average D2cc sigmoid were 2.7Gy, 2.6Gy and 2.4Gy respectively)for the three sets of plans. However, there was statistically significant difference between the D2cc rectum ($p=<0.001$)(average D2cc rectum were 4Gy,3.3Gy and 1.8Gy respectively) and the right, left, anterior, posterior vaginal surface dose points and 5mm depth dose points for the three sets of plans ($p<0.001$)

Conclusion
Manipulating the ovoid loading pattern significantly reduced the dose to vaginal dose points and rectum without compromising the dose to CTV. Hence in carefully selected cases, ovoid loading pattern can be changed to decrease the dose to the vagina and thereby reduce the vaginal morbidity after high dose rate intracavitary brachytherapy.

PO-0188 Are active dwells always necessary in the applicator ring in the brachytherapy of cervical cancer?

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Purpose or Objective
To compare the dosimetric parameters of brachytherapy (BT) treatment plans performed with or without active dwell positions in the applicator ring in locally advanced cervical cancer patients.

Materials and Methods
25 patients of stage IB2-IVA were selected, who received intracavitary/interstitial BT without active dwell positions in the ring. These were cases where the HR-CTV did not contain the upper part of the vagina. An additional plan with active ring was created. The EQD2 total doses of the target volumes and organs at risk (OARs) were compared using Wilcoxon-Matched Pairs Test. The locoregional status was checked on MRI at the first follow-up.

Results
There was no significant difference in the dose to the HR-CTV between the plans with inactive vs active ring (mean D90: 91.2 vs 91.5 Gy, D98: 80.6 vs 81.0 Gy). Similar results were obtained for the GTV (D90: 115.3 vs 109.1 Gy, D98: 97.2 vs 95.5 Gy). The mean D98 of the IR-CTV was significantly lower with inactive ring (60.8 vs 63.9 Gy, p=0.0464), however the GEC-ESTRO criteria were fulfilled in 96% in both plan types. There was no difference in dose homogeneity (DNR: 0.55 vs 0.54), but the conformity of the plans with inactive ring was higher (COIN: 0.62 vs 0.38, p<0.001). Doses to all of the OARs were significantly lower in plans without ring activation: D_{2cc}(bladder) was 72.4 vs 86.5 Gy (p<0.001), D_{2cc}(rectum) was 57.9 vs 75.2 Gy (p<0.001), $D_{recto\text{-}vaginal}$ was 58.8 vs 77.5 Gy (p<0.001), D_{2cc}(sigmoid) was 61.7 vs 67.3 Gy (p<0.001), D_{2cc}(bowel) was 69.2 vs 72.1 Gy (p=0.0038) and D_{2cc}(vagina) was 78.2 vs 117.3 Gy (p=0.0022) in plans with inactive vs active ring. While all the plans without ring activation fulfil the GEC-ESTRO dose criteria for bladder, rectum and sigmoid, the plans with activated ring satisfy the same criteria in 72%, 56% and 88%, respectively. Four patients (16%) had residual tumour at the first follow-up.

Conclusion
Inactivation of the applicator ring results similar dose coverage of the target volumes with lower doses to all of the OARs, than active ring in cervical cancer patients without vaginal involvement. Active dwells in the ring yields decreased fulfilment of the GEC-ESTRO criteria for OARs. The early tumour control corresponds to the literature in our patient cohort.

PO-0189 The second planning-CT in a two daily fractions implant can be omitted in cervical cancer IGABT

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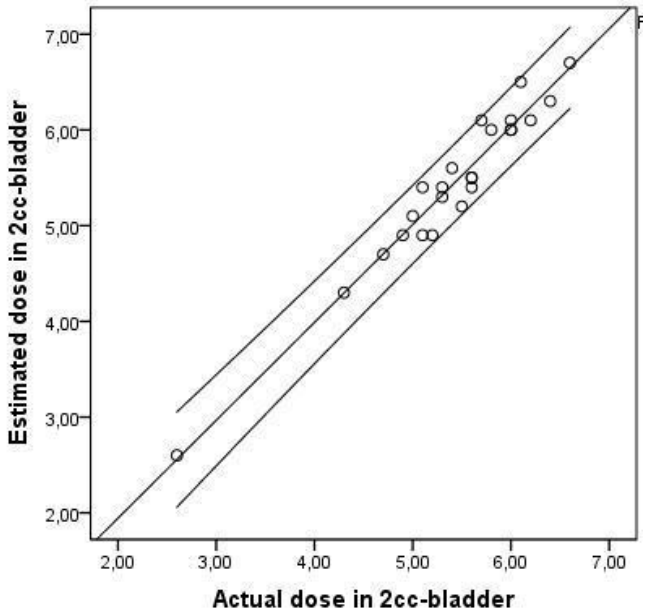
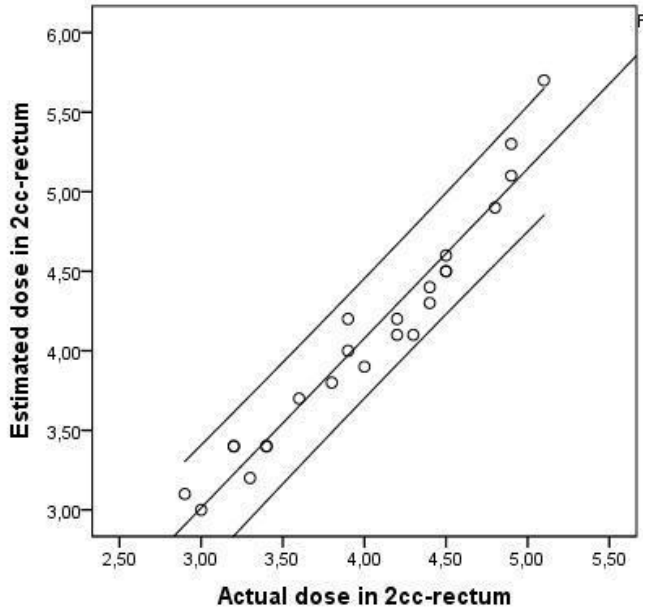
Purpose or Objective
To evaluate the need of a second planning-CT in a two daily fractions implant schedule in MRI-image-guided brachytherapy (IGABT) for locally advanced cervical cancer (LACC).

Materials and Methods
Between Nov 2019 and October 2020, 12 patients with LACC were treated in our department. Mean age: 51 years (range from 42 to 65). Disease stage according to FIGO 2018 IB2-IIIC2. All patients were treated with external beam radiotherapy (EBRT) using IMRT and daily IGRT with concomitant weekly Cisplatin, followed by IGBT. EBRT to a total dose of 45 Gy, 1.8 Gy/f, was administered to pelvic +/- retroperitoneal nodes regions with concomitant boost up to 57.5 Gy, 2.3 Gy/f to involved nodes. Based on GEC ESTRO recommendations, we performed two implants separated by one week, delivering two daily fraction for each implant (total IGBT dose: 4 x 7Gy). In 5 patients we combined intracavitary and interstitial application. The primary imaging modality for IGBT planning was MRI for each individual first applicator insertion, and subsequent CT (all four fractions). In order to elucidate the need of a second planning CT for each implant, we compared the actual dose (AD) to OARs in the second and fourth fraction with an estimated dose (ED) based on dose distribution of the previous fraction. Statistics: Pearson´s correlation coefficient (R^2).

Results
The mean EQD2 of the D90HRCTV, D98GTVres, and D98IRCTV were 91.60Gy, 111.15Gy and 65.36Gy respectively. Mean EQD2 to 2cc and 0.1 cc organs at risk (OARs) were as follow: bladder: 79.7Gy and 99.01Gy; rectum 65.22Gy and 80.24Gy; sigmoid 65.41Gy and 78.6Gy; and bowel 54.65Gy and 62.63Gy, respectively. Differences between actual dose and estimated dose to 2cc and 0.1 cc-OARs are shown in the table. We found a strong correlation between the AD and ED to OARs (2cc and 0.1cc). The Pearson ´s correlation coefficient (R^2) for 2cc-bladder, rectum, sigmoid and bowel were 0.975 (p<0.001), 0.970 (p<0.001), 0.971 (p<0.001) and 0.932 (p<0.001), respectively. The corresponding figures for 0.1cc-OARs were 0.969 (p<0.001), 0.902 (p<0.001), 0.929 (p<0.001) and 0.874 (p<0.001). Figure 1 shows the scatter plot with a 95% confidence interval for 2cc-bladder and 2cc-rectum.





	Bladder		Rectum		Sigmoid		Bowel	
	AD	ED	AD	ED	AD	ED	AD	ED
2cc	5.41Gy	5.43Gy	4.01Gy	4.09Gy	4.02Gy	3.94Gy	2.36Gy	2.22Gy
0.1cc	7.0Gy	7.05Gy	5.61Gy	5.76Gy	5.31Gy	5.15Gy	3.22Gy	3.09Gy

Conclusion
We demonstrate no advantage of replanning prior to second fraction of each implant in MRI-image-guided endocavitary (+/-interstitial) brachytherapy for locally advanced cervical cancer.

PO-0190 A single institution review of vaginal brachytherapy with customised moulds and interstitial needles

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Purpose or Objective
To review a single institution's pattern of practice, dosimetry results and clinical outcomes for patients with unresectable malignancies of the vagina, vulva or urethra receiving brachytherapy delivered using customised vaginal moulds, with or without interstitial needles.

Materials and Methods
21 consecutively treated patients were reviewed. Patients were treated using customised vaginal moulds, with or without interstitial needles implanted with a free-hand technique. Technical implementation such as the type of implant and the imaging used were recorded. D90 and D98 of the CTV, D0.1cc of the urethra and D2cc and D0.1cc of the bladder and rectum were analysed. Plan quality indices were calculated. Any adverse clinical outcomes were reported.

Results
Eleven patients had endometrial cancer recurrences, one a cervical cancer recurrence and nine had vaginal or peri-urethral primary disease. After a median follow up of 3.5 years, local control was achieved in 14 patients (67%). The median D98 and D90 to the CTV was 73.7 Gy and 78.3 Gy respectively. One patient died from disease progression, one developed distant metastasis and seven failed locally.
The median D2cc and D0.1cc to the organs at risk and relevant toxicity are summarized in Table 1.

	Median D2cc (Gy)	Median D0.1cc (Gy)	Toxicity
Bladder	64.8	81.2	Low grade toxicity
Urethra		66	None recorded
Rectum	62.9	80.3	One developed rectal proctitis
Sacrum			One had insufficiency fracture

It was presumed that the upper vagina received the total dose, with two patients developing vaginal ulcers that both resolved, and 10 patients reported mild telangiectasia, fibrosis, or stenosis.

Conclusion
A review of patients treated with a customised vaginal mould and interstitial needles showed that this technique allows for acceptable doses to the CTV with local control achieved in 67% of patients and reasonable doses to the organs and risk and acceptable toxicity.

PO-0191 Plan evaluation of the interstitial contribution in brachytherapy for cancer cervix

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Purpose or Objective
Patients with locally advanced cancer of cervix are treated with external beam radiotherapy (EBRT)and concurrent chemotherapy followed by brachytherapy. Brachytherapy is done using tandem and ovoids in most. Addition of interstitial needles was suggested to improve dose to the parametrial residual disease. This study aimed to find out whether additional interstitial component provide better dose distribution and less Organ At Risk (OAR) dose compared to plans without needles for patients with gross residual disease after EBRT. This was done by assessment of D90 and D98 coverage of HRCTV by intracavitary /Interstitial(IC/ ISl) compared to Intracavitary (IC) alone and by comparison of doses received by D2cc of rectum, sigmoid and bladder

Materials and Methods
Nine consecutive patients with bulky residual disease after chemo-irradiation for locally advanced cancer cervix were selected for the brachytherapy treatment. There were four IIB and five IIIB patients. Residual disease after EBRT was assessed using clinical and MRI. Brachytherapy was done with hybrid IC/ISl Utrecht applicator. After the insertion, planning and contouring were done using MRI. The doses of EBRTand brachytherapy were added and converted to 2Gy dose equivalent (EQD2).Planning aims were D90 between 85-95Gy,D98 >75Gy,Bladder 2cc<85-90Gy,Rectum 2cc <75Gy,Sigmoid 2cc <75 Gy. All patients achieved the aims and were treated with a total of 4 fractions. Then unoptimised and optimised plans were created without interstitial component and point A prescription of 7Gy was used for plan comparison. Comparison was done using Friedman's two way ANOVA test for repeated measures and further pair wise analysis was done using Wilcoxon signed ranks test.

Results
The mean D90 dose was 87.78 Gy and D98 was 77.4 Gy for the whole group. The mean rectal 2cc dose was 61.3Gy, mean 2cc Bladder dose was 82.2 Gy and 2cc sigmoid dose was 57.02 Gy. The mean D90 and D98 doses for unoptimised plans were 90.01 Gy and 78.61 Gy, and for optimised plans 83Gy and 78.03 Gy respectively. The mean 2cc rectal, bladder and sigmoid doses were 76.54 Gy, 99.48 Gy and 69.58 Gy respectively for unoptimised and 69.57 Gy, 101.94 Gy and 62.0 Gy respectively for optimised plans.The differences of D2cc of OAR were significantly favoring IC/ISl plan, for D2cc of rectum (p=0.016),bladder (p=0.027), and sigmoid(p=0.044) when IC/ISl plan was compared with unoptimised and optimised plan without interstitial contribution. No statistically significant difference observed when D90 and D98 coverage of IC/ISl plan was compared with unoptimised and optimised plans.

Conclusion
Patients with carcinoma cervix treated with IC/ISl brachytherapy showed significantly lower doses to OARs compared to brachytherapy plan using tandem and ovoids alone in patients with residual disease after EBRT. Hence interstitial needles are recommended along with IC application, to reduce the risk of toxicity in such patients.

PO-0192 Prototype testing the 3D-printed Montreal split-ring applicator (GYN) using biocompatible materials

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Purpose or Objective
An adaptive technique combining intracavitary GYN applicators with interstitial needles is associated with improved outcomes in locally advanced cervical cancer involving tumor extensions to the parametrium. The multicenter EMBRACE II study protocol provides dose constraints as planning aims and dose limits for MR-delineated target structures. Expensive applicators needed to perform combined intracavitary/interstitial (IC/IS) brachytherapy and achieve the EMBRACE II planning aims are only available in a few specialized centers limiting the adoption of IC/IS brachytherapy. The purpose of this work is to show the feasibility of upgrading a widely used IC-only applicator; the CT/MR split-ring (E&Z BEBIG, Berlin, Germany) using relatively inexpensive 3D-printing technology to enable a more widespread and patient-specific use of IC/IS brachytherapy.

Materials and Methods
The CT/MR split-ring applicator comes with disposable or reusable buildup caps that work as sleeves for each split-rings. A CAD model of the standard 5 mm buildup cap was designed using Fusion 360™ (Autodesk Inc., California, USA). The cap was then extended outward and notches were modeled to allow attachment of guiding tubes used with the interstitial lunar ovoids of the Venezia IC/IS applicator (Elekta, Stockholm, Sweden). These upgraded sleeves were then printed using a Form3 SLA printer (Formlabs Inc., Massachusetts, USA) using two resins; Surgical Guide (ISO 10993 biocompatibility & 50 µm resolution) and BioMed Clear (USP Class VI biocompatibility & 100 µm resolution). Sleeves were steam sterilized at 132 °C in an autoclave for 4 minutes followed by a 25 minutes dry phase. Finally, the sleeves were tested for the following properties both pre- and post-sterilization: split-ring, guide-tube and fixation screw attachment.

Results
Figure 1. and 2. show the upgraded split-ring IC/IS applicator with the Surgical Guide and BioMed Clear sleeves respectively. Successful insertion of each split-rings and attachment of interstitial guide tubes was verified both pre- and post-sterilization. Guiding tube notches for interstitial needle obliquity angles of 15°, 30° and 45° were successfully tested. Fixation screw threads were found to be the most sensitive features of the printed sleeves. However, optimizing the protocol/models we increased the number of times the screw can be re-used before stripping the threads to over ten times which is satisfactory considering the disposable nature of these sleeves.

Figure 1. Fixation of a 3D-printed sleeve (Surgical Guide resin from Formlabs) on a CT/MR split-ring (from E&Z Bebig).

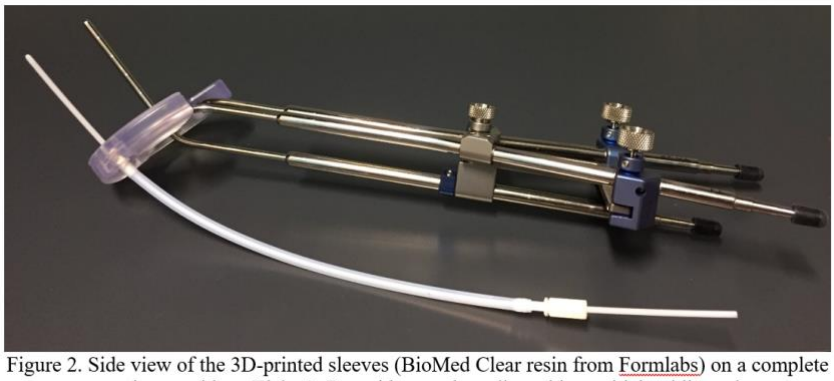

Figure 2. Side view of the 3D-printed sleeves (BioMed Clear resin from Formlabs) on a complete setup shown with an Elekta's Proguide round needle and interstitial guiding tube.

Conclusion
3D-printing technology was successfully used to produce the affordable 3D-printed Montreal split-ring applicator for combined IC/IS brachytherapy. A collaboration is ongoing to develop a dedicated software module in Adaptiiv's brachytherapy software (Adaptiiv Medical Technologies, Inc., Halifax, Canada) that would allow patient-specific needle trajectories (obliquity angles ≤ 45°) for adaptive brachytherapy.

PO-0193 Impact of Vaginal Reference Length on Organs at Risk doses in Carcinoma Cervix Brachytherapy

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Purpose or Objective
To analyze the impact of Vaginal Reference Length on doses to the Bladder, Rectum and Small Bowel in Carcinoma Cervix image guided Brachytherapy

Materials and Methods
A total of 30 patients of Carcinoma Cervix treated at our institute were included for analysis. All patients underwent external beam radiotherapy to a total dose of 50Gy in 25 fractions along with three fractions of HDR intracavitary brachytherapy using tandem and ovoid applicator. The brachytherapy dose was 7Gy to Point A for three applications, one week apart to a total dose of 21Gy. CT scan was used for target and organs at risk delineation and image guided brachytherapy planning. The Vaginal Reference Length (VRL) was defined from the midpoint of ovoids to the posterior inferior border of pubic symphysis (PIBS) in sagittal view. All patients underwent a bladder filling protocol of 30cc saline infusion through the bladder catheter at the time of CT scan and during treatment

Results
The mean Vaginal Reference Length was 4.5cm (2-7cm). The 0.1cc, 1cc and 2cc mean doses to the bladder were 101.2Gy, 89.6Gy and 82.4Gy respectively ($EQD2_{\alpha/\beta=3}$). The mean dose to the ICRU Bladder point was 80.6Gy $EQD2_{\alpha/\beta=3}$. The 0.1cc, 1cc and 2cc mean doses to the rectum were 81.5Gy, 74Gy and 68.4Gy respectively ($EQD2_{\alpha/\beta=3}$). The mean dose to the ICRU Recto vaginal point was 68.5Gy $EQD2_{\alpha/\beta=3}$. The 0.1cc, 1cc and 2cc mean doses to the bowel were 76.4Gy, 65.5Gy and 63.2Gy respectively ($EQD2_{\alpha/\beta=3}$). A Vaginal Reference Length of less than 3.8cm was statistically significant for higher bladder 2cc doses (p=0.003). The rectum and bowel doses and ICRU Bladder and Recto vaginal points were not significantly affected by short Vaginal Reference Length

Conclusion
Shorter Vaginal Reference Length resulted in higher bladder doses in our study. Further studies are necessary for clinical correlation

PO-0194 Intracavitary brachytherapy for endometrial carcinoma: experience with Co-60 HDR brachytherapy.

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Purpose or Objective
To report vaginal cuff brachytherapy (VCB) treatment dosimetry parameters and treatment outcome of patients with localized endometrial cancer treated with curative intent.

Materials and Methods
Between 2011 and 2017, 93 patients were diagnosed endometrial cancer and treated with radical surgery and adjuvant radiotherapy (exclusive VCB or combined EBRT+VCB). Dosimetric variables studied included D2cc/D1cc/D0.1cc (rectum and bladder) and distance from cylinder surface to V150% and V200% isodose line in vaginal mucosa.

Results
Mean age at diagnosis was 66 years (range 45-85). Adjuvant EBRT (46-50.4 Gy) was performed in 52.7% and adjuvant chemotherapy in 38.7% of cases. Most common subtype was endometrioid adenocarcinoma (61.7%), papillary-serous carcinoma (11.8%) and clear-cell carcinoma/uterine-carcinosarcoma (7.5% each). There were 69.1% patients FIGO stage I (34.4% IA and 35.5% IB), 12.8% stage II and 16% stage III. Mean follow-up was 39 months (5-84 months). 3 year OS was 87.5% and PFS was 85.5%. Vaginal recurrence was seen in 2.2% of cases, nodal recurrence in 7.5% and distant metastasis in 12.9%. Mean rectum D2cc/D0.1cc were 88.1% and 116%. Mean bladder D2cc/D0.1cc were 79.2% and 103.2%. Mucositis ≥ G2 was seen in 8.6%. Vaginal stenosis ≥ G1 was seen in 23.7% of patients (6.5% G2). Mean distance from the top of the applicator to V150% and V200% isodose lines were 1,71 mm and 0,06 mm, respectively. Mean lateral distance from cylinder surface to V150% isodose line was 0,76 mm.

Conclusion
Co-60 HDR brachytherapy for patients with endometrial cancer is well tolerated with survival and toxicity outcomes comparable to Ir-192 HDR brachytherapy.

PO-0195 Clinical outcome of intracavitary and interstitial brachytherapy in locally advanced cervical cancer

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Purpose or Objective
to report clinical outcomes and side effects of CT-based image-guided combined intracavitary and interstitial brachytherapy

Materials and Methods
1. between 2014 and 2019, 114 patients were treated with chemoradiation and brachytherapy
2. computed tomography (CT) and/or magnetic resonance imaging (MRI) were done at baseline and before brachytherapy to plan implantation
3. Target delineation defined by the GEC-ESTRO guideline with prescribed doses of 6-8 Gy in 4-6 fractions
4. Planning aim doses (EBRT with BT in EQD2) were D90 HRCTV > 85 Gy, D2cc bladder < 90 Gy, D2cc rectum <75 Gy, D2cc sigmoid<75 Gy.

Results
Median follow-up was 17 months. Seventy percent of complete response rate was correlated with D90 HRCTV > 85 Gy in EQD2 (p=0.03). IC/IS brachytherapy was used 36.8% of patients with bulky tumor, parametrial and vaginal extension. In addition of 49.1% of patients were used to Vienna-ring applicators. EBRT and BT median doses in EQD2 were D90 HRCTV 87.9 Gy, D2cc bladder 75.8 Gy, D2cc rectum 67.9 Gy and D2cc sigmoid 63.6 Gy.
Total D2cc bladder >90 Gy in EQD2, D2cc rectum and sigmoid >75 Gy in EQD2 were not correlated with grade 3 toxicities (p=0.97, 0.25 and 0.88, respectively). Grade 3 proctitis and cystitis were 5.3% and 0.9% respectively.

Conclusion
CT-based IC/IS brachytherapy can achieve good local control and acceptable toxicity. Clinical examination and MRI should be done before brachytherapy session to select implantation. Long term outcome is needed to assess efficacy of this treatment especially in developing country which has limitation of MRI-based brachytherapy.

PO-0196 Dosimetric Analysis of Combined Intracavitary and Interstitial Needles Placement for Cervical Cancer

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Purpose or Objective
To compare the target volume coverage and normal tissue avoidance for high-dose rate (HDR) brachytherapy boost for cervical cancer between intracavitary (IC) tandem and ovoid (T&O) with additional free-hand interstitial (IS) needles (IC-IS) vs. IC brachytherapy alone under ultrasound guidance.

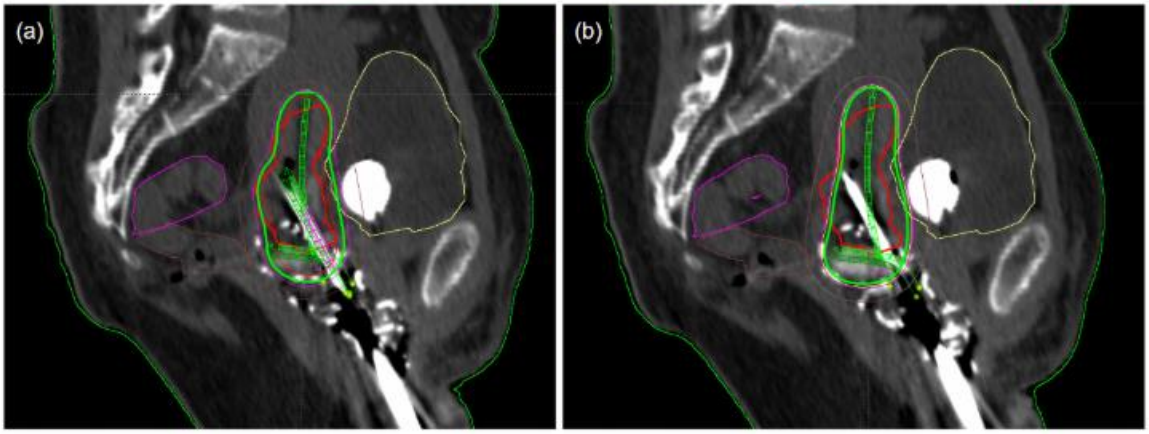
Materials and Methods
We reviewed cases of HDR brachytherapy utilizing IC T&O with free-hand IS needles for the treatment of cervical cancer performed at our institution from November 2018 through October 2019. Using ultrasound guidance for IS needle placements and CT simulation for treatment planning, high-risk clinical target volumes (HR-CTVs) as well as organs at risk (OARs) were delineated before each fraction. Minimum acceptable target coverage was defined as 90% of the prescription dose delivered to 100% of the HR-CTV (D90). If these objectives were perceived to be unmet with the standard IC applicator, IS needles were added at the discretion of the physician to improve dosimetric coverage of HR-CTV while minimizing OARs. For patients who had an IS needle placed during one or more fractions, dosimetric parameters for HR-CTV, bladder, rectum, sigmoid for each fraction were extrapolated. Each IC-IS case was then replanned with IC alone, matching the dose-limiting normal tissue structure for that treatment. HR-CTV with D90 and D98 along with OARs D2cc means and standard errors were evaluated between IC-IS and IC plans using a paired t-tests, p=0.05. Acute side effects were evaluated using CTCAE v5.0 criteria.

Results
We identified 6 patients with 20 IC-IS treatments after whole pelvis radiation. Between two to six IS needles were placed for each treatment (13 cases with 2 IS needles; 2 cases with 3 IS needles; 2 cases with 4 IS needles; 2 cases with 5 IS needles; 1 case with 6 needles). All fractions were planned for 7 Gy. Mean D90 (Gy) per fraction to the HR-CTV with and without IS needles was 7.57 Gy ± 0.28 vs. 7.09 Gy ± 0.32 (p=0.007), respectively, with a relative percent-dose increase of 6.7%. Regarding OARs, mean D2cc (Gy) per fraction with and without an IS needle were: Bladder - 5.34 Gy ± 0.22 vs. 5.48 Gy ± 0.18 (p=0.236); Rectum - 3.14 Gy ± 0.17 vs. 3. Gy2 ± 0.17 (p=0.304); Sigmoid - 3.41 Gy ± 0.15 vs. 3.38 Gy ± 0.15 (p=0.707). Dosimetric results demonstrated in **Table 1**. An example demonstrating a case showing dosimetric advantage to needles is demonstrated in **Figure 1**. All patients tolerated the procedure well without any documented CTCAE v5.0 Grade 3 to 5 severe adverse events.

Table 1. Comparison of IC + IS cases (black) vs. IC alone re-plan (red)

Patient Number	Brachy Dose (Gy)	D90 HRCTV	D90 HRCTV-re plan	D98 HRCTV	D98 HRCTV-re plan	D2cc Bladder	D2cc Bladder-re plan	D2cc Rectum	D2cc Rectum-re plan	D2cc Sigmoid	D2cc Sigmoid-re plan
1	7	4.85	4.9	3.55	3.6	6.4	6.4	2.65	2.8	2.3	2.6
	7	10.64	10.25	8.2	8.2	3.6	3.6	2.2	2.2	2.53	2.5
	7	7.35	7.6	6.25	6.4	3.75	4.25	2.35	2.8	1.97	2.05
2	7	8.2	7.55	7.25	6.4	5.5	5.95	3.55	3.3	4	4
	7	7.8	8.4	6.75	7.15	3.65	4.65	2.8	2.95	4.25	4.15
	7	7.25	7.75	5.95	6.25	3.7	4.1	2.45	2.35	3.4	3.25
	7	7.65	7.7	6.45	6.55	4.95	5	2.25	2	4.1	4.1
3	7	6.6	5.5	5.4	4.45	4.9	6.15	4.25	3.65	3.3	2.55
	7	6.65	6.45	5.3	5.25	6	6	4.3	4.15	3.45	3.1
	7	7	5.95	5.75	5	6.2	6.2	3.8	3.9	3	2.85
4	7	7.9	7.4	6.85	6.15	5.8	6.05	3.65	4.1	3.15	3.2
	7	9.5	9.4	7.5	7.75	4.65	5.4	3.2	3.75	3.6	4
	7	8.7	7.25	7.15	5.95	6.1	6	2.1	2.1	3.2	3.5
	7	8.85	8.1	6.85	6.85	6.1	6.1	2.2	2.5	3.7	3.1
5	7	6.6	4.85	5.45	3.85	6.4	5.6	3.9	4	4	4
	7	6.3	4.8	5.25	3.7	6.45	5.85	3.8	4	3.35	3.7
	7	8	6.5	6.9	5.3	5.6	5.15	3.35	3.8	3.9	4.05
6	7	6.8	7.15	5.15	5.45	5.9	5.9	2.5	2.5	3.65	3.8
	7	7.55	7.25	6.25	6.05	5.45	5.5	3.3	3.2	4.45	4.3
	7	7.25	7	6	5.6	5.7	5.656	4.1	4	2.85	2.85
Total		7.57 +/- 0.28	7.09 +/- 0.32	6.21 +/- 0.23	5.80 +/- 0.28	5.34 +/- 0.22	5.48 +/- 0.18	3.14 +/- 0.17	3.20 +/- 0.17	3.41 +/- 0.15	3.38 +/- 0.15
p - value		0.007		0.014		0.236		0.304		0.707	

Figure 1. (a) IC + IS needles for a cervix tumor involving the posterior uterine segment with dosimetric advantage compared to (b) IC alone re-planned, HR-CTV (red), rectum (brown), bladder (yellow), sigmoid (pink), 100% isodose line (green)



Conclusion

For appropriately selected patients, adding IS needless to IC HDR brachytherapy boost can improve dose coverage of HR-CTV for cervical cancer while not increasing dose to OARs. As this study series matures, long term follow-up is warranted for evaluating differences in clinical outcomes and associated toxicity.

PO-0197 Systemic analysis of vaginal wall dose between various vaginal brachytherapy: phantom case

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Purpose or Objective

Cervix and uterus have a relatively high radiation tolerance for brachytherapy. However, organs at risk surrounding these structures have been a major concern. Tolerance dose for rectum, sigmoid and bladder have been well evaluated using

D_{2cc}. However, tolerance dose for vaginal wall dose is not well defined. To reduce vaginal wall dose, several investigators have suggested modification of vaginal surface sources and/or the use of vaginal obturator sleeve.
The purpose of this study is to compare the vaginal wall dose between various vaginal brachytherapy source positions with or without obturator sleeve.

Materials and Methods
To compare vaginal wall dose from various vaginal brachytherapy, a phantom case was generated with parallel sources (needles) position for vaginal cylinder brachytherapy (CBT) and interstitial brachytherapy (ISBT). The vaginal wall was contoured as a 0.5 cm expansion. The prescription dose was 2000 cGy in four fractions to 0.5 cm from the vaginal cylinder for CBT and 0.5 cm from the outer needle for ISBT. Four different treatment plans were generated with geometric optimization with/without 0.3 cm vaginal sleeve for CBT and ISBT with vaginal cylinder. Four CBT plans were generated, Plan 1: central source only, Plan 2: vaginal surface source only, Plan 3: both central/vaginal surface source, and Plan 4: the same as Plan 3 but with vaginal sleeve. For ISBT, Plan A, B, C, and D were the same source arrangement as Plan 1, 2, 3, and 4 with additional semi-circular source around the vaginal cylinder (total 20 needles, ten needles each side) (Fig.1, 2).

Results
Plan 1, 2, 3 and 4 of CBT resulted in a V150% was 7.29, 40.57, 27.09 and 9.02% respectably and D2cc of 3180, 6130, 5370 and 3390 cGy respectably. Among these four plans of CBT, the highest V150% was the plan with peripheral obturator source only and the lowest V150% was the plan with central obturator source only (Fig 3, Fig 4).
Plan A, B, C and D of ISBT resulted in a V150% was 0, 45.57, 65.06 and 45.72, respectively and D_{2cc} of 2620, 4210, 4370 and 3570 cGy, respectively. Among these 4 plans of ISBT, the highest V150% was the plan with peripheral and combined peripheral/central sources, and the lowest was the plan with central obturator source only.

Conclusion
4. The lowest vaginal wall dose was seen with the use of central obturator source without peripheral source in both CBT and ISBT. The combined use of the central source and vaginal surface source can reduce vaginal wall dose slightly in CBT, but not in ISBT.
5. Adding a vaginal sleeve reduce the vaginal wall dose significantly in CBT but not much in ISBT due to the effect of nearby needle source.
6. Compared with CBT, ISBT has much higher V150% but more homogeneous dose.
7. For an actual patient case, individualized graphic optimization is necessary to reduce D2cc and V150% due to the unparalleled needle position in ISBT.

PO-0198 Applicator-guided SBRT boost combined with intracavitary brachytherapy for advanced cervical cancer

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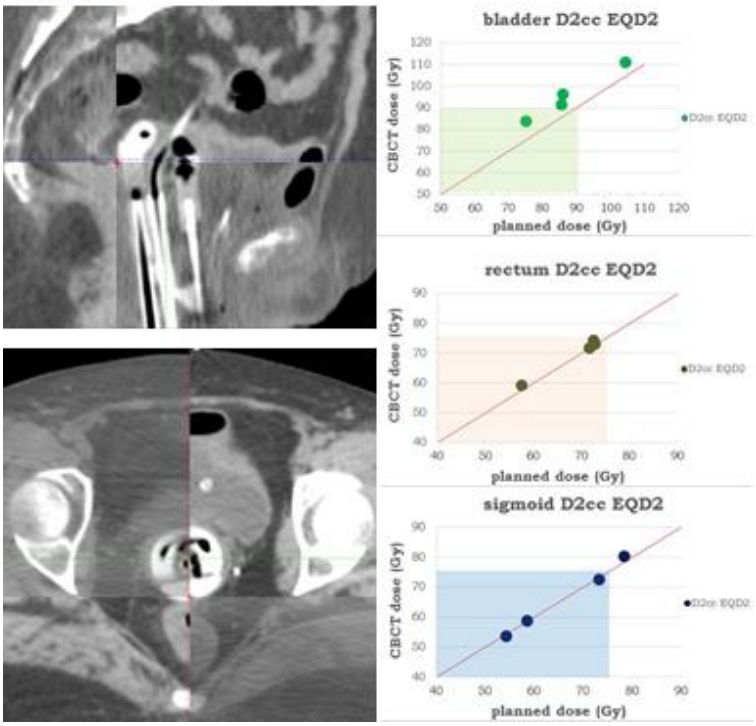
Purpose or Objective
To present the feasibility of IGBT combined with applicator-guided SBRT boost for locally advanced cervical cancer. To assess the effects of SBRT set-up errors and intra-fractional OARs variation on the delivered dose.

Materials and Methods
Four patients with locally advanced/recurrent cervical cancer were selected for SBRT parametrial boost in addition to IGBT due to the extent of residual disease at the time of BT. They received whole pelvis VMAT of 45 Gy/25 fractions, with SIB of 55-60 Gy to pathologically enlarged lymph nodes, followed by intracavitary HDR BT of 21-28 Gy/3-4 fractions combined with SBRT parametrial boost. CT scans with 2 mm slice thickness were acquired for each BT session, for contouring and dose calculation for BT and SBRT. Patients had empty rectum and bladder filling protocols. HR-CTV delineation was guided by MR images. After BT plan optimization, a VMAT SBRT plan was performed, aiming for adequate coverage of HR-CTV. The dose constraints for OARs were EQD22cc of 90 Gy for bladder and 75 Gy for rectum and sigmoid. HDR BT was delivered using intra-uterine and ring or ovoids. The SBRT was carried on with the applicators in situ, immediately after BT. The bladder filling was controlled during BT+SBRT delivery. CBCT was used for SBRT image-guidance by registration with the planning CT and BT applicators as landmarks. Couch translations were applied to correct the set-up errors. No correction was applied for the rotation of the applicators. The OARs were retrospectively re-contoured on CBCT images. D2cc and respective EQD2 were recalculated and compared to the planned ones. The dosimetric variations were evaluated by the relative percentage difference between the doses on planning CT and verification CBCT. The rotations of the applicators were measured and their effects on the delivered dose were estimated for D90% of HR-CTV.

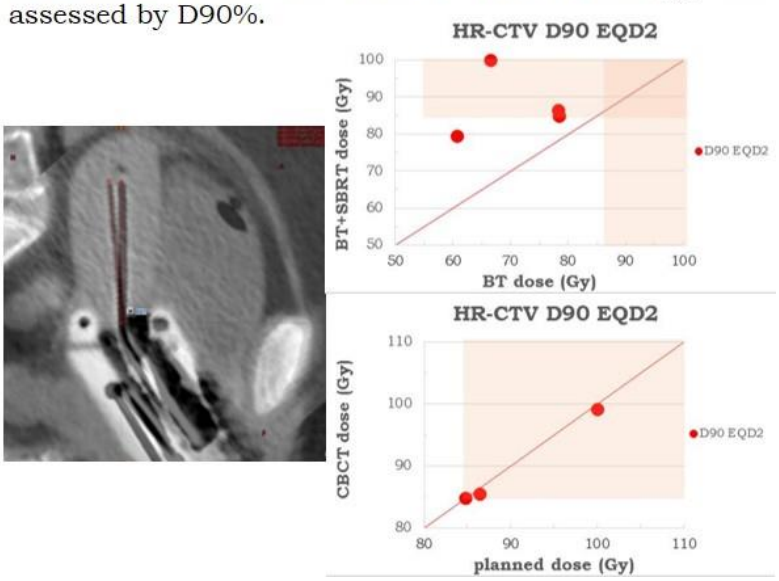
Results
In each BT+SBRT fraction, variations in OARs (volume, shape and/or position) always occurred between planning CT and treatment, resulting in intra-fractional dose differences. Their mean values for EQD2cc were: 9.1%$\pm$3.2% (range 6.1%-11.9%) for bladder, 1.4%$\pm$1.5% (range 0.%-3.%) for rectum, and 0.1%$\pm$1.6% (range -1.1%-2.4%) for sigmoid. Yet, the dose constraints for OARs were met in all patients for rectum, but failed for bladder and sigmoid in one patient.

Figure 1. Example of OARs variation observed during the time between planning CT and CBCT acquisition. For this patient, bladder, rectum and sigmoid show some variations, along with gas moving in the rectum and bowel. Comparison between the planned and CBCT individual $EQD2_{2cc}$ of bladder, rectum and sigmoid.



Small rotations of the applicators between planning CT and CBCT were noticed, with mean values of: -3.2±1.9deg in the roll, 0.1±2.9deg in the pitch, and 0.±1.7deg in the yaw direction. They did not detrimentally affect the HR-CTV D90%.

Figure 2. Example of residual applicator rotations. Their values reach 5.6 deg in the roll, 5.1 deg in the pitch and 3.3 deg in the yaw direction, with no remarkable effect on HR-CTV dose coverage, as assessed by D90%.



Conclusion
Cautious image-guided verification of the SBRT is mandatory when combining this treatment with intracavitary BT. OARs intra-fraction dose variations occur and might exceed their clinical threshold level. The HR-CTV coverage appears to not be affected by small rotational set-up errors. We managed to deliver a therapeutic dose to the HR-CTV while keeping the OARs acceptable in most patients.

Poster: Head & Neck

PO-0199 HDR brachytherapy as a salvage therapy in head and neck cancers

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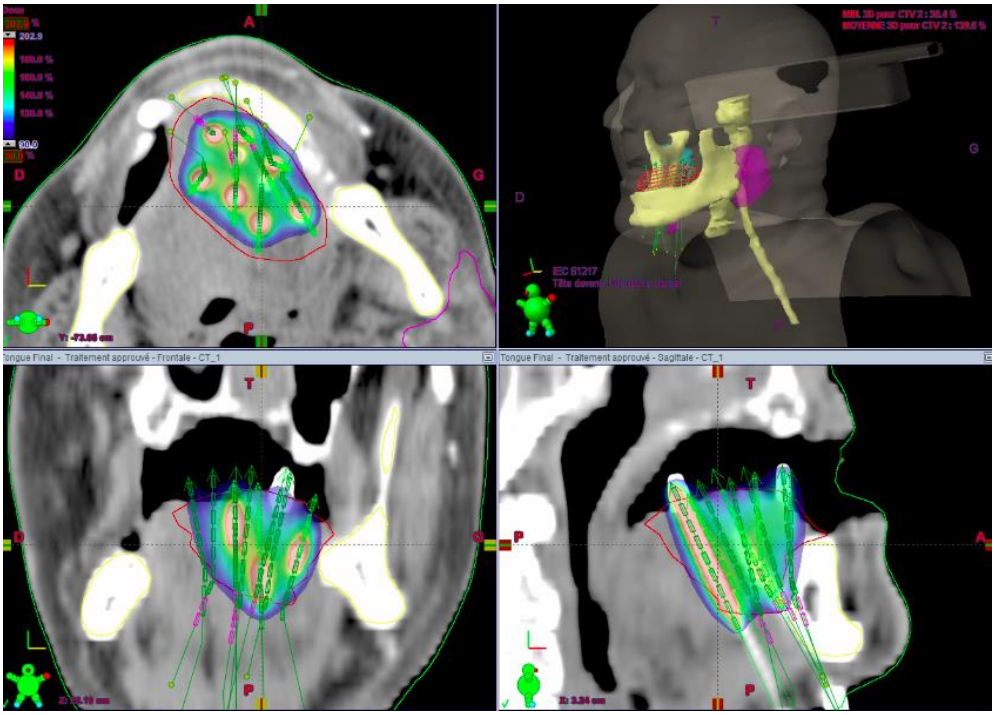
Purpose or Objective
HDR brachytherapy is still the best conformal radiotherapy technique. It is less expensive than any EBRT technique and could be used in developing countries as a curative intent or a salvage option and in some rare cases as palliative intent. We report our experience in its use as a salvage treatment in pre irradiated sites of head and neck cancers

Materials and Methods
This is a retrospective study of 9 patients : 8 with with nasopharyngeal cancer recurrence and 1 with oral tongue recurrence collected in the radiotherapy department of the University Hospital Hassan II in Fes between January 2014 and December 2019.

All patients with nasopharyngeal cancer received external radiation therapy at 70 Gy on macroscopic tumor volume (tumor and lymphadenopathy) during initial irradiation with or without chemotherapy. The patient with squamous cell carcinoma of the tongue had surgery (tumor excision with lymph node dissection) and adjuvant chemoradiotherapy at 60 Gy with concomitant cisplatin.
All recurrence were histologically proven.
For nasopharynx : Relapse was localized in 5 patients and associated with lymph node involvement in 3 patients. For the oral tongue : it was localized.

Concerning the technique of brachytherapy :
Intracavitary brachytherapy with Rotterdam applicator was used in nasopharyngeal recurrences : 2 patients received exclusive high-dose-rate brachytherapy at a dose of 30 Gy in 10 fractions and 6 received external radiation radiotherapy followed by brachytherapy (40 -50 Gy in EBRT followed by brachytherapy boost of 2-4 x 3 Gy.

Interstitial brachytherapy with flexible needles was used for the local recurrence of the oral tongue with trans-submandibular insertion at a dose of 12 x 4 Gy.



Results
The average age of our patients is 42 years old. There were 1 woman for 8 men. The mean time from symptoms to consultation was 6 months. Histology of nasopharyngeal carcinoma was WHO III and SCC for the oral tongue.

The average time to onset of relapse is 29 months.
With an average follow-up of 20 months, 37.5% of NPC patients and the patient with oral tongue recurrence are alive and in complete remission.

Conclusion
Brachytherapy alone or after EBRT could play an important role in reirradiation of locally recurrent Head and Neck cancers with acceptable toxicity

Poster: Physics

PO-0200 Comparison of catheter position planning algorithms for HDR prostate brachytherapy under uncertainty

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Purpose or Objective
The purpose of this work was to compare two optimization algorithms for catheter position planning for HDR prostate brachytherapy while taking into account uncertainties in organ reconstructions and actual catheter placement. We considered the Multi-Objective Real-Valued Gene-pool Optimal Mixing Evolutionary Algorithm (MO-RV-GOMEA) and the adapted Centroidal Voronoi Tessellations (CVT) algorithm. MO-RV-GOMEA optimizes directly on dose-volume indices, whereas CVT optimizes on the distribution of the catheters in the target volume(s). To calculate dose-volume indices, a reconstruction algorithm is used to determine the 3D organ shape from 2D contours. We take into account the uncertainties associated with changing the settings of the reconstruction algorithm.

Materials and Methods
The ultrasound data of 20 prostate cancer patients treated with HDR brachytherapy was used, obtained at the time of catheter placement. Catheter position optimization was performed with MO-RV-GOMEA in 5 minutes, and with CVT in seconds. Catheter positions were restricted to be inside the prostate or seminal vesicles, and outside of urethra, rectum, and bladder. The variation of actual catheter placement was simulated by randomly displacing all catheters independently by 1 mm in the insertion plane. Next, dwell times were optimized with MO-RV-GOMEA in 15 minutes. For a given treatment plan, L is the smallest difference between the dose-volume indices and their corresponding planning-aims in the clinical protocol:

$$\mathrm{L} = \min \left\{ \begin{array}{c} V_{100\%}^{\mathrm{prostate}} - 95\%, V_{80\%}^{\mathrm{vesicles}} - 95\%, \\ 86\% - D_{1\mathrm{cm3}}^{\mathrm{bladder}}, 74\% - D_{2\mathrm{cm3}}^{\mathrm{bladder}}, 78\% - D_{1\mathrm{cm3}}^{\mathrm{rectum}}, 74\% - D_{2\mathrm{cm3}}^{\mathrm{rectum}}, 110\% - D_{0.1\mathrm{cm3}}^{\mathrm{urethra}}, \\ 50\% - V_{150\%}^{\mathrm{prostate}}, 20\% - V_{200\%}^{\mathrm{prostate}} \end{array} \right\}.$$

If L>0%, all planning-aims were satisfied. A larger L means superior satisfaction of all aims. Dose-volume indices were based on the planning-aim dose of 13 Gy for the prostate, considering 8 possible organ reconstructions. Optimization with MO-RV-GOMEA resulted in multiple plans, of which the plan maximizing L was selected. A hard constraint $V_{200\%}$<0.125N cm^3 for the healthy tissue was used, with N the number of catheters. This constraint was previously designed with a radiation oncologist to avoid hot spots. For each patient, optimization was performed for 10, 12, 14, and 16 catheters, and the median over 10 runs was taken (as MO-RV-GOMEA and the catheter displacements are stochastic).

Results
For 16, 14, 12, and 10 catheters, MO-RV-GOMEA found plans satisfying the planning-aims for 18, 17, 16, and 13 out of 20 patients, respectively. CVT achieved this for 16, 15, 8, and 3 patients, respectively. The patient-wise difference between MO-RV-GOMEA and CVT was statistically significant for all numbers of catheters (p<0.001, Wilcoxon signed-rank test) and at most 1.5%, 2.0%, 3.2%, and 4.3%.

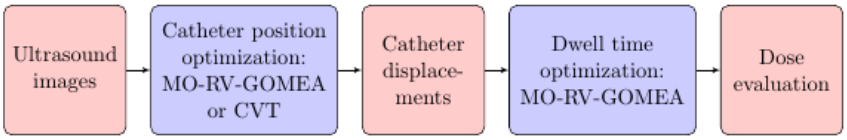

Figure 1. The simulation workflow used to study catheter position optimization with MO-RV-GOMEA and CVT. Purple blocks indicate optimization stages. For catheter position optimization with MO-RV-GOMEA, 20,000 dose-calculation points were used in the healthy tissue. Optimization was performed on 5,000 points per organ, and re-evaluation on 20,000 points per organ. For catheter position optimization with CVT, 100 iterations and 2,500 sample points were used. For dwell time optimization with MO-RV-GOMEA, 100,000 dose-calculation points were used in the healthy tissue. Optimization was performed on 20,000 points per organ, and re-evaluation on 100,000 points per organ.

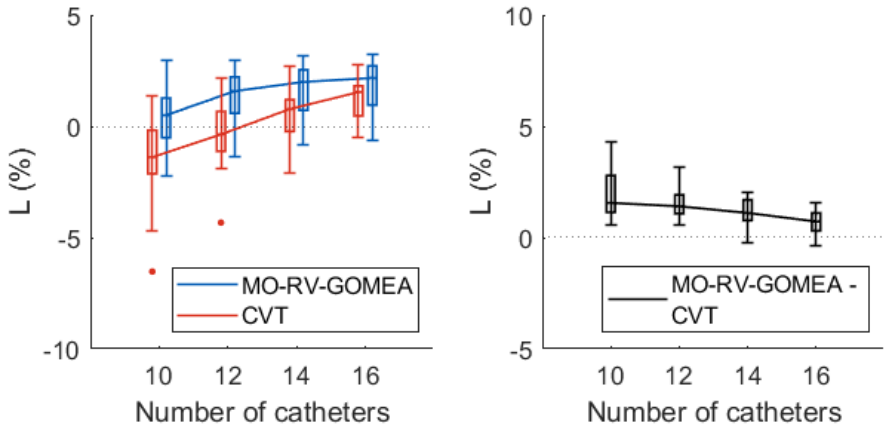

Figure 2. The results for MO-RV-GOMEA and CVT catheter position optimization for 10, 12, 14, and 16 catheters are shown. For each patient, the median over 10 runs is taken, after which a boxplot over all patients is shown (median at 50%, box from 25% to 75%, whiskers at 0% and 100%, excluding outliers based on 1.5 times the interquartile range). The left figure shows the values of L for both MO-RV-GOMEA and CVT (each moved slightly to either left or right for improved visualization). The right figure shows the patient-wise difference between MO-RV-GOMEA and CVT.

Conclusion
Especially for lower numbers of catheters, MO-RV-GOMEA outperforms CVT in finding robust plans satisfying all planning-aims. For most patients however, the difference is small.

PO-0201 A Miniature Robotic System for Interstitial Brachytherapy Needle Insertion

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Purpose or Objective
Precise needle placement in interstitial LDR and HDR brachytherapy can be directly correlated to the quality of the treatment plans, and consequently, to radiation treatment outcomes. In some cases, common complications such as incontinence, permanent urinary symptoms, and radiation proctitis could be avoided with improved treatment planning. In this study, we report the development and pre-clinical testing of a miniature robotic system(MRS) for needle insertion in interstitial brachytherapy.

Materials and Methods
MRS was designed to govern the cannula by two DC-servo motors. One motor drives the needle in transverse direction while the second motor is responsible for continuous or partial needle rotation. Needle insertion is achieved through a timing belt by a motor mounted inside the handle. The rotation motor is mounted near the needle. A set of quick-exchange connectors were designed for efficient needle loading. The system is designed to be lightweight and compact allowing for one-hand operation(Fig.1). Robust proportional, integral and derivative controller(PID) has been developed to govern the system. PID utilized position control while the needle reaches the target. Therefore, the insertion speed is maintained constant during this phase. In the insertion phase, the needle is inserted using variable speeds through position and force control to allow for accurate needle placement to the predefined position. To evaluate the functionality of the system, a phantom study was performed (Fig.2).

Results
The following parameters were confirmed during the functionality testing: the maximum needle insertion depth was 150 mm, the insertion force was up to 25 N, the maximum insertion speed was 100 mm/s, the maximum rotation speed was 20 rps, and the maximum torque was 47.75 Nmm. The device dimensions were 270 mm x 230 mm x 56 mm in length, height, and width, respectively. The phantom study revealed submillimeter accuracy in needle placement only if the needle rotation was engaged. Needle replacement was uncomplicated due to the quick-exchange connectors.

Figure 1: Miniature robotic system; a) a model – 3D printed prototype, b) fabricated testing device; (1-handle, 2-forward motor, 3-pulley, 4-rotating motor, 5-quick-exchange connector, 6-guide mechanism, 7-limit switch, 8-guide rail, 9-force sensor)


Figure 2: Needle insertion in gelatin phantom; a) full view, b) detailed view

Conclusion
The implementation of the proposed robotic system can potentially improve dosimetry in both the HDR and LDR brachytherapy procedures. This study reveals that automatic needle insertion is feasible and efficacious. The automated needle insertion device delivers the needles into the desired location more precisely within a shorter period.

PO-0202 commissioning of a Venezia applicator: discrepancies between expected and actual source positions

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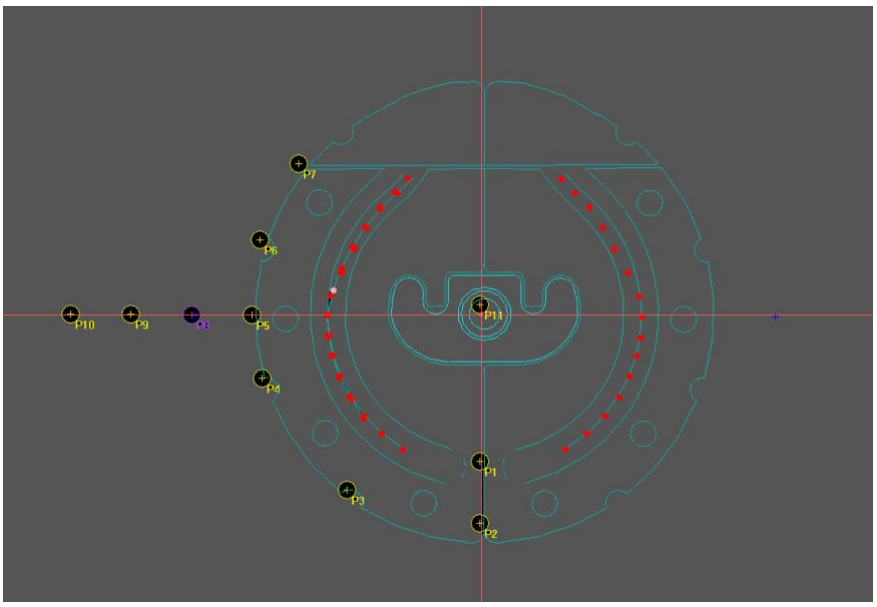
Purpose or Objective
The Venezia Advanced Gyneacological applicator developed by Elekta is an insterstitial-intracavitary hybrid applicator. This work reports on some discrepancies encountered between the expected dwell positions and the actual source positions in the commissioning process of the 26 mm diameter Venezia applicator.

Materials and Methods
We obtained and compared the most distal source position in relation to the applicator by three methods: i) using the Oncentra applicator library (central path (C) and "real" source path (SP)); ii) by auto-radiography (AR) using Gafchromic EBT3 (a distance of 1300 mm was entered following manufacturer specifications); and iii) X-Ray imaging (RX) with the Varian OBI imaging system. For the last, the source trajectory was reproduced with a dummy source and the applicator was held in horizontal position in order to simulate clinical conditions.

Results
A relevant deviation from the expected was detected for the first position in the semilunar ovoid 2 (Ov2, table 1) when using auto-radiography: 3mm to that predicted by SP. After further investigation, we determined that the source was not able to reach positions beyond the 4th position, which resulted in an overdosage at that position. This problem was attributed to internal friction, although Flexitron did not warn about any obstruction.



Geometry	Ov1 (mm)	Ov2(mm)
Central	6.4	6.4
Source path	6.8	6.8
X-ray	5.6	6.6
Autoradigraphy	6.6 ± 0.1	9.8 ± 0.1

Dosimetry	
P1	10.3%
P2	5.1%
P3	2.0%
P4	-2.9%
P5	-0.5%
P6	0.0%
P7	3.3%
P8	-0.9%
P9	0.0%
P10	0.7%
P11	3.4%

In order to establish possible clinical implications if the defect had not been detected, we calculated differences in dose delivery (shown in table 2) at several points around the applicator (image 1). Calculation was performed using the TG43 algorithm implemented in OncentraBrachy 4.5.3. treatment planning system.

Conclusion
Despite the resulting dosimetric differences not being relevant clinically in principle (points 3 to 10), the Ov2 was replaced with a new one. The commissioning of the new Ov2 resulted in no important geometric discrepancies (less than 1mm).
Brachytherapy entails a lot of uncertainties, so all personnel involved should ensure that uncertainties are minimized. Specifically, the medical physicist should perform the necessary measures to know in detail their applicators and ensure that they are suitable for clinical use.

PO-0203 Range of intra-fraction dose uncertainty in cervical cancer HDR brachytherapy.

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Purpose or Objective
Organ at risk (OAR) motion causes intra-fraction dosimetric uncertainties. To minimize its impact, OAR preparation protocol, repeated imaging and re-planning are needed. The aim of this project is investigate dosimetric uncertainties of MR-based IGABT.

Materials and Methods
216 patients received radio-chemotherapy and HDR BT (4 fraction of 7Gy delivered within 2 different applications). After implantation, CT/MR scan were taken. HRCTV and OAR were delineated according GEC ESTRO recommendations and treatment was optimized directly on MR dataset. The following day a new MR/CT scan was carried out and dose distribution was re-optimized according to actual OAR position. Overall planning aim (EBRT+BT Gy_{EQD2}) was HRCTV D90 >86 Gy; Bladder D2cc <90 Gy; Rectum D2cc <70 Gy; Sigmoid D2cc <75 Gy. For this study we simulated a virtual scenario where the 2nd and 4th fractions were delivered without re-optimization (reusing plans of 1st and 3rd fractions). We compared dosimetric results of both scenarios (virtual vs. real). A sub-analysis was carried out to evaluate which characteristics of the applicator/tumor have an influence on the dosimetric variations observed.

Results
Intra-fraction variability magnitude for OAR and HRCTV is shown in Fig.1. No-replan protocol patients with >2Gy increase OAR dose (or >2Gy decrease of HRCTV dose) were 17 (7.9%) for bladder, 17 (7.9%) for rectum, 73 (33.8%) for sigmoid, and 19 (8.8%) for HRCTV. Nevertheless, a dosimetric uncertainty causing a violation of dosimetric constraints was less common, being observed in 12 (5.6%), 6 (2.8%), 13 (6%) and 11 (5.1%) for HRCTV, bladder, rectum and sigmoid, respectively. The range of dosimetric uncertainty correlates with the type of applicator used (T-O vs Vaginal Cylinder), the volume of packing (>95cc) and tumor characteristics (FIGO stage III-IV vs. I-II).

Conclusion
Intrafraction Uncertainty is still a problem especially in conditions where repeated imaging and replanning is not at hand. Our results suggest that is maybe possible to find out subgroups of patients with different risk of potentially dangerous intrafraction variability.

PO-0204 Towards an absolute dosimetry for 192-Ir high dose rate sources with micro-ionization chamber

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Purpose or Objective
To establish a method for the direct measurement of the absorbed dose delivered by ^{192}Ir high-dose-rate (HDR) brachytherapy (BT) sources using a PinPoint 3D ionization chamber. After a literature review, a quality control procedure for the absorbed dose-in water is developed and included in the quality assurance of the GammaPlus iX HDR unit (Varian Medical Systems) belonging to UHNM.

Materials and Methods
The dose to water in water medium (D_w) can be determined from the detector measurement in a phantom material using the following proposed formalism [D. Baltas, L. Sakelliou, N. Zamboglou, *The Physics of Modern Brachytherapy for Oncology*, 2009]:

$$D_w = M \cdot ACF \cdot DCF,$$

$$DCF = N_{K,Q}^{cross} \cdot k_{ch,Q} \cdot k_{\rho} \cdot k_{ion} \cdot k_{ph} \cdot (1 - g_{\alpha}) \cdot \left(\frac{\mu^{en}}{\rho}\right)_{\alpha}^{w}$$

$$N_{K,Q}^{cross} \cdot k_{ch,Q} = N_{K,Q_0}^{cross} \cdot k_{ch,Q_0} \cdot k_{Q,Q_0} \cdot k_V \cdot k_{ap},$$

Annual cross-calibrations have been performed between the field instruments (PTW 31016 PinPoint-UNIDOS electrometer) and a National Physics Lab secondary standard (NE2611) as reference detector, in a Gulmay D3300 machine by means of simultaneous irraditions in a Perspex phantom. For this aim, the calculation of the cross calibration factors for a Half Value Layer of 2.0mmCu is derived from the IPEM X-rays Code of Practice.

For the absolute dose measurements in BT, single line plans are delivered with the normalization of 1.0Gy in the effective point of the chamber (nominally located at 4.8cm from the closest dwell position). A CT scan of the BT slab phantom is used, with an insert which hosts consistently the chamber and a 6F-source guide.

Results
The data are recorded in a software developed in Visual Basic 2010 which enables the user to add, delete and compare the results with the expected values estimated by BrachyVision Treatment Planning System (TPS) and Monte Carlo general purpose code Geant4 within a data-table. On average, the measured absorbed dose over the last 3 years has been: 102.3± 1.0 cGy (k=2).

Overall, the results show a satisfactory agreement between measurements and expected values by independent theoretical estimations. The discrepancy in the mean differences is less than 3%, what is a tight tolerance given the existing limitations in this field.

The expanded uncertainty for every measurement has been 4.0% (k=2), estimated by quadratic propagation of the variance. This is slightly lower to the estimation found in the literature for TLDs, MOSFETs, radio-chromic films and semiconductor detectors.

Conclusion
This work provides a necessary framework for a shift from indirect ^{192}Ir BT dosimetry to a more accurate, direct and absolute measurement of absorbed dose to water.

Apart from describing the methodology and the necessary correction factors, this study includes a detailed uncertainty analysis for the measured absorbed doses, thus providing sufficient confidence in the reported results. The experimental values obtained show a good agreement with the expected numerical simulations and all lie within 5%. Likewise, it involves a more realistic uncertainty estimation for absorbed dose to water determination compared to the determination based on air-kerma strength in the TG-43 protocol.

PO-0205 Deep learning for automated applicator reconstruction in high-dose-rate prostate brachytherapy

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Purpose or Objective
To develop a deep-learning-based algorithm that automates the segmentation of treatment applicators on CT images for high-dose-rate (HDR) brachytherapy prostate patients implanted with titanium needles. The automation of applicator reconstruction can improve quality and consistency, while reducing the time that the patient is under anesthesia.

Materials and Methods
A U-Net deep learning algorithm was developed to perform applicator digitization on CT images for HDR prostate brachytherapy treatment planning. The algorithm was trained using approximately 50,000 patient images generated from 26 distinct patient data sets using data augmentation with random rotations and noise. The patient DICOM CT image files were obtained using a standard reconstruction filter, a 50 cm nominal field of view, 0.977 mm to 1.25 mm slice thickness, and 512 x 512-pixel resolution. CT images were cropped to a 30 cm field of view and resampled to a uniform 0.5 mm x 0.5 mm x 0.5 mm voxel resolution for this study. The data sets were divided into 16 patients for training and 10 patients for validation. Each patient was implanted with between 15 and 20 titanium needle applicators. DICE score was used as the U-Net's loss function for training and testing the deep learning algorithm. The model was trained on a GPU cluster to produce a normalized probability map of the likelihood that a pixel lies inside of an applicator. A global threshold of 0.8 was used to discriminate the applicator points from non-applicator points. HDBScan, a density-based clustering algorithm, was used to assign the applicator points to distinct applicators.

Results
The deep learning algorithm converged after 36 epochs and a runtime of 6 hours using a single CPU. Figure 1 illustrates the algorithm performance on a representative CT image. The distribution of the DICE scores for all applicators from 25 patients is provided in Figure 2A. The median DICE score was 0.90, which is consistent with previously published results for metal applicator digitization on CT images. Density-based clustering provided an 'off-the-shelf' solution for the assignment of applicator points to distinct needles (Figure 2B)

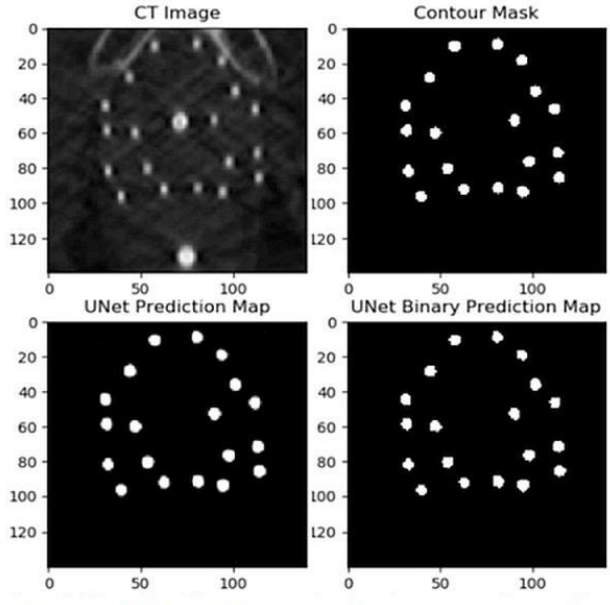

Figure 1: Illustration of human versus deep learning contours. The metallic needle applicators in CT images (upper left) can be identified by their relatively large HU values compared with soft tissue, as well as their circular shape. In this example, the human-performed contour mask (upper right) that was obtained from the DICOM structure file was in close agreement with the U-Net probability map (lower left), as well as the final output (lower right) after a 0.8 probability threshold was applied to the U-Net probability map.

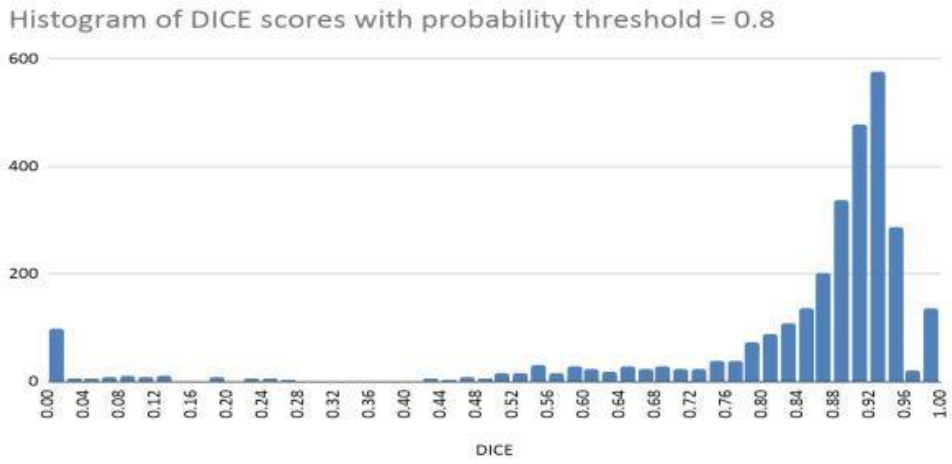

Figure 2A: DICE score distribution from all patient applicators (N=25 patients). The median DICE score was 0.90. The DICE score of zero represents circumstances where the U-Net mislabeled patient tissue voxels as applicators.

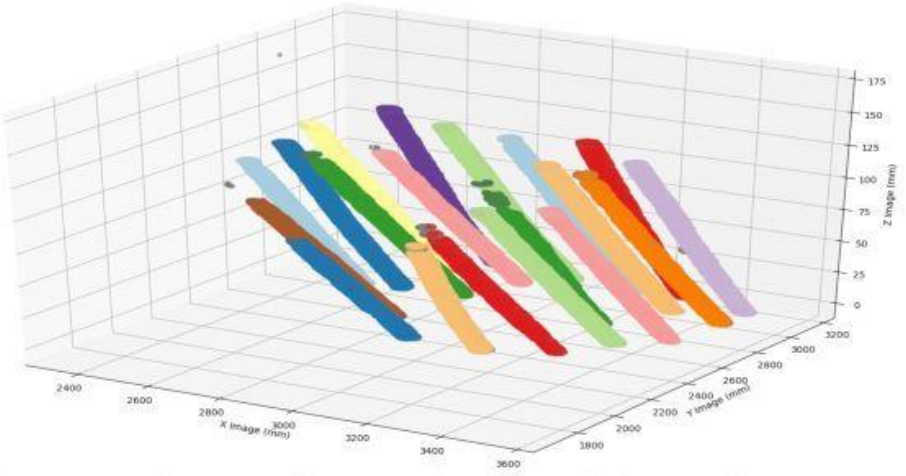

Figure 2B: Assignment of segmented voxels to distinct applicators. A density-based clustering algorithm, HDBScan, was used to cluster all of the segmented voxels into distinct needle applicators. Each color represents a distinct needle applicator.

Conclusion

Deep learning algorithms are an effective strategy for automating the digitization of brachytherapy applicators, and a 2-dimensional U-Net approach provided an excellent correspondence between the automated and human segmentations for prostate treatments using titanium needles. The automation of brachytherapy applicator digitization is expected to improve the consistency, efficiency, and quality of brachytherapy treatments.

PO-0206 A dosimetric index to assess cervix brachytherapy implants: Dovix

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Purpose or Objective

The aim of this study was to introduce the Dovix index (*I*). This is a new dosimetric index that takes into account the objective and tolerance doses for CTV and OARs introduced by the EMBRACE II study and the dosimetric data coming from the HDV of the HDR cervix brachytherapy implant.

Materials and Methods

392 patients treated between 2010 and 2019 in three different institutions were analysed. Several information of each patient was gathered: volume of CTV HR, number of interstitial component (needles), date, D_{90} of CTV HR and D_{2cc} of bladder, rectum and sigmoid. The statistical distribution of these magnitudes was analysed for each institution split into two periods of time; before and after the EMBRACE II protocol. The introduced index is based on the collected dosimetric magnitudes (D_{90} and D_{2cc}) and it rewards the equilibrium between coverage to CTV HR and doses to the OAR. The index has

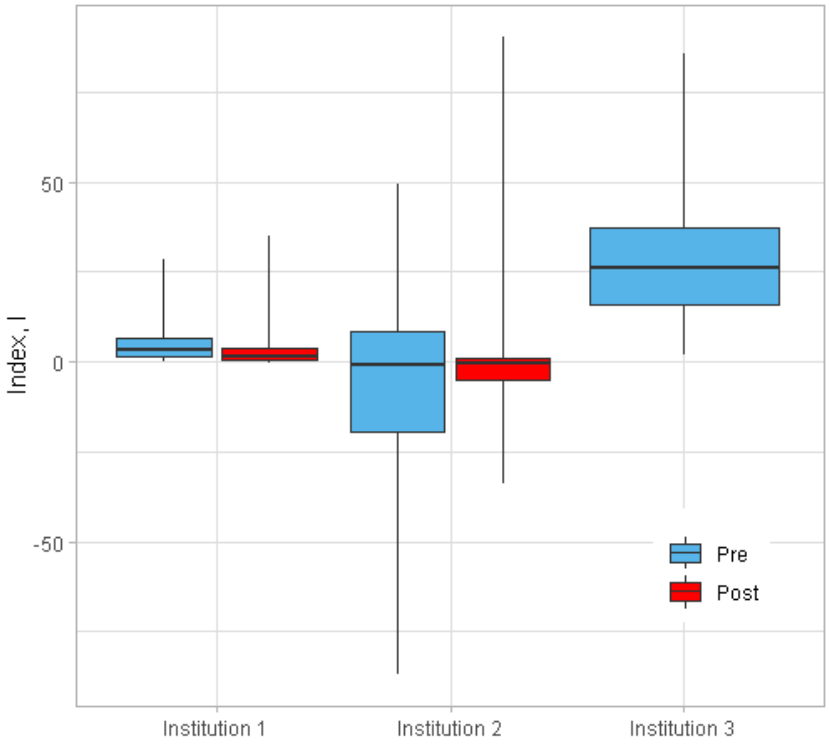
$$I = I_{CTV} * I_{OAR} = \left(D_{90}^{lim}/D_{90}^{obj} - D_{90}/D_{90}^{obj}\right) * \left(D_{2cc,bladder}/D_{2cc,bladder}^{obj}\right) * \left(D_{2cc,rectum}/D_{2cc,rectum}^{obj}\right) * \left(D_{2cc,sigmoid}/D_{2cc,sigmoid}^{obj}\right)$$

been defined as:

where D_{90}^{obj} y $D_{2cc,i}^{obj}$ are the objective doses (in EQD2) for the CTV HR and the tolerance levels for the different OAR and D_{90}^{lim} is the upper limit dose for the CTV HR. It has to be bear in mind that this objective and tolerance doses referred only to the BT component. All implants were assessed by the Dovix index. An evaluation of the dependence of the introduced index with the CTV HR volume and its evolution through the studied period was also performed.

Results

Implants with higher interstitial component and lower CTV HR volumes had a better assessment from the Dovix index. The adaptation of the institutions to the EMBRACE II protocol was shown as a tendency over time of the index towards its optimal value, I = 0. Moreover, this adaptation was not found to be the same in all institutions. Institution 1 had a statistically significant increase on D_{90} of CTV HR while institution 2 had a decrease of D_{2cc} of all OARs.



Conclusion

The introduced Dovix index was able to assess the HDR cervix BT implants and capture the different strategies followed by the institutions, the difficulty of coverage of high CTV HR volumes and the dosimetric enhancement coming from the interstitial component.

PO-0207 Radiation protection preparedness using LASAIR in case of malevolent use of brachytherapy sources

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Purpose or Objective
Ir-192 is one of the most used radioisotopes for cancer treatment with brachytherapy. Many of the Ir-192 sources are shipped throughout the European Union to and from hospitals or companies. The sources have high activity and should be considered as a possible health threat if stolen or lost. There is nowadays also a fear of terrorist actions involving radioactivity. In this context, the Swedish Radiation Protection Authority recently issued a call for improving dosimetric preparedness and competence to cope with large emergencies involving various sources of radioactive material, including those used in brachytherapy clinics. The aim of this study was to simulate a radiological dispersion device using brachytherapy Ir-192 sources as in a malevolent attack in order to increase awareness of the effects of improper disposal, transportation or storage at the clinic.

Materials and Methods
Two main scenarios of relevance for radiation protection officers at brachytherapy clinics, and for the society in general, involving a radiological dispersion device as well as the transportation of Ir-192 sources were simulated. They were based on a scenario in which brachytherapy sources temporary stored at the hospital before being picked-up by the vendor for being disposed were stolen. The accidents and the attacks were assumed to happen in strategic places in Stockholm based on three infrastructural targets: political, communication and healthcare.
The dispersion of the radioactive debris was simulated using the the decision support system LASAIR (Lagrange-Simulation of the dispersion and Inhalation of Radionuclides). The total activity from all sources was calculated and summed up as source input. The amount of explosives and the source activity is classified; hence the results are only presented as dose rates and total deposition.

Results
Figure 1 shows the total deposition of the radioactive compounds 5 minutes after the events in both scenarios. A large area of Stockholm was exposed in the simulations mostly because of the meteorological conditions that were similar for both scenarios. In case of fire, as plausible in the transportation accident scenario, the radioactive fallout was taken longer time than in the situation of an explosion. After 30 minutes of fire it was assumed that all radioactive compounds were dispersed leading to approximately the same results in terms of total deposition as in the case of explosion.

Conclusion
Radiological preparedness involving brachytherapy sources can be developed through studying close to real life scenarios simulated in LASAIR. The dispersion of radioactive debris will be influenced by the meteorological conditions and the urban landscape.

PO-0208 Do the results improve when using inverse planning multi-solution tool in HDR prostate BT?

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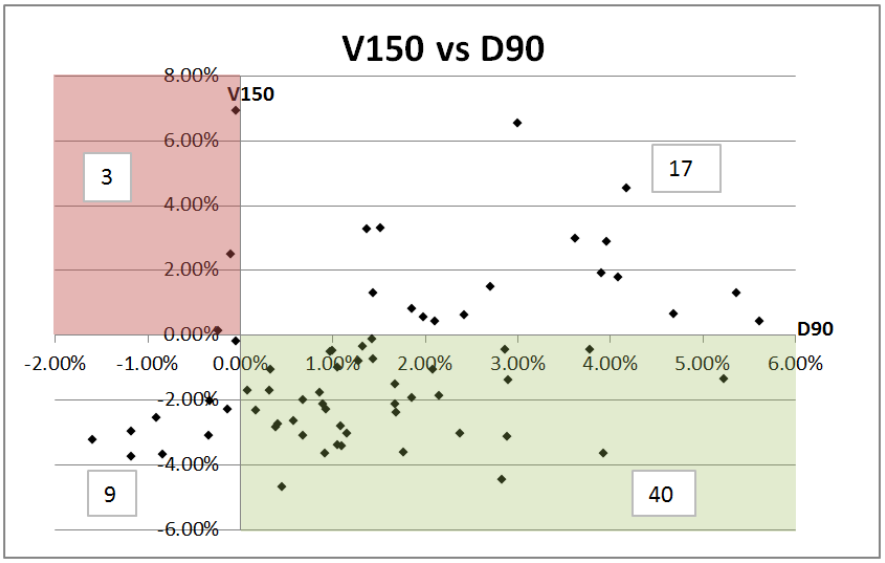
Purpose or Objective
When planning HDR prostate treatments, it is very common to use inverse dose optimization. Oncentra Prostate (Elekta) planning system incorporates a *multi-solution* tool, which offers various solutions for the same initial optimizing parameters. The aim of this study is to compare relevant dosimetric parameters obtained using two modes of inverse planning: direct solution and multi-solution tools

Materials and Methods
The needle distribution and the active dwell positions were manually entered into the treatment planning system (TPS) based on the acquired US images, whereas dwell times were computed making use of the inverse planning. The Direct Solution (DS) is obtained calculating inversely on dose and weighting factors entered by the user. On the other hand, the multiple solution tool (MS) offers different possible plans, which are obtained by slightly modifying the initial parameters introduced for the DS. The user is then allowed to filter solutions by applying selection criteria based on dosimetric parameters. Our filtering criteria included the following: D90>105% and V100>95% for the CTV, D1cc<120% for the urethra and D2cc<75% for rectum. Visual review of isodoses was also made, in order to check the dose received by normal tissue. In all cases we prioritized that organs at risk did not worsen when selecting a plan from among all those offered by the TPS.

Results
The analysis performed for a total of 69 treatments showed that MS plans improve significantly CTV parameters: V150 was reduced in 71% of the cases (mean value of 2.19%, reaching a maximum of 4.67%) while D90 was increased in 82% of the cases (mean value of 2% and a maximum of 5.61%). The variation in OAR doses is not relevant in this study due to the selection criteria applied for MS plans, but in most of the cases a reduction of the D90 was accompanied by an improvement in the D1cc of the urethra (9 out of 12 cases).
We also appreciated a slight increase in time when using the MS tool, going 15 min compared to the about 10 min needed for DS.



Conclusion
The MS tool generally results in an improvement of the doses delivered, especially in terms of coverage of the CTV, reducing typical hot spots created in brachytherapy. The increase in planning time is not significant if we take into account all the time needed for making the implant and the treatment time. Furthermore, this increase in time is outweighed by the dosimetric improvement implied by the MS inverse planning, which makes it, in conclusion, a useful tool.

PO-0209 Practical considerations on the use of EM tracking technology for clinical HDR brachytherapy

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Purpose or Objective
The electromagnetic tracking (EMT) system for intra-op US based HDR brachytherapy is a new technology for tracking and automatic reconstruction of catheters. The aim of this work is to summarise the challenges pose by the technology and how to tackle them

Materials and Methods
The *Uronav Therapy* system from *Philips Disease Management Solutions* was commissioned and integrated in our clinical practice (Fig.1). The calibration of the EMT to the US image is a crucial step, and to obtain good results, a list of conditions should be respected. The calibration validation must be done at the OR with the same clinical set-up and in a US compatible prostate phantom. The clinical use of that system also comes with special requirements starting with the patient set-up, equipment used around the system, etc. Finally, organ delineation and catheter's tracking also come with challenges. Various solutions were explored and are presented

Results
A critical step to ensure accurate results is the registration of the EMT reference frame to the US. This needs to be done in accordance to TG-128 (salty water - 43g/L). No metal part should be within the EM field. A small metal rod hidden in our water container hinge introduced an error up to 1.8mm. This further includes any support with metallic parts used to hold the calibration phantom. Another aspect is the clinical environment. Metallic parts on the OR table can create EM disturbances and introduce errors (Fig.2). In our set-up, the distance between the EM generator and the table stand needs to be more than 70cm to avoid disturbance, which translate in error of 2mm on tip positions and height of reconstructed catheters. Cell phones, metal clamps and so on shouldn't be placed close to the EM field, as they introduce error relative to the calibration up to 2mm. However, stirrups as well as surgical or vasectomy clips did not show any effect. In this trial, no patient with pacemaker, neurostimulator, implanted insulin pump, hip or knee prosthesis was allowed in order to avoid disturbance. Finally, the stylet used for EM tracking and automatic reconstruction is not rigid enough to allow for an easy tissue perforation, but stiffer than the source cable, sometimes introducing catheter motion during retraction with an AP shift of the tip up to 3mm. Thus, it remains important to visualize the reconstruction with sagittal live US imaging.

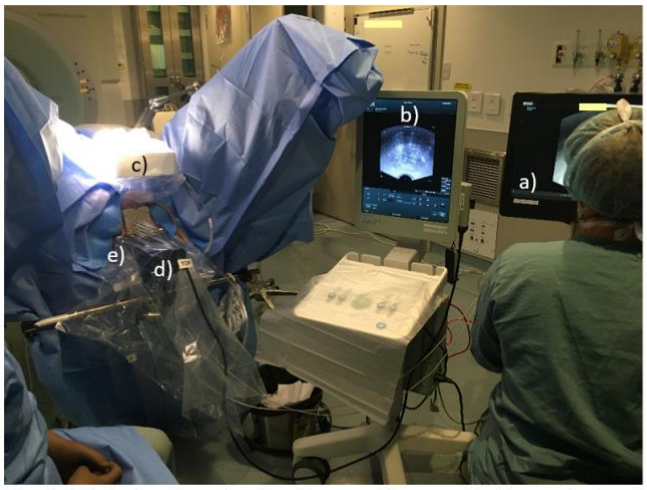

Fig. 1: Clinical set-up for the Uronav Therapy System: a) planning station, b) BK ultrasound with 8848 probes, c) EM generator, d) stepper, e) EM captors

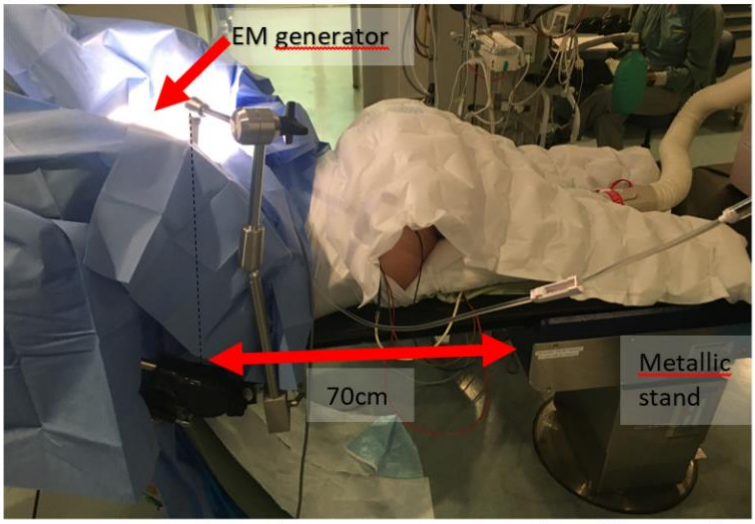

Fig. 2: Distance from the EM generator to the table metallic stand should be more than 70cm to avoid disturbances and influence the calibration.

Conclusion
EM tracking offers the possibility of fast and accurate solution for catheter guidance and reconstruction in US-guided prostate HDR. Pointers were given beyond the vendor provided guidance to avoid potential pitfalls and ensure that the stated accuracy is indeed reached

PO-0210 Status of HDR measurements at PTB

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Purpose or Objective
High dose rate (HDR) brachytherapy sources (^{60}Co and ^{192}Ir) are calibrated at PTB with a calibrated spherical ionization chamber at a distance of 1 m from the source resulting in the reference air kerma rate (RAKR). Likewise, ionization chambers (well-type) are calibrated by means of a calibrated source. For the latter, PTB normally keeps HDR brachytherapy sources (^{60}Co and ^{192}Ir) at its disposal. Since the beginning of 2018, PTB's calibration certificates refer to the data basis of ICRU 90 [1] and are issued with uncertainties of 2.5 % up to 2.6 % (k = 2).
The measurement system for both the source as well as well-type chamber calibrations, has been updated by means of hard- and software.

Materials and Methods
HDR sources and well-type chambers have been calibrated for a considerable time at PTB [2],[3] using an afterloading system to position the source and a robot arm to position the measurement devices. The high-voltage generator for the ionization chambers and the electrometer to measure the ionization currents as well as the software controlling the afterloader and robot arm have been replaced by newer versions. Finally, the laser system for positioning the instruments has been modernized.

Results
The high-voltage generator and the electrometer are PTB made. The electrometer has a leakage current < $5 \cdot 10^{-16}$ A. The current without radiation source is measured at the beginning and end of each measurement and subtracted from the that measured with the source present.
The software is written in Lazarus, a Delphi compatible programming cross-platform. It uses well established components previously utilized at other measurement facilities of PTB.
With the modernized system, positioning is possible with an uncertainty of about ± 1 mm and current measurements with an uncertainty of < ± 0.1 % (both at $k = 1$).

Conclusion
An up to date measurement system is used at PTB to perform calibrations in the area of HDR brachytherapy for both ^{60}Co and ^{192}Ir sources.
Literature

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PO-0211 BrachyClip with I-125 seed

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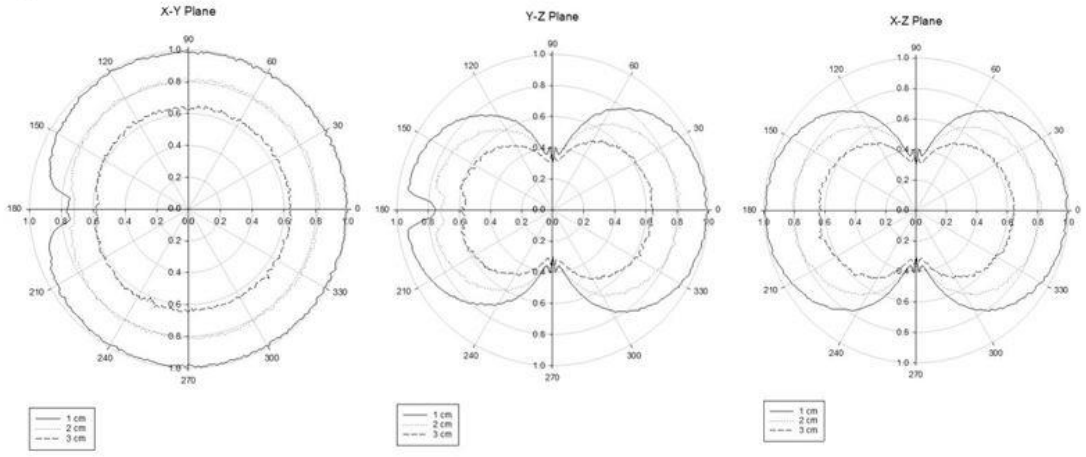
Purpose or Objective
Iodine-125 interstitial brachytherapy seeds commonly are used after lobectomy or wedge resection to treat residual disease and reduce the risk of local recurrence. Using CT guided imaging, the seeds are either sewn into the tissue, or sutured onto a mesh which is then implanted. Yet a limitation to this procedure is a high hand dose to the surgeon.
We propose a novel design to minimize this hand dose- the BrachyClip, which consists of a standard I-125 seed placed in a seed holder tube attached to a ligation clip. These clips are delivered using a custom applicator designed to work with a videothoracoscope port.

Materials and Methods
A standard seed-core is modified with a 3 mm long silver marker with flat ends and coated with an active I-125 layer. This modified seed is enclosed in a titanium shell with a laser weld on each end. It is then placed in a seed holder, which is attached to the clip. Figure 1 shows the BrachyClip design and associated applicator. The BrachyClips are permanently implanted, delivering a dose of 125-140 Gy, from the total decay of the I-125 seed, at a depth of 10 mm from the resection margin. Each seed is about 2 mCi and the seed spacing is 10 mm. The total length of the seed is 4.5 mm and the height of the BrachyClip (containing the seed) is 7.2 mm. A Monte Carlo simulation was performed using MCNP6 to characterize the absorbed dose in the volume immediately surrounding the BrachyClip with the source parallel to the z-axis.

Figure 1

Results
The Monte Carlo simulation was used to calculate the dose to water around the BrachyClip containing a standard I-125 seed, modeled in the "deployed" condition. Figure 2 compares the dose distributions of the BrachyClip on the XY, YZ, and XZ planes in a polar plot at 1, 2, and 3 cm from the source.

Figure 2



Conclusion
The BrachyClip is an alternative approach to interstitial brachytherapy in cancer of the lung. The clip itself contains a standard I-125 seed, which eliminates the need for suturing on the sources. A custom designed applicator combined with high z material is used to deliver the BrachyClips, therefore hand dose to the surgeon would be negligible. The applicator was also designed to be used with a videothoacoscope port. The Monte Carlo dose distributions of this design are encouraging and the next step of this study is to experimentally verify these results using Gafchromic EBT3 film dosimetry.

PO-0212 Use of rectal spacing hydrogel significantly reduces rectal dose in prostate LDR brachytherapy

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Purpose or Objective
Low dose rate (LDR) prostate brachytherapy (LDR-PB) is an effective treatment for early prostate cancer. Used either as monotherapy in low to intermediate risk patients, or in combination with androgen deprivation therapy (ADT) and external beam radiotherapy (EBRT) in patients with more advanced disease. Acute and especially late GI toxicity due to adverse dosimetry of the anterior rectal wall can impact patients' quality of life.
The purpose of this study is to assess whether the use of rectal spacing gel can reduce rectal dose, and therefore reduce the risk of rectal toxicity.

Materials and Methods
A detailed analysis of patients treated with I^{125} LDR-PB was conducted using our prospective patient database. All patients included had a same day, post-implantation CT scan prior to catheter removal with rectal dosimetric analysis, as per local protocol. SpaceOAR hydrogel (SpOAR), a polyethylene glycol based gel, was injected transperineally posterior to Denonvilliers' fascia under ultrasound guidance. In patients treated with LDR-PB as part of a trimodal approach (ADT+EBRT+ then LDR-PB), SpOAR was inserted at the time of fiducial marker insertion under LA. Patients treated with LDR-PB alone, or LDR-PB in combination with ADT, had SpOAR inserted immediately following LDR-PB seed implantation.
Consecutive patients treated with SpOAR were compared with control patients without SpOAR, who were matched for age, clinical stage, Gleason score, iPSA and prostate volume; identified from our database and matched using GenMatch.
The rectal dosimetry assessed was maximum dose received by 0.1cc of the rectum (D0.1cc Gy) and maximum dose received by 2cc of the rectum (D2cc Gy).
Patients were divided into three treatment groups for analysis: LDR-PB monotherapy; LDR-PB+ADT; and trimodal treatment. Using unpaired t-test analysis, with significance set at $p<0.05$, rectal dosimetry was compared in patients with and without SpOAR.

Results
67 patients with SpOAR were identified, with 201 controls matched for age, stage, Gleason score, PSA and prostate volume (Figure 1). 29 patients had BXT alone, 19 ADT + BXT and 19 trimodal therapy.
Figure 1. Baseline characteristics of patients.

	LDR-PB		LDR-PB+ADT		Trimodal	
	SpOAR n=29	no SpOAR n=87	SpOAR n=19	no SpOAR n=57	SpOAR n=19	no SpOAR n=57
Age (yrs)	66	67	72	72	70	70
Stage						
T1-T2b (%)	100	100	100	98	78	77
≥ T2c (%)	0	0	0	2	22	23
Total Gleason score						
<7 (%)	21	17	5	3	0	0
7 (%)	79	83	84	90	58	60
>7 (%)	0	0	11	7	42	40
PSA (ng/ml)	6.37	6.5	10.2	9.85	9.9	9.74
Prostate vol (cc)	30.6	29.6	28	26.6	24	24.3

Patients receiving LDR-PB alone or LDR-PB+ADT were treated to a dose prescription of 145Gy, patients receiving trimodal treatment were treated to 110Gy.
Rectal dosimetric analysis demonstrated significant reduction in rectal doses in patients with SpOAR across all treatment groups ($p<0.05$) (Figure 2).
Figure 2. Rectal dosimetry in patients with SpOAR and without.

	SpOAR	no SpOAR	p value
LDR-PB			
D0.1cc (Gy)	83.37	135.47	<0.001
D2cc (Gy)	54.73	21.94	<0.001
LDR-PB+ADT			
D0.1cc (Gy)	82.53	142.94	<0.001
D2cc (Gy)	51.56	83.07	<0.001
Trimodal			
D0.1cc (Gy)	62.37	115.58	<0.001
D2cc (Gy)	46.99	66.62	<0.001

Conclusion
Use of rectal spacing gels in patients treated with LDR-PB results in a significant reduction in rectal dose. Longer-term follow-up is underway to assess whether this correlates with improved quality of life outcomes.

PO-0213 Development of equidistance marker to predict dwell position for MR-guided cervix brachytherapy

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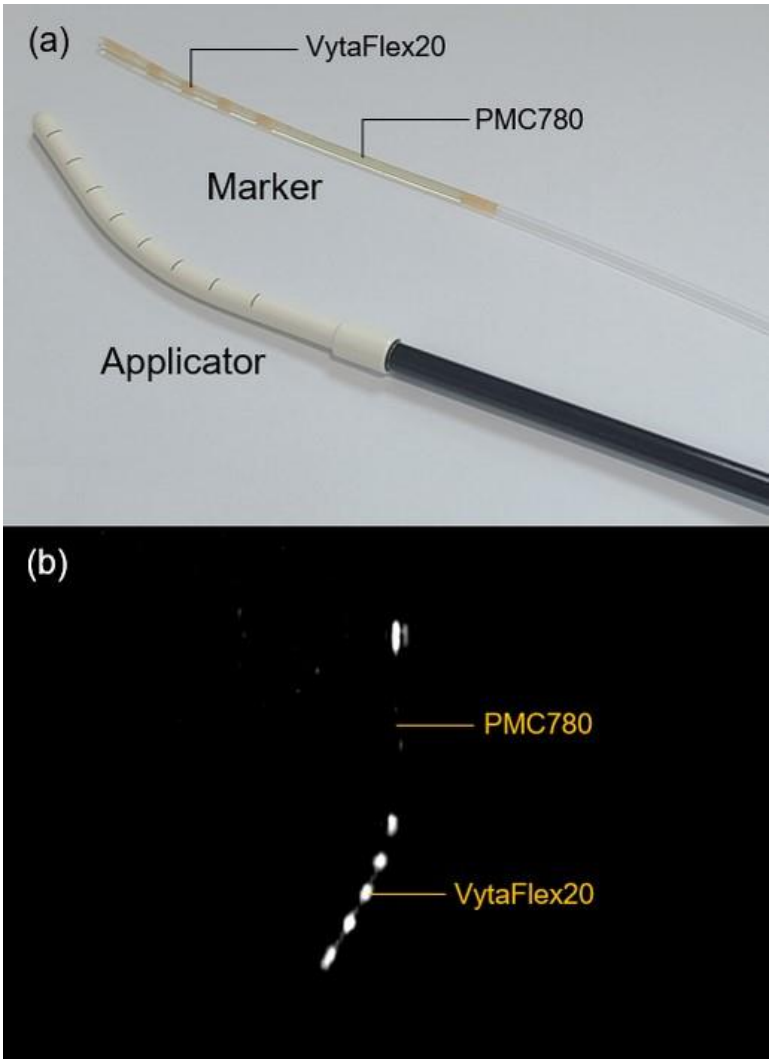
Purpose or Objective
MR imaging-based cervix brachytherapy has advantages such as superior soft tissue contrast and lower dose exposure compared to conventional CT or C-arm imaging-based brachytherapy. However, the conventional X-ray catheter with markers is made of metal. Thus cannot be used in MR-guided brachytherapy. This study aims to develop a equidistant MR marker for MR-guided brachytherapy.

Materials and Methods
MR markers were fabricated by imitating the X-ray catheter for the applicator used in the Nucletron equipment. The marker (Figure 1.a) comprises a high signal intensity component and a low signal intensity component for checking dwell positions. The high and low signal intensity components were fabricated using VytaFlex20 and PMC780 (Smooth-On Inc, USA), respectively. The MR images (Figure 1.b) of the markers were acquired by MRIdian (Viewray Inc, USA) with 0.35 T. A true fast imaging was used with a steady state precession sequence, yielding a T2/T1-weighted contrast. The resolution of the MR images was 1.5×1.5×1.5 mm^3, with an imaging time of 172 seconds, and the field of view was 50×45×43 cm^3. The signal intensity and the distance of markers was analyzed using 3D Slicer.

Results
The mean signal intensity of the VytaFlex20, PMC780 and background were 92±7.83, 22.37±8.66 and 5.87±4.54, respectively. The contrast to noise of the VytaFlex20 and PMC780 were 18.97 and 3.63, respectively. The mean distance between VytaFlex20 marker centers were 10.5±0.08 mm.

Conclusion
We have developed a novel marker that has high sensitive on low magnetic field. The markers may be used in the fletcher applicator for MR-guided cervix brachytherapy, replacing the conventional markers.



PO-0214 Investigation of obstructions in ring applicators during pulsed dose rate cervix brachytherapy

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Purpose or Objective
During intracavitary pulsed dose rate (PDR) brachytherapy (BT) for cervical cancer using ring applicators, intermittent friction or obstruction errors are encountered with the check and source cables, requiring operator intervention. This study ascertains patterns and plausible causes of these errors by analyzing the actual source paths in the rings.

Materials and Methods

Errors from 60 consecutive 58-hourly-pulse BT treatments using Interstitial CT/MR ring applicators on 2 microSelectron PDR afterloaders (Elekta, Sweden) were identified. We evaluated obstruction patterns caused by the check and source cables during both out- and in-drives. To determine the Ir-192 source paths in the rings (diameters of 26 and 30 mm), a portable x-ray machine (GE AMX-4, GE Healthcare, USA) was used to image the source capsule (Fig. 1(a)) at pre-programmed dwell positions: (i) 6 dwells at 15 mm separation (Fig 1(b); illustrates complete path in ring) and (ii) 5-6 dwells at 5 mm separation (Fig 1(c); illustrates capsule position at adjacent dwells). The check cable path was fluoro-imaged when the capsule reached the distal ring end; however, the cable's high travel speed precluded images suitable for drawing conclusions. Repeated runs were performed with the transfer tube in different arrangements (alignment, curvature) relative to the ring to reproduce the obstructions.

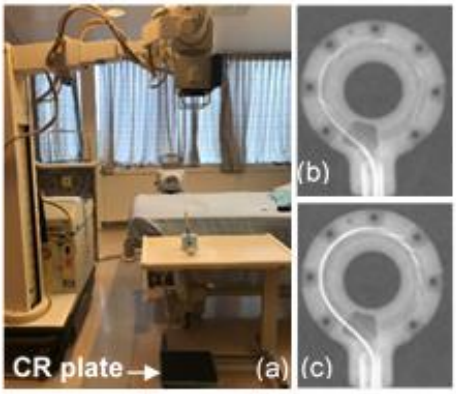

Figure 1: (a) Setup used to image source dwell positions in the ring applicators using a portable x-ray machine and CR plate; 26 mm ring with (b) 6 dwell image at 15 mm separation, and (c) 5 dwell image at 5 mm separation.

Results

In 45 of 60 ring treatments (26 mm (n=37) and 30mm (n=23), the check cable produced in total 625 obstructions, mostly in the curved portion of the ring (81.9% for 26mm (54.9% from 180°-0°) and 78.8% for 30mm (55.7% from 0°-180°)) during out-drive. Only 2 obstructions arose during in-drive. Image analysis showed that the source capsule tip comes quite close to the outer wall of the lumen (width ~ 3.0mm for all rings) near 90° and 270° (Fig 2). With greater drive power for the source cable (~ 10% more), fewer obstructions were encountered: 24 during out-drive and none during in-drive. 15.1% (26mm) and 16.4% (30mm) of obstructions during check cable out-drive occurred at the neck where the source enters the curved ring from a straight path in the shaft. None of the obstructions were reproducible during repeated runs with the transfer tube aligned with the ring. However, with curving of the transfer tube (as can be seen in clinical PDR setups), occasional obstructions could be generated, but only for the 26mm ring, demonstrating the importance of transfer tube alignment with the rings during treatment.

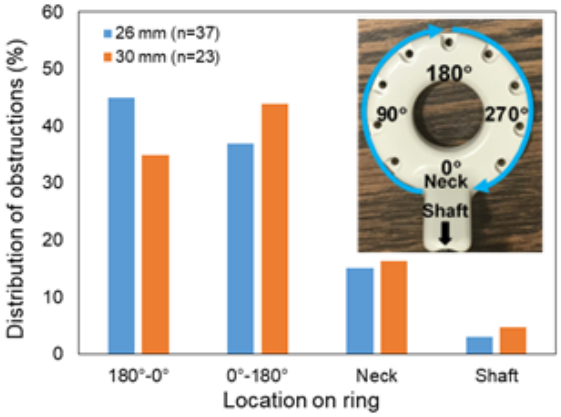

Figure 2: Graph shows the distribution of obstructions of the check cable during out-drive in the 26 and 30 mm diameter rings from clinical treatments. Inset shows the locations, angles, and source path direction used for discussion.

Conclusion
Obstruction errors in cervix BT may be mitigated by delivery in lithotomy setup and ideal transfer tube alignment with the ring, more easily achievable in high-dose-rate BT settings. For PDR treatments with multiple hourly in- and out-drives in the ring, and patient movement during/in-between treatment, frequent transfer tube inspections to maintain path of least curvature between the ring and afterloader indexer head should be performed, particularly for smaller ring sizes.

PO-0215 A novel in-vivo 3D dosimetry device in GYN HDR brachytherapy using Micro Silica Bead TLDs

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Purpose or Objective
Evaluating the potential use of micro silica bead TLDs for point/3D in-vivo dosimetry in high dose rate brachytherapy (HDR BT) of cervical cancers.

Materials and Methods
After assessment the feasibility of using silica bead TLDs for 3D dosimetry in BT in a pelvis phantom, the dose delivered to the rectum and bladder of 30 patients with cervix carcinoma was measured using them. Rectal dose was measured using 80 calibrated bead TLDs arranged on a rectal tube, covered with a layer of gel (Fig.1a). For bladder dose, 10 calibrated bead TLDs were arranged in a linear array inside the balloon of a folly catheter and inserted into the bladder in theater. A TLD reader (Fimel LTM reader, PTW FREIBURG) was used to readout the TLDs. After identifying the 3D position of each bead TLD on the patient's CT images (Fig.1b), the expected calculated dose from the treatment planning system (TPS) was compared with the measured doses. A scatter diagram of the measured and calculated doses for each organ is provided in Fig 1c,d. The measured dose map of the rectal wall was compared with the dose calculated by the TPS using myQA Patients software for each patient

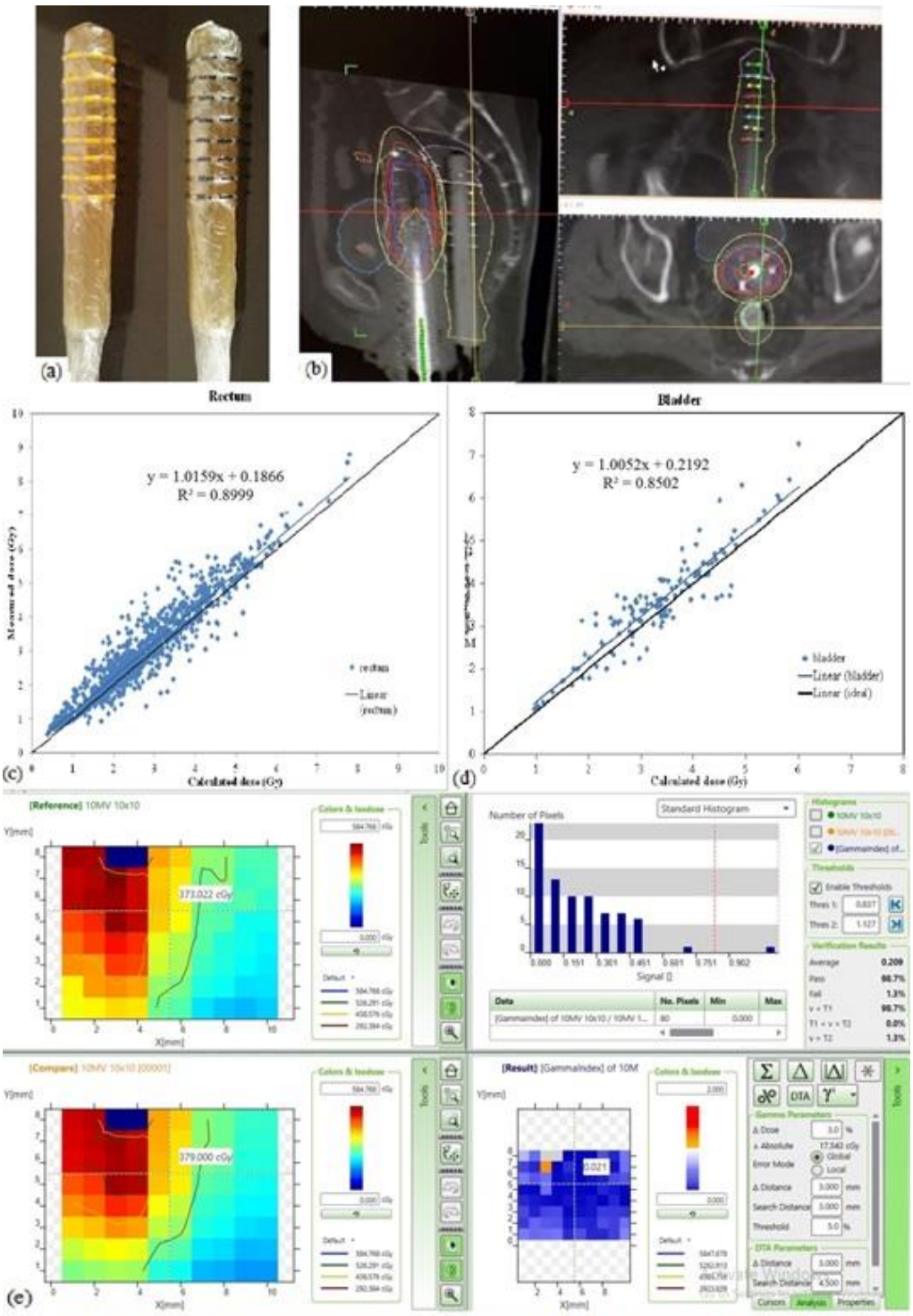

Fig1. (a) A gel-covered rectal tube insertion for placing the bead TLDs into the rectum showing arrangement of silica bead TLDs, (b) CT image of a patient with bead TLDs in the rectum and bladder indicated by colored dots, (c,d) Scatter diagram of in-vivo measured and TPS calculated doses for the rectum and bladder. The parameters for the linear regression, the slope and the intercept and the correlation coefficient are specified. The 'ideal' curve when measured and the calculated doses are equal (no difference) is shown, (e) Gamma analysis performed between measured and calculated doses for a patient's rectal wall.

(Fig.1e).

Results

The mean differences between computed and measured doses after averaging results over all patients was -8.3% ±19.5% (-86.7% to 50.9%), -0.23Gy±0.43Gy for rectum and -7.2% ± 14.6% (-67.9% to 24.1%), -0.24Gy ±0.45Gy (1SD) for bladder (negative sign indicates larger measured dose). Rectal and bladder measurements were performed for logistic reasons only in 29 and 25 of the 30 patients. According to Fig1c,d, the correlation between calculated and measured dose for rectum

and bladder was 0.90 and 0.85, respectively. Table1 shows gamma analysis performed between measured and calculated rectum doses of the patients. Results showed a mean gamma passing rate of 82.5%, 89%, 91.3% using criteria of 3%,2mm, 3%,3mm and 4%,2mm global normalization and distance to agreement (DTA).

Table 1: Gamma analysis between in vivo measured and TPS calculated rectal doses

Patient No	Criteria: 3%, 2mm	Criteria: 3%, 3mm	Criteria: 4%, 2mm
	Pass Rate	Pass Rate	Pass Rate
1	75.6%	87%	92.1%
2	90.1%	98%	98.1%
3	84%	88.2%	96%
4	66.8%	79.3%	88%
5	72.1%	86.4%	96%
7	69.3%	81.1%	90%
8	71.7%	84.3%	94%
9	79%	88.8%	82.4%
10	33.3%	42.8%	57.5%
11	71.4%	84.7%	84.9%
12	75.6%	80%	80.3%
13	79.5%	88.5%	88.6%
14	91.5%	98.8%	98.2%
15	93.5%	98.7%	98.8%
16	91.9%	97.5%	97.5%
17	93%	96.3%	96.3%
18	88.6%	92.1%	92.4%
19	85.3%	86.7%	93.8%
20	90.2%	93.8%	94.2%
21	69.7%	78.8%	78.9%
22	91.3%	96.9%	93.8%
23	80.1%	86.3%	86.5%
24	83.2%	92.4%	92.4%
25	88.2%	92.5%	93%
26	98.1%	98.8%	99.2%
27	86.3%	92.5%	90.2%
28	97.9%	98.8%	99.3%
29	91.2%	96.3%	95.6%
30	98.2%	98.8%	99.1%
mean	82.5%	89.0%	91.3%

Conclusion

Experimental results illustrated that the proposed method is feasible for in vivo dose verification purposes. The found differences most probably arise from variation in size and position of the OARs, also applicator, organ and patient movement between CT scan and treatment delivery. Also by using the large number of bead TLDs for rectum dose measurements, we could utilize gamma analysis for comparing extracted TPS calculated and measured doses. The gamma pass rate for 3%, 3mm and 4%, 2mm criteria was more than 79% for all of the patients except one with probably larger rectal tube movement. By employing a device with firm fixation into the rectum and bead TLDs placement, better result can be achievable. The significant labour intensive and time consuming work to analyse a large number of bead TLDs was a constraint of this study which can be solved with an automatic TLD reader. This dosimetry system is now available for routine clinical use.

PO-0216 Healthy tissue constraints for catheter position optimization in HDR prostate brachytherapy planning

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Purpose or Objective

Simultaneous catheter position and dwell time optimization for HDR prostate brachytherapy (BT) based directly on dose-volume indices (DVIs) has shown promising results. However, resulting treatment plans satisfying the planning aims often contained large hot spots in the healthy tissue (having no clinical constraint), especially if few catheters were used. Calculating hot spot sizes during optimization could prevent this, but is too computationally expensive. DVIs can be calculated more quickly, but do not distinguish between multiple small hot spots occurring in a plan with many catheters, and few large hot spots occurring in a plan with few catheters. A constraint on a DVI of healthy tissue should therefore be dependent on the number of catheters. We aim to define and validate such a constraint.

Materials and Methods

The original optimization model combines the DVIs of the clinical protocol into two objectives, Least Coverage Index (LCI) and Least Sparing Index (LSI). Here, volume indices are defined as percentage of the total organ volume, covered by the given percentage of the planning-aim dose of 13 Gy. Dose indices are defined as percentage of the planning-aim dose encompassing the most irradiated part (in absolute volume in cm^3) of the organ:

$$\mathrm{LCI} = \min\left\{V_{100\%}^{\text{prostate}} - 95\%, V_{80\%}^{\text{seminal vesicles}} - 95\%\right\},$$

$$\mathrm{LSI} = \min\left\{\begin{matrix} 86\% - D_{1\mathrm{cm}3}^{\text{bladder}}, 74\% - D_{2\mathrm{cm}3}^{\text{bladder}}, 78\% - D_{1\mathrm{cm}3}^{\text{rectum}}, 74\% - D_{2\mathrm{cm}3}^{\text{rectum}}, 110\% - D_{0.1\mathrm{cm}3}^{\text{urethra}}, \\ 50\% - V_{150\%}^{\text{prostate}}, 20\% - V_{200\%}^{\text{prostate}} \end{matrix}\right\}$$

Catheter (center) positions are optimized with the restriction to be inside the prostate or seminal vesicles and outside of a 2mm margin around the OARs. This results in a front of plans, where plans with both LCI and LSI larger than zero satisfy the protocol. We extended the model by defining N as the number of catheters and C = 0.125 * N - $V_{200\%}$ for healthy tissue with the constraint C ≥ 0. Both the original and the extended model were tested on data of 6 prostate cancer patients treated with HDR BT. Plans were optimized using the evolutionary algorithm GOMEA. To test the effectiveness, for 24 pairs of plans for 6 patients and 4 different numbers of catheters from each model, the 3D isodose distributions were visually evaluated together with a radiation oncologist. To test required computation time, a GPU parallelization was evaluated on an NVIDIA Titan Xp GPU.

Results

The figure shows the fronts of optimized plans, together with the 24 selected pairs of plans. All 24 plans from the new model were visually evaluated as feasible in terms of healthy tissue dose. Moreover, 22 plans from the new model were deemed superior to corresponding 22 plans from the original optimization model. With GPU parallelization, each front was obtained in 5 minutes.

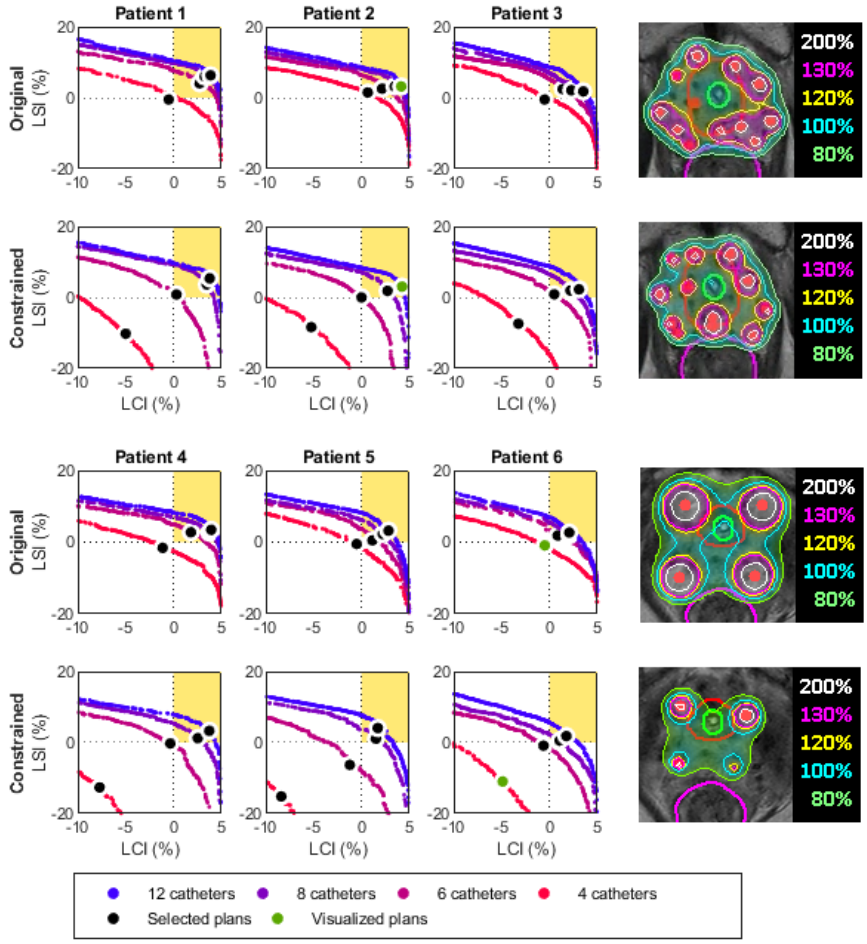

Figure: Fronts for both the original and the extended optimization model, for 6 patients, for 4 different numbers of catheters. Each front is a set of possible treatment plans. Plans in the yellow rectangle have an LCI and LSI larger than zero and satisfy the clinical protocol. A total of 48 plans (24 pairs) was selected to study the dose distribution with a radiation oncologist (black dots) of which a few are visualized on the right (corresponding to the green dots in the fronts).

Conclusion
We proposed a hard constraint on healthy tissue dose that successfully avoids large hot spots and improves clinical feasibility of BT treatment plans independent of the number of catheters used. GPU parallelization enables a clinically feasible running time.

PO-0217 Effect of transit dose on HDR brachytherapy – a 4D Monte Carlo study

Abstract withdrawn

PO-0218 Characterising a Papillon 50 electronic brachytherapy source using a plastic scintillation detector

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Purpose or Objective
To characterise a Papillon 50 (P50) electronic brachytherapy (eBT) source using a small plastic scintillation detector (PSD).

Materials and Methods
The P50 delivers 50 kVp X-rays (half value layer ~ 0.7mmAl) via collimating steel applicators (Ø22-30 mm). The delivered dose from the P50 source was measured using a PSD system and an internal ion chamber in the P50. The P50 output is given in monitor units (MU), where 100 MU ~ 1 Gy. The PSD system is based on a cylindrical BCF-12 plastic scintillator (Ø1 mm, L=0.5 mm) coupled to an optical fiber, which transmits the scintillation light to a photo multiplier tube (PMT) (H5783 SEL3, Hamamatsu). The PMT is coupled to an electrometer (unidos webline, PTW). The PSD was placed in a block of solid water and the P50 applicator was placed on top of the block pointing towards the PSD, corresponding to a 5 mm solid water depth. The following quantities were determined.

MU precision: Irradiation was done for ten different MU-values and repeated ten times for each. The total dose of each irradiation was measured with the PSD, and the mean and SD determined.

Temporal stability: Irradiations for a long period of time were performed to investigate the P50s temporal stability. The P50 was set to irradiate for 200-600 s and the accumulated dose over 10 s was measured repeatedly throughout each irradiation.
Depth-dose curves: The distance between the PSD and P50 was varied by inserting plates of solid water in between. The dose was measured at each depth during a 10 s irradiation. The results were compared to published results with an ionization chamber and Monte Carlo simulations[1].

Results
MU precision: Fig. 1a shows the measured mean signals for the 10 MU values. The SD was 5.2% for 50 MU and up to 1.1% for the remaining MU values. The dashed line is a fit to the mean measured signal as a function of MU, only including MU ≥ 400. The mean signal show a strong linear relation. Fig. 1b shows the residuals between the fit and measurements on fig. 1a. The fit overestimates the signal at MU below 400, likely due to the PSD measuring the decaying irradiation when the P50 is turned off unlike the intrinsic ion chamber.

P50 stability: Fig. 1c shows the measured signal as function of time from irradiation start. The signal decreases exponentially over time by up to 3%. Fig. 1d shows the signals after an exponential time correction. The SD then becomes 0.18% on average.
Depth-dose curves: Fig. 2 shows the relative dose of the P50 source measured at depths ranging between 7 mm to 49 mm in solid water. The results agree within the uncertainty of MC and ion chamber results.

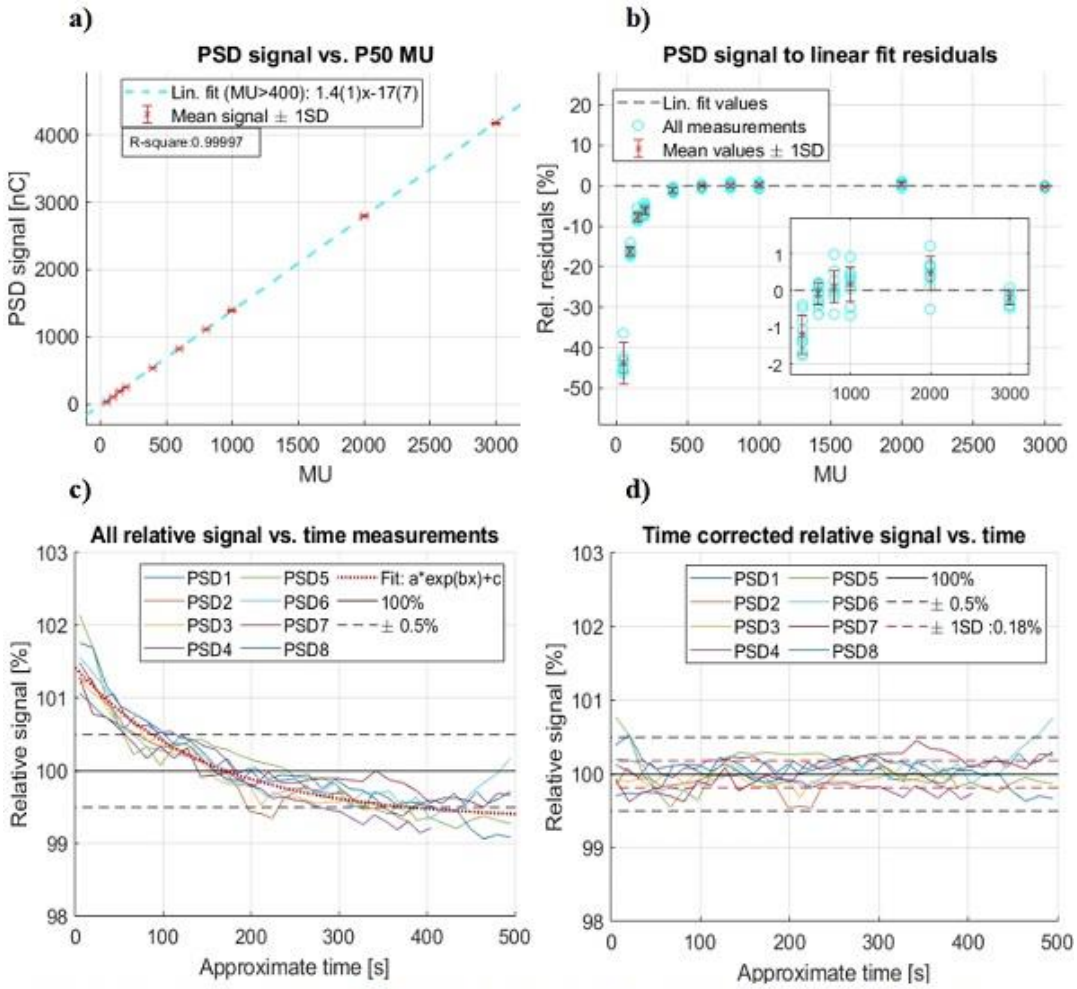

Figure 1: a) Measured signal for different MUs. The dashed line is a linear fit to the mean values for MU above 400. b) Relative residuals between linear fit and measurements. The insert is a zoom in of MU above 400. c) The P50s dose rate as function of irradiation duration. The red dashed line is an exponential function fitted to the mean of all measurements at each measured time. d) The measured signals from figure 1c corrected using the exponential function. The dashed lines indicate 0.5% deviations from the signal mean values (black) and ± 1 of the average SD (red).

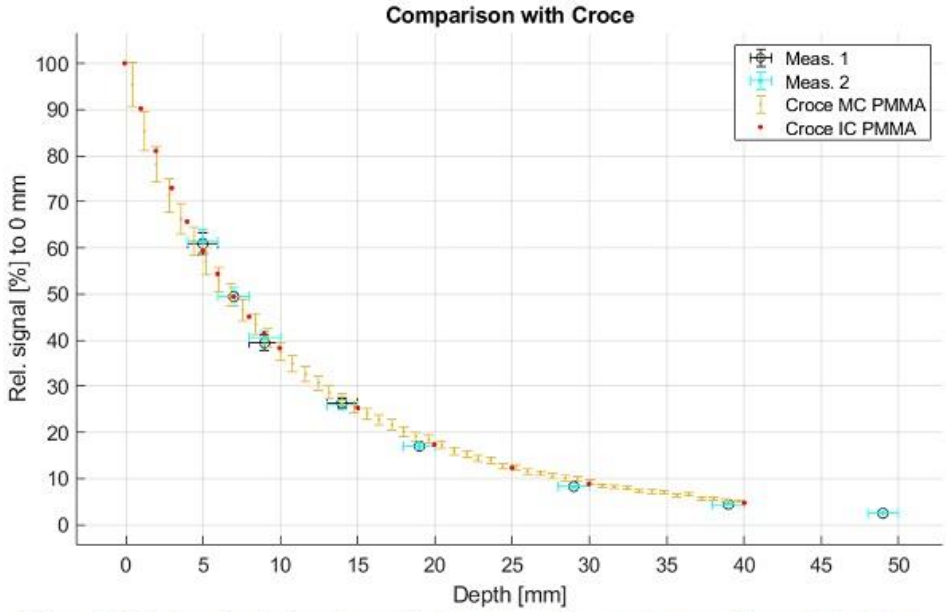

Figure 2: Relative depth dose (normalised at 0 mm distance from applicator tip) of the P50 source with a 25 mm diameter applicator measured with the PSD (black circles and cyan dots), an ion chamber (red dots), and MC simulations (yellow dots). Ionisation and MC results are taken from Croce et. al. (2012)[1]. Vertical errorbars indicate ±1 SD on measurements while horizontal bars indicate ± 1 positional uncertainty.

Conclusion
The dose from a P50 can be measured with good accuracy using a PSD system. The PSD could therefore potentially be used to characterise P50 and other eBT sources in terms of both temporal and positional dose distribution.

[1] O. Croce, S. et al. Radiation Physics and Chemistry 81 (2012) 609-617

PO-0219 Analysis of the image quality of two different I-125 seed models using TRUS, MR and CT

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Purpose or Objective
Iodine-125 seeds are used in the treatment of prostate cancer. Treatment planning and implantation is performed by TRUS imaging (transrectal ultrasound). In addition, MR and CT images are taken for follow-up purposes. Using these images, a post-operative radiation plan is calculated based on the current position of the seeds. It is therefore important to be able to well identify the I-125 seeds in the images.
The aim of this work is to examine the image quality of seeds from two different manufacturers in TRUS, MR and CT images with regard to their recognizability and artifacts.

Materials and Methods
In a water phantom measuring 30x18x15 cm^3, the seeds were attached to a wooden construction. A strand of 5 I-125 seeds from Eckert & Ziegler BEBIG GmbH (Berlin), model I25.S17Plus1-xx and 2 strands of 3 I-125 seeds from Bard Brachytherapy (Illinois), model STM 1251 were used. The strands were placed parallel and had a distance of 1cm to each other.
First, a CT (GE Healthcare, Optima 580W) and a MR (GE Healthcare, Signa HDxt 1.5T Advantage plus) with T2 weighting of the phantom were acquired. Subsequently, a round opening for the TRUS probe (US: GE Healthcare, Logic P6 PRO) was cut into the water phantom and a thin plastic foil was laid into the phantom and it was filled again with water. The acquired DICOM images were imported into ARIA v15 (Varian Medical Systems, Palo Alto). In the module "Contouring", profiles of the Hounsfield units (HU) through the seeds were generated. The values were exported, analyzed and compared.

Results
The seeds of both manufacturers can be well identified in all three image modalities (TRUS, MR and CT). In the MR both HU-profiles show hardly any differences. The gradient and values of the profile can be considered as almost identical. In the CT, higher HU can be observed in the center of the Bard seeds. The slope and values of the profile show only slight differences. There are slightly more artifacts produced by the Bard seeds, but this could be changed by adjusting the CT protocol. The biggest difference in this case is seen in the TRUS images. Both models produce an equally strong signal in the US, which is easy to recognize. Behind the Bard Seeds, however, artifacts are seen, so that the trend line of the profile decreases with a gradient of 5.4. The signal behind the Bebig Seed decreases significantly faster and the profile behind the seed is flatter (gradient 1.8). However, this may be due to the not perfect angle of the Bebig seeds.

Conclusion
Seeds from both manufacturers (Eckert & Ziegler BEBIG GmbH, Bard Brachytherapy) can be easily recognized in all three image modalities (TRUS, MR and CT). It would be desirable to have a stronger signal in the MR T2-sequence as well as fewer artifacts in CT images. This could be performed by inserting MR Markers and a smaller diameter of the seeds. The quality of the treatment plans could hereby be improved.

PO-0220 Determination of dose deposition from an Ocular Brachytherapy source: simulation data with TOPAS

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Purpose or Objective
Ophthalmic applicators used in brachytherapy contain radioactive sources, which are placed in contact with or close to the region to be treated. Due to the high dose gradient in regions close to the source, experimental measurements for dosimetric calculations are a challenge. Thus, ICRU (International Commission on Radiation & Measurements) Report 72 and TG-43 protocol, proposed by the American Association of Physicists in Medicine (AAPM), recommend the use of Monte Carlo simulation to determine dose distributions and dosimetric parameters. Therefore, the objective of this work is to analyze the percentage of relative dose along the central axis using the Monte Carlo simulation with TOPAS (Tool for Particle Simulation) code.

Materials and Methods
The applicator simulated in this work was the SIA.20 model, which uses a $^{90}Sr/^{90}Y$ source whose decay occurs by 0.55 and 2.27 MeV beta particles, depositing its energies in a few millimeters of tissue. Its decay spectrum was determined according to literature data. The active part of the source has 9 mm diameter and its geometry is flat, while the homogeneous cylindrical phantom has 24 mm diameter and 30 mm high, filled with water and positioned in contact with the source (figure 1). A relative dose along the central axis of the applicator was calculated with the deposited doses in 0.5 mm^3 voxels using the programming in Python language.

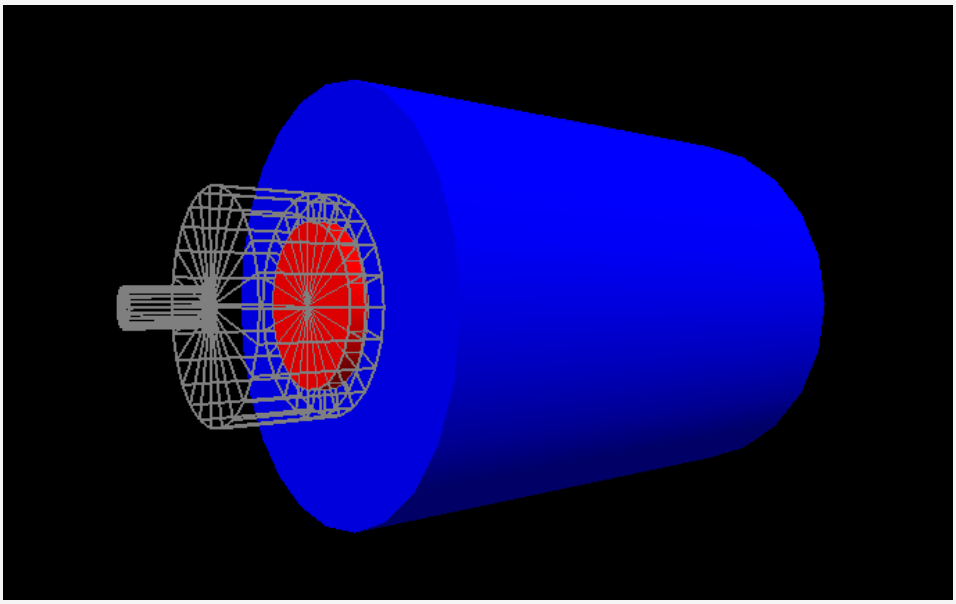

Figure 1

Results
This work compared data from the ICRU, well established for dosimetry in brachytherapy (figure 2). The data used for the comparison were obtained in the central plane (in the direction of the central axis of the applicator), which contains the largest dose gradient, using normalization at the reference point (1 mm). The greatest uncertainty for dose deposition was approximately 0.01%, at the point of normalization. A maximum difference of approximately 3.91% was found among the compared data at 1.6 mm depth.

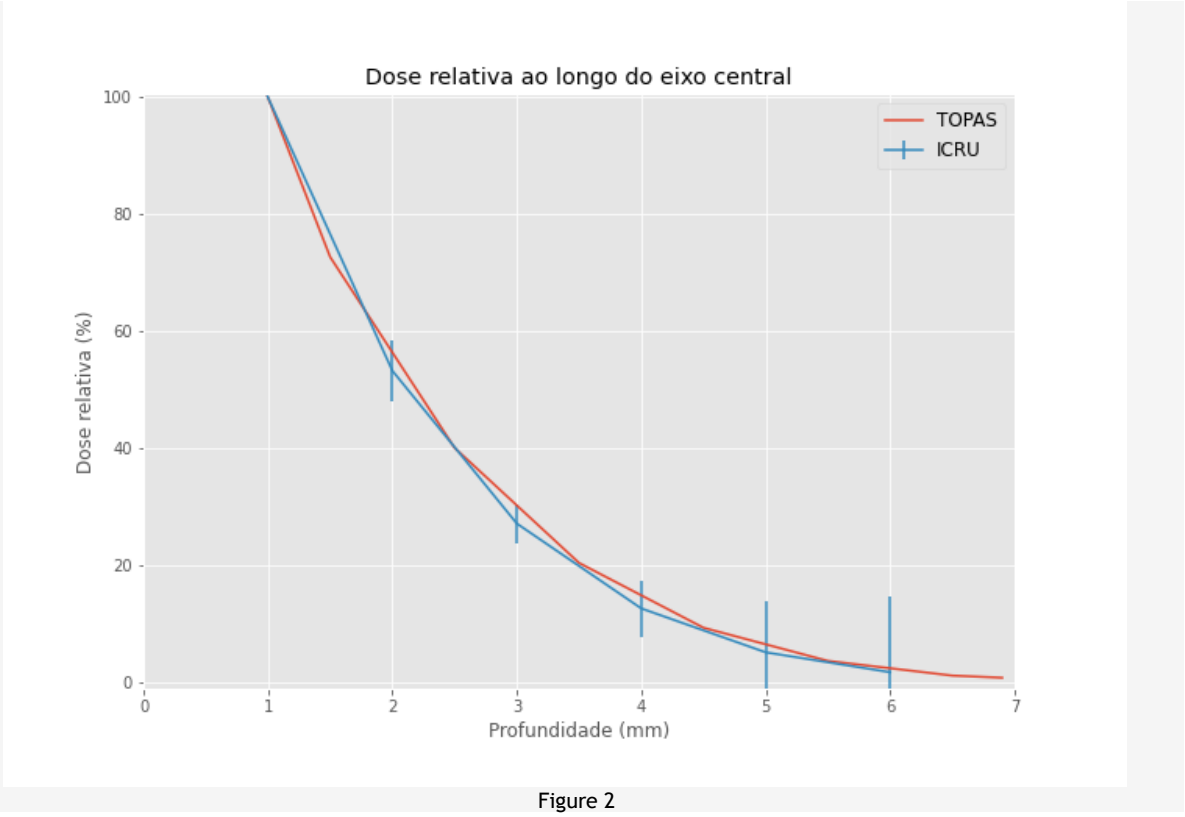

Figure 2

Conclusion
The results obtained showed the same trend shown by the ICRU, indicating TOPAS as a promising tool in dosimetry in brachytherapy.

PO-0221 Doses to OAR during LDR permanent prostate treatment for monotherapy patient cohort

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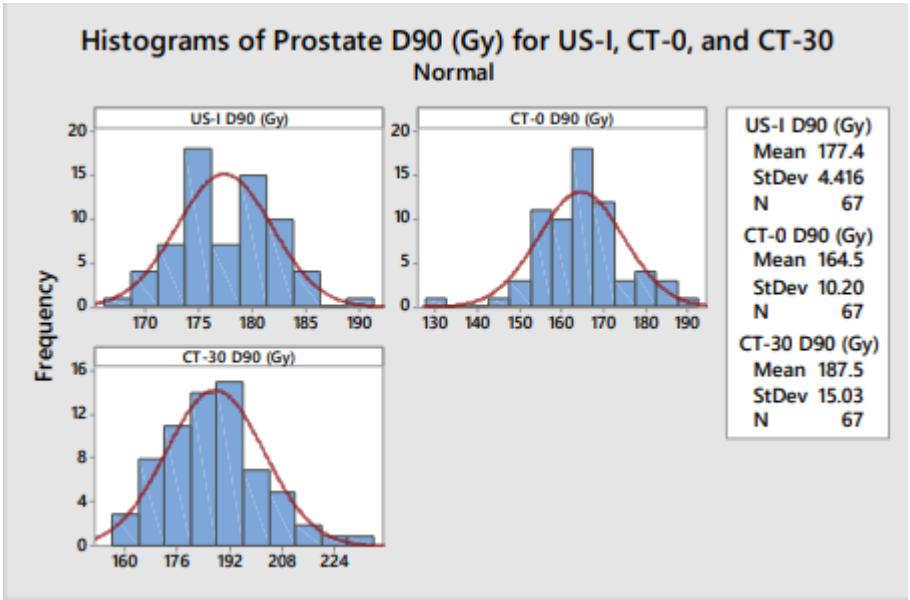
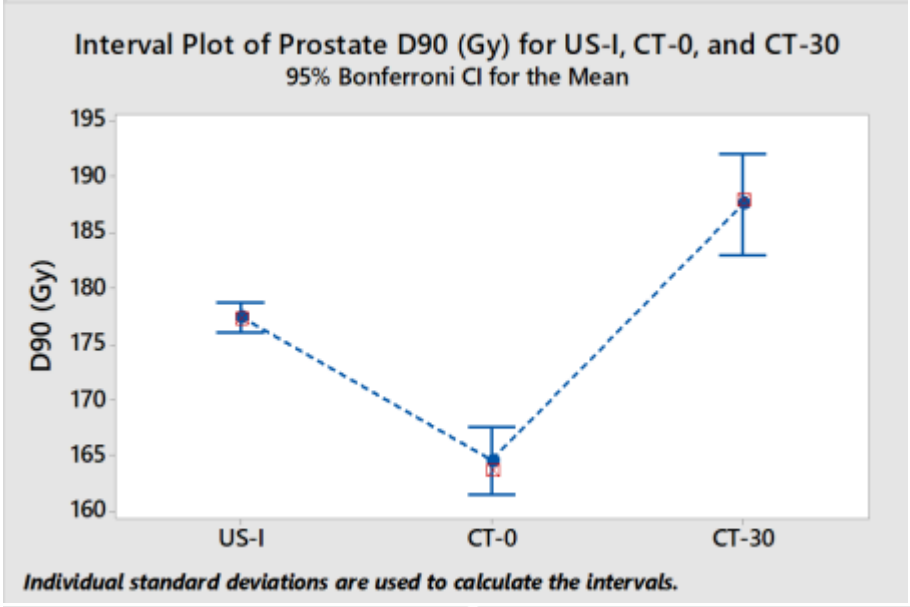
Purpose or Objective
Globally, prostate cancer is the 3rd most commonly occurring cancer overall, and the 2nd most commonly occurring cancer in men, with Ireland having the 3rd highest age-adjusted rate of prostate cancer in the world. Moreover, prostate cancer resulted in the 5th highest number of cancer deaths among men worldwide in 2018. (Bray *et al.*, 2018)

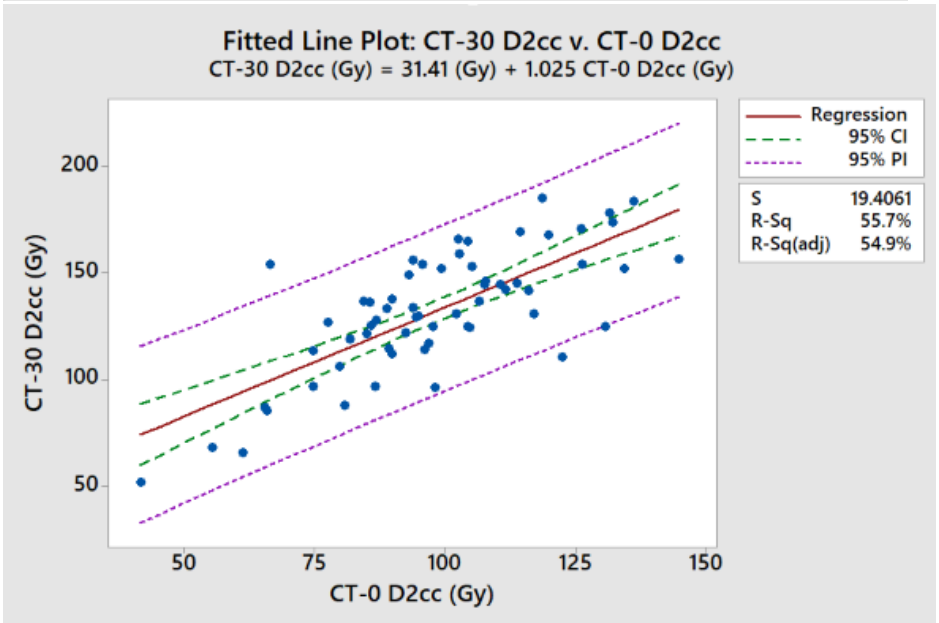
An appropriate treatment for *early-stage* (largely organ-confined) prostate cancer is low dose-rate (LDR) permanent prostate brachytherapy (PPB) (Nath *et al.*, 2009). This project analysed prostate volumes and dose-volume indices (DVIs) of the target and organs at risk (OAR) (prostatic urethra & rectum) from a monotherapy patient cohort consisting of a total of 142 patients. All of the patients underwent a PPB procedure at the same institution, in which ^{125}I seeds were inserted into the prostate using a Mick applicator. To ensure the quality of the implant, dosimetry is assessed on the day of the procedure (Day-0) using intra-operative ultrasound and post-operative CT (i.e. US-I and CT-0), and approximately 30 days post-procedure (Day-30) also using CT (i.e. CT-30). A frequent challenge in PPB is the disagreement between Day-0 and Day-30 dosimetry.
The **aims** of this project were to establish whether there are statistically significant differences in mean prostate volume and mean DVIs between US-I, CT-0, and CT-30, and to investigate whether Day-0 dosimetry is a useful predictor of CT-30.

Materials and Methods
The prostate volume, target and OAR DVIs (prostate D_{90} & V_{100}, urethral D_{30}, rectal D_{2cc} & $V_{145\ Gy}$) were evaluated at US-I, CT-0, and CT-30 through statistical analysis on the Minitab 17 software.

Results
For the prostate volume, and for all DVIs, statistically significant differences were shown to exist (�� < 0.05) – additionally, where those differences occurred, and how large those differences were, was also elucidated. Furthermore, it was investigated, using simple and multiple linear regression whether Day-0 dosimetry could be a useful predictor of CT-30 dosimetry for certain target and OAR DVIs (prostate D_{90} & V_{100}, rectal D_{2cc} & $V_{145\ Gy}$). It was observed that a substantial proportion of the variation in the response variable (i.e. CT-30), for all of the DVIs analysed, *cannot* be accounted for by the explanatory variable (i.e. US-I and/or CT-0).


Histograms of Prostate D90 (Gy) for US-I, CT-0, and CT-30
Normal
US-I D90 (Gy)
CT-0 D90 (Gy)
CT-30 D90 (Gy)
Frequency
US-I D90 (Gy)
Mean 177.4
StDev 4.416
N 67
CT-0 D90 (Gy)
Mean 164.5
StDev 10.20
N 67
CT-30 D90 (Gy)
Mean 187.5
StDev 15.03
N 67


Interval Plot of Prostate D90 (Gy) for US-I, CT-0, and CT-30
95% Bonferroni CI for the Mean
D90 (Gy)
US-I
CT-0
CT-30
Individual standard deviations are used to calculate the intervals.


Fitted Line Plot: CT-30 D2cc v. CT-0 D2cc
CT-30 D2cc (Gy) = 31.41 (Gy) + 1.025 CT-0 D2cc (Gy)
Regression
95% CI
95% PI
S 19.4061
R-Sq 55.7%
R-Sq(adj) 54.9%
CT-30 D2cc (Gy)
CT-0 D2cc (Gy)

Conclusion
It was concluded that the variation of mean DVIs between US-I, CT-0, and CT-30 was likely due to procedure-induced prostate oedema and its resolution. Furthermore, it was determined that accurate predictions of CT-30 for individual patients are impractical, which underlines the importance of CT-30 dosimetry for assessing the quality of the implant. However, a linear regression model was concluded to still be useful in so far as it could potentially be used to gain insight into the distribution of CT-30 DVIs as a function of US-I and CT-0 indices, and to help facilitate a deeper understanding of how DVIs at US-I and CT-0 relate to the mean value of the DVIs at CT-30.

PO-0222 Primary standards and measurement methods for X-ray emitting electronic brachytherapy devices

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Purpose or Objective
Within the framework of the European Metrology Programme for Innovation and Research (EMPIR), six European National Metrology Institutes (NMIs) together with partners from universities and clinics will collaborate in a Joint Research Project with the aim of establishing a harmonised, simplified and traceable dosimetry for electronic brachytherapy (eBT) in terms of absorbed dose rate to water.

Materials and Methods
The specific objectives of the EMPIR project PRISM-eBT (July 2019 – June 2022) are:
1. To establish primary standards for the absorbed dose rate to water for eBT devices at 1 cm depth of water for interoperative radiotherapy, to evaluate currently used transfer instruments and corresponding measurement procedures and to establish simple and robust tools for dissemination of the absorbed dose rate to water to clinical practice.
2. To establish a dosimetric methodology for (skin) contact eBT traceable to a primary standard developed under item 1.
3. To characterise detectors and measurement instruments suitable for the determination of 3D dose distributions in water by eBT devices. To develop a standardised traceable calibration process for these detectors, allowing a reduction in the uncertainties in dose, dose distribution and dose-effect-relation to a level recommended in IAEA Human Health Report No. 31.
4. To provide traceable dosimetry for 3D dose distribution measurements in water for eBT systems and to make them available for the end user community.
5. The data provided in this project will be compiled in Good Practice Guides and submitted to the IAEA and Standards Developing Organisations (SDOs) for uptake in their written standards.

Results
All activities together will reduce the uncertainties in dose, dose distribution and dose-effect-relation to a level recommended in IAEA Human Health Report No. 31 and improve the efficacy of eBT treatments. These activities will enable greater confidence in the therapeutic and clinical benefit of these radiotherapy modalities through improved data and this, in turn, will increase uptake.

Conclusion
An outline of the PRISM-eBT project will be presented to make the eBT user community aware of the work planned for the next three years (July 2019 to June 2022) and to enable end-users to comment on the proposed objectives. The results of this European Joint Research Project with contributions from six National Metrology Institutes, two University Hospitals and several external stakeholders will enable SDOs to draft a new standard for harmonised dosimetry of eBT devices which will increase the treatment efficacy of eBT.
ACKNOWLEDGEMENT
This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

PO-0223 Ir-192 position measurement for pre-treatment QA using a fluorescent screen-based optical detector

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Purpose or Objective
Daily quality assurance of Ir-192 source position is required before treatment according to AAPM report 56. The test is usually performed using radiochromic film or source position check ruler to verify if it is within the tolerance of 1mm. However, source position relative to the reference position is user-dependent. This study aims to demonstrate the feasibility of using a fluorescent screen-based optical detector with an in-house phantom and Matlab algorithm to give a quantitative measurement for the position of the source.

Materials and Methods
The Raven (LAP Laser, Germany) is an optical and radiosensitive system with fluorescent screen imaged using a CCD camera. A phantom was made using acrylic with lead lines and catheters embedded on it, running in orthogonal directions. The lead line separations were 1 cm each while the catheters' length was the treatment indexer length. There were 13 channels and 10 dwell positions in each channel of the phantom. The size of the acrylic phantom was designed to fit the surface of fluorescent screen to ensure the reproducibility of the position of the phantom during the quality assurance test. The reference image of the phantom with Raven was taken using x-ray irradiation from an Intergrated Bracytherapy Unit (IBU). The algorithm detected all the intersections of lead lines and catheters (red crosses) to be the reference positions of all tested dwell positions (Figure 1). The catheters on the phantom were connected to a microSelectron afterloader (Elekta, Sweden). The Ir-192 source was delivered channel by channel with step size of 1 cm and dwell time of 1 second. The

camera's shutter duration was set at 200ms and captured all of the source positions along one catheter. The algorithm detected the center of the source then calculated the difference between the source and reference position in mm. A text file was then generated to include all the positions difference for x and y directions for all catheters.

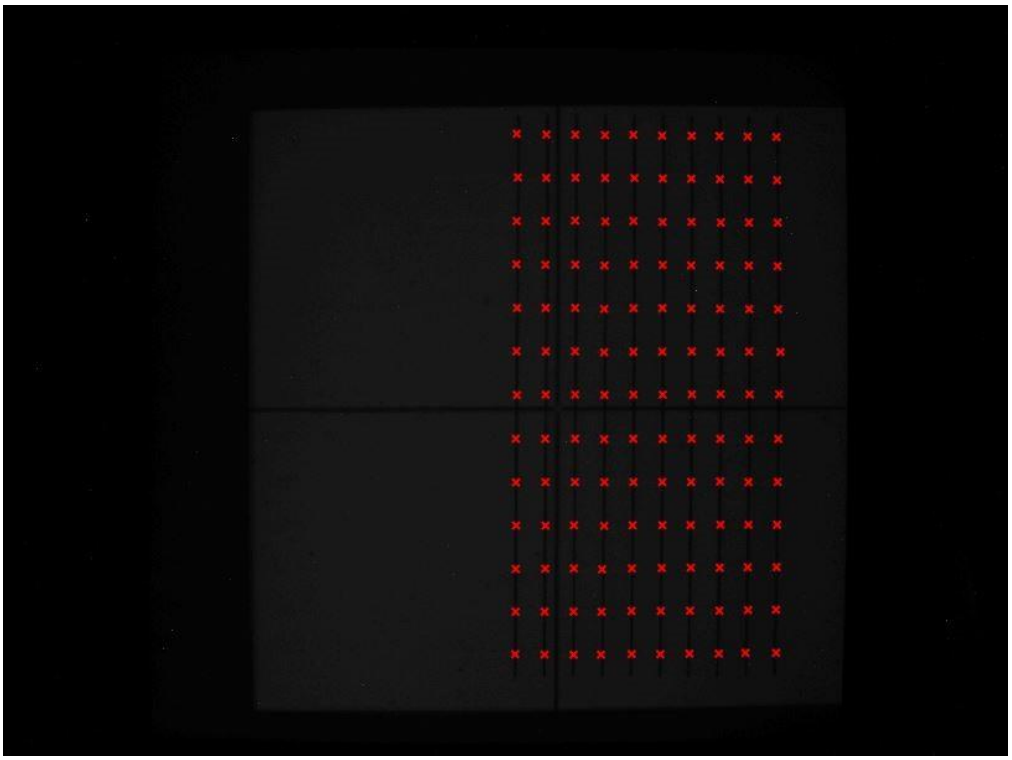

Figure 1 The algorithm located all reference positions in red crosses.

Results

The text file shows all of the difference in positions between the reference and source positions in both x and y directions (Figure 2). The results showed that all the difference in positions are within 1mm.

order	x(mm)	1	2	3	4	5	6	7	8	9	10
ch01		0.027402	0.005306	0.003679	0.017092	0.082213	0.077052	0.042123	0.091202	0.108618	0.138907
ch02		0.038385	0.000007	0.002409	0.026897	0.056420	0.029107	0.047088	0.100074	0.125843	0.095768
ch03		0.074798	0.055180	0.067535	0.024890	0.009723	0.013822	0.015615	0.054306	0.074738	0.093674
ch04		0.042316	0.069015	0.096060	0.135497	0.107061	0.117933	0.158915	0.184618	0.232042	0.210319
ch05		0.082672	0.108006	0.155199	0.169074	0.182146	0.195873	0.232840	0.258548	0.280644	0.223838
ch06		0.057778	0.062190	0.079419	0.094295	0.138168	0.141593	0.176370	0.211075	0.218414	0.199496
ch07		0.056481	0.011100	0.012673	0.032908	0.056529	0.077104	0.121042	0.157810	0.154131	0.133380
ch08		0.078669	0.049717	0.038102	0.007406	0.002214	0.023479	0.071448	0.077696	0.115053	0.125251
ch09		0.035012	0.064436	0.062338	0.070487	0.098167	0.086760	0.127225	0.149163	0.166262	0.188483
ch10		0.014707	0.010807	0.015244	0.056749	0.045051	0.074664	0.110869	0.162450	0.128087	0.117440
ch11		0.059433	0.040423	0.050551	0.032318	0.019908	0.033762	0.125749	0.102999	0.096425	0.096358
ch12		0.089277	0.113342	0.113677	0.045181	0.025252	0.000680	0.088874	0.057548	0.056957	0.040253
ch13		0.036041	0.071575	0.010480	0.036871	0.064480	0.074919	0.215735	0.150275	0.163621	0.165664

order	y(mm)	1	2	3	4	5	6	7	8	9	10
ch01		0.094440	0.083236	0.088561	0.082073	0.083721	0.101186	0.084759	0.126805	0.148037	0.189056
ch02		0.102814	0.117951	0.119229	0.125314	0.093382	0.096790	0.112262	0.118640	0.100269	0.118017
ch03		0.123709	0.106409	0.088096	0.117011	0.103593	0.134751	0.101636	0.153723	0.110387	0.115079
ch04		0.067563	0.071109	0.049518	0.060263	0.066141	0.077782	0.052531	0.095241	0.085247	0.094631
ch05		0.072214	0.071271	0.054006	0.069083	0.065874	0.043308	0.009593	0.078316	0.081571	0.084172
ch06		0.042373	0.048713	0.018160	0.051926	0.033959	0.011593	0.008663	0.057276	0.070149	0.071141
ch07		0.093317	0.086716	0.101541	0.080544	0.064336	0.060907	0.049602	0.085432	0.086877	0.062329
ch08		0.001743	0.023073	0.017505	0.018259	0.001918	0.010823	0.007254	0.028744	0.030901	0.014399
ch09		0.001559	0.000567	0.022601	0.001887	0.004734	0.005173	0.011093	0.024955	0.012071	0.014748
ch10		0.039672	0.037202	0.035579	0.045389	0.043480	0.043435	0.043722	0.005060	0.012412	0.011941
ch11		0.028075	0.016961	0.023978	0.006285	0.020636	0.042908	0.062352	0.024966	0.043466	0.063798
ch12		0.010137	0.022076	0.045456	0.030682	0.034281	0.008035	0.046468	0.025640	0.037350	0.032503
ch13		0.090329	0.077113	0.098218	0.079511	0.080813	0.068536	0.100447	0.103972	0.040876	0.024815

Figure 2 The text file shows the difference between reference position and source

Conclusion

The algorithm and Raven successfully demonstrated the feasibility of automatically detecting the Ir-192 source center and correlated with the reference positions in the phantom to give a quantitative result. This would be highly useful as a daily quality assurance tool.

PO-0224 Dosimetric impact of a model based algorithm for skin cancer interventional radiotherapy

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Purpose or Objective
The purpose of this study is the comparison of treatment plans for non-melanoma skin cancer (NMSC) interventional radiotherapy (IRT) calculated with the TG-43 protocola and with the Advanced Collapsed cone Engine (ACE, Elekta Stockholm, Sweden) TG-186 model based dose calculation algorithm (MBDCA)b. The introduction of a bolus has been investigated in order to mimic the presence of water outside the body as it is considered for the calculation with the TG-43 algorithm.

Materials and Methods
Seven patients with NMSC, treated using 192Ir high dose rate IRT (HDR-IRT) with the Freiburg Flap applicator (Elekta), were studied. Treatment plans were calculated with the TG-43 and with the ACE algorithms by using the same dwell positions and dwell times. The plans were recalculated by introducing a 2cm bolus. In order to avoid a second CT scan to the patients, one CT with a 2 cm bolus was acquired. When performing the calculations without the bolus, the material of the bolus was assigned to be air. Three isodoses (1Gy, 3Gy and 5Gy) were chosen for the comparison of both calculations in order to evaluate the dose distribution inside the tumor, inside the healthy tissues of the patient and outside the body.

Results
Figures 1a and 1b show the 3 isodoses for both algorithms without the bolus and with the bolus respectively. When there is no bolus on top of the skin applicator (Fig. 1a) the differences in the CTV are up to 3% (5 Gy isodose), whilst at the 1 Gy isodose level, far from the implant, the calculation differences are up to 8%. When a bolus is introduced (Figure 1b) the differences between the TG-43 and the ACE calculations are minimized, varying from less than 1% in the CTV to a maximum of 5% at the distance inside the patient. The higher percentage differences at the distance, corresponding to the 1 Gy isodose, are due to the performance of the ACE algorithm with the multiple scatter component of the dose. Even if the differences at the distance resulted to be up to 8%, there is no clinical impact as they represent 0.08 Gy or less in absolute values. Differences larger than 10% are found outside the bolus because of the presence of air but these differences are also not clinically relevant as being outside the body of the patient.

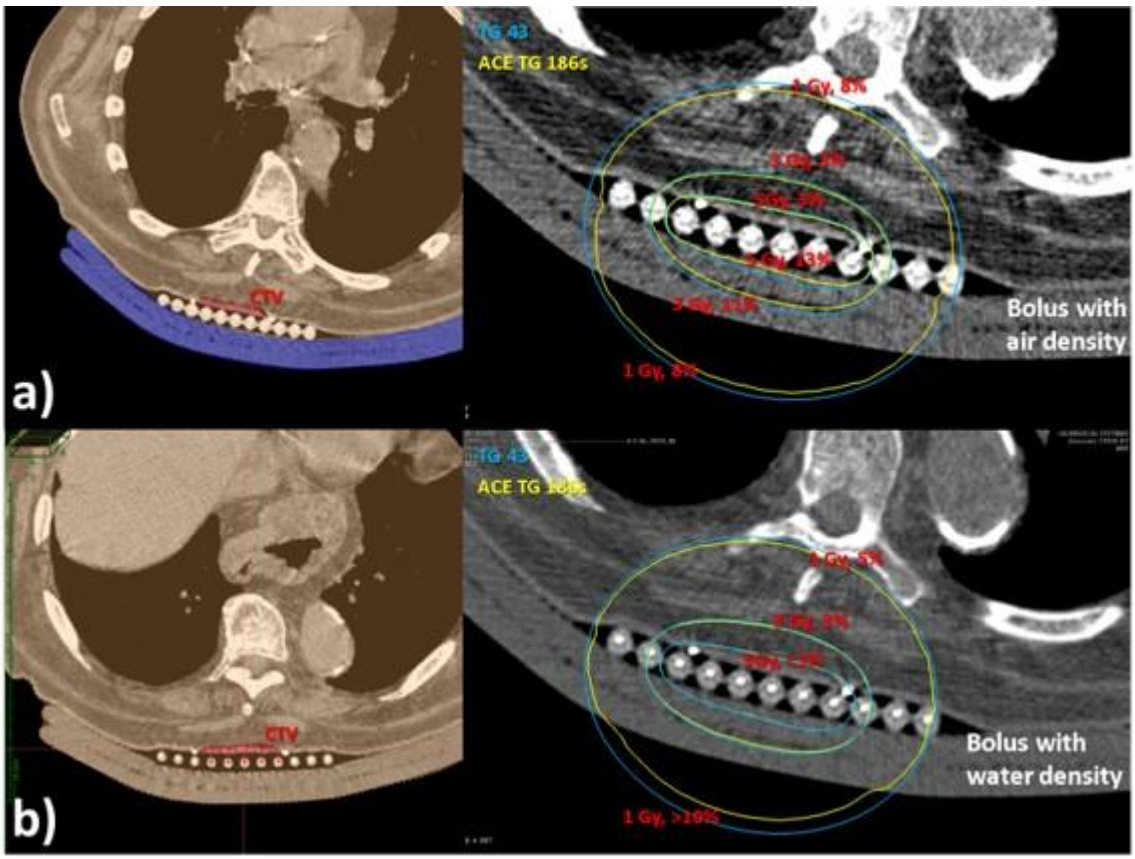

Fig. 1. Isodoses comparison for a patient without (a) and with (b) the bolus.

Conclusion
In the present study, we evaluated the impact of a MBDCA on HDR-IRT NMSC treatments. The introduction of a bolus was investigated and the differences between the TG-43 and the ACE algorithms were reduced from 3% to less than 1% in the CTV. Therefore, this study shows that for NMSC treatments, the introduction of a bolus may be beneficial when MBDCA are not available or when it is not possible to cope with their longer calculation times.

References.

[a] *Nath R et al. AAPM Task Group 43. Med Phys 1995;22:209–34.*
[b] *Beaulieu L et al. AAPM Task Group 186. Med Phys 2012;39:6208–36.*

PO-0225 Automatic reporting of vaginal dose points for cervical cancer HDR-brachytherapy

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Purpose or Objective
A set of eight points at the upper part of the vagina (12 o'clock, 6 o'clock, 3 o'clock,9 o'clock and the respective points at 5 mm from the surface of the applicator) have been recommended to be reported by ICRU 89 and EMBRACE II protocol. The aim of this study is to present a simple new method to automatically determine the upper vaginal points for cervical cancer brachytherapy treatments.

Materials and Methods
Three patients treated at three different institutions were analysed. For each patient, three experienced observers reported dose at the recommended vaginal points with the methodology stablished in routine in their institution (completely manual for institutions 1 and 3 and semiautomatic for institution 2) and with the introduced automatic method. The new method uses the known geometry of the applicators and the dwell position coordinates in order to stablish the position of the vaginal points. With the coordinates of the dwell positions, the half plane of both ovoid is stablished. Then, by simple trigonometry, the eight vaginal points are found. The enhancement provided by the new method was assess by comparing the interobserver deviation in position and absorbed dose between all methods.

Results
The manual method used by institutions 1 and 3 provided a standard deviation in position ranging from 0.25 mm to 3.16 mm with a range in reported dose between 0.06 Gy to 1.011 Gy. The semiautomatic method of institution 2 had lower dispersion ranging the deviation in the position determination between 0.04 mm and 0.8 mm and the deviation in absorbed dose encompassing the interval between 0.02 Gy and 0.22 Gy. In all the routine methods, the vaginal points with higher determination uncertainty were 12 o'clock and 6 o'clock. The automatic method had zero deviation in the determination of the position with the corresponding lack of dispersion in the absorbed dose.

Conclusion
The developed automatic method to determine the vaginal points position completely eliminates the inter- and the intraobserver variation helping to the standardization in the reporting and the comparison to upper-vaginal dose tolerances and limits.

PO-0226 3-D Printed modified S-Tube for treatment of cervical cancer with high dose rate brachytherapy

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Purpose or Objective
The indwelling intrauterine tube (IIUT) was first designed at Tygerberg hospital in 1990 and named the S-Tube, in honour of its designer Prof Ben Smit, then head of oncology. Since then it has been successfully used in our hospital, allowing easy and safe administration of multiple fractions of HDR-BT, while eliminating the need for anaesthetic doses with each fraction. Recently new ring applicators were purchased, together with vendor-specific S-Tubes. The oncologists found these S-Tubes to be too flexible and frequently slipping out of position. Unfortunately, stitching the S-Tubes in place is often not possible because of the extent of the disease. The existing S-Tubes could not house the new ring applicators, which needed a larger diameter tube.

Materials and Methods
The original S-Tubes were drawn as computer-aided design drawings and converted into a recognizable printer format and printed on a Creality 3-D printer. The diameter was increased from 3 to 4 mm. After experimenting with different materials, it was decided to use Polyethylene Terephthalate Glycol (PETG), a non-toxic thermoplastic printer filament, as printing material. This material provided a good compromise between rigidity and brittleness and had good visibility on the patient CT scans following insertion. Six small pillars were added to the outside of the S-Tube to provide a ribbed surface and thus an improved grip.
During the design process it was established that the IU tube of the ring applicator had a 6 mm offset at tip of the applicator, meaning the first source position starts lower than the tip of the IU applicator. Therefore the S-Tube design was changed to incorporate this offset.
The S-Tubes were placed in a Hibataine solution for 3 days to determine the durability.

Results
The new universal printed S-Tubes were named T-Tubes, to keep the honor at Tygerberg hospital. The new design T-Tube accommodates both the straight applicator that is commonly used for 2D brachytherapy treatments at Tygerberg hospital, as well as the IU applicator of the ring applicator sets. .Our oncologists are pleased with the new design and the new T-Tubes are clearly visible on the patients' CT data sets. The T-Tubes have been used on three patients to date, without slipping out of position or any other side-effects. One T-Tube can be manufactured for R1,00 (South African rand), once the initial cost for the Creality 3 D printer of R 7000 is absorbed relative to R1500,00 per S-Tube if ordered from the manufacturer.

Conclusion
The 3-D printed T-Tubes are manufactured on-site and on demand and cost effective, this is ideal in a low-resource setting. The ribbed surface helps to keep the tube in position during all five treatment fractions. The design of the T-Tube has undergone several of iterations to get to the existing model. The design is easily adaptable should this become necessary in the future.

PO-0227 Verification measurements for brachytherapy reference data

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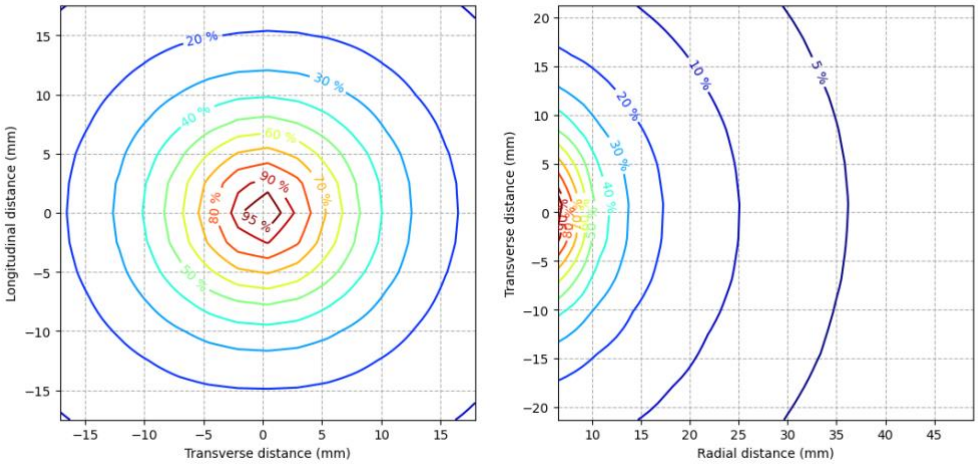
Purpose or Objective
Dose calculation algorithms in brachytherapy are challenging to verify with measurements due to steep dose gradients and detector setup uncertainties. AAPM TG43 and model-based algorithms are therefore primarily verified using independent calculations and Monte Carlo reference data. However, this reference data is not comprehensive and does not cover all materials used in brachytherapy treatments. This study introduces a method of performing accurate and precise measurements for the purpose of validating TPS calculated dose distributions including any available material.

Materials and Methods
A gynaecological applicator was suspended in a PTW BeamScan water phantom using an in-house designed, 3D printed jig. A Pinpoint 3D chamber was then used to measure an isodose plane parallel to the source axis at 7 mm from the source (Figure 1(left)), followed by a radial isodose plane perpendicular to the source axis (Figure 1(right)). Each 2D plane was produced with a 2.5 mm resolution and took approximately 6 minutes.

Results
The matrices of point doses collected using the pinpoint ionisation chamber are displayed in Figure 1. These planes represent the dose distribution of a single dwell position in water, accurately demonstrating the high dose gradients inherent in brachytherapy due to minimal setup uncertainties.



Conclusion
A water phantom designed for external beam reference dosimetry was successfully repurposed for accurate and precise measurements of a brachytherapy source. These measurements could be performed in air or water, with the potential addition of a material of interest (e.g. shielding) between the source and detector for additional validation of model-based calculation algorithms.

PO-0228 Inverse versus forward optimisation methods in brachytherapy of breast, cervix and prostate cancer

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Purpose or Objective
Dosimetric comparison of HIPO (Hybrid Inverse Planning Optimization) and IPSA (Inverse Planning Simulated Annealing) inverse and forward optimisation (FO) methods in brachytherapy (BT) of breast, cervix and prostate cancer.

Materials and Methods
Materials and methods: 38 breast, 47 cervix and 50 prostate cancer patients treated with image-guided interstitial High-Dose-Rate BT were selected. Treatment plans were created using HIPO and IPSA inverse optimisation methods as well as FO. The dose-volume parameters of different treatment plans were compared with Friedman-ANOVA and LSD post-hoc test. *Results:* Both HIPO and IPSA methods decrease the time of planning process compared to FO; from 25 to 15 min in breast BT, from 10 to 7 min in cervix BT and from 20 to 10 min on average in prostate BT. IPSA creates lower dose coverage to the target volume, than HIPO or FO; the mean V100 was 91.7%, 91% and 91.9% for HIPO, IPSA and FO plans (p=0.1784) in breast BT, 90.4%, 89.2% and 91% (p=0.0045) in cervix BT and 97.1%, 96.2% and 97.7% (p=0.0005) in prostate BT, respectively. In cervix BT plans, IPSA created larger volumes irradiated by the prescribed dose, V_{100} was 48.5 cc, 59.6 cc and 52.8 cc in HIPO, IPSA and FO plans (p<0.001).

Results
The volume irradiated with high doses was also larger in IPSA plans, V_{150} was 26.7 cc, 30.3 cc and 28.9 cc (p<0.001), respectively. In breast BT, all of the plans were appropriately homogeneous, DNR was 0.3, 0.3 and 0.29 in HIPO, IPSA and FO plans (p=0.1524). In the case of cervix BT, IPSA produced the most homogeneous plans with DNR values of 0.55, 0.50 and 0.54 (p<0.001). HIPO plans were more homogeneous in prostate BT, DHI was 0.7, 0.6 and 0.6 (p<0.001), respectively. HIPO resulted in more conformal plans; COIN was 0.72, 0.71 and 0.69 (p=0.0306) in breast BT, 0.6, 0.47 and 0.58 (p<0.001) in cervix BT and 0.8, 0.7 and 0.7 (p<0.001) in prostate BT. In breast BT, dose to the skin and lung were smaller with HIPO and FO, than with IPSA. In cervix BT, dose to the rectum, sigmoid and bowel was larger using IPSA than with HIPO or FO. In prostate BT, dose to the urethra was higher, the rectal dose was smaller using FO than with inverse methods (Figure).

Conclusion
In interstitial breast and prostate BT, HIPO results in comparable dose-volume parameters to FO, but HIPO plans are more conformal. In cervix BT, HIPO produces dosimetrically acceptable plans only when more needles are used. The dosimetric quality of IPSA-plans is suboptimal and results in unnecessarily larger active lengths. In breast and prostate BT HIPO, in cervix BT the combination of HIPO and FO are recommended to use in clinical treatment planning.

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PO-0229 Towards informed and digitized HDR brachytherapy QA: Quantitative analysis of GYN applicators

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Purpose or Objective
To present a novel methodology that combines digitization and spatial tracking of the HDR source and its marker within the applicator structure. To share the results of using this method in quantifying positional accuracy in gynecological brachytherapy applicators.

Materials and Methods
A total of 151 QA procedures of gynecological applicators were performed in this study between 2019-2020 together with their corresponding markers. This included the Venezia, Utrecht, Fletcher, vaginal cylinders, multichannel cylinders, and the intrauterine tandems of the tandem and ring sets. Each set of applicators was fixed to a 5" by 8" piece of EBT3, XRQA2 or RTQA2 radiochromic films (Figure 1A). Four ball bearings (BBs) and ink-dots were placed at each corner of the film prior to imaging to allow for accurate image-registration (Figure 1B-C). First, the *x*-ray markers were inserted into the applicators and imaged using *x*-rays and then removed so the HDR source could be sent to the distal position and deliver an amount of radiation set by a local Ci.sec nomogram. The film was scanned and the image was registered to the *x*-ray image based on an affine four-points registration (circled red/blue, Figure 1B-C). A source tracking model was developed and integrated within the registration algorithm for automatic position assessment of the HDR source and marker coordinates. All shifts are reported in the direction of the source trajectory only (Figure 1D).

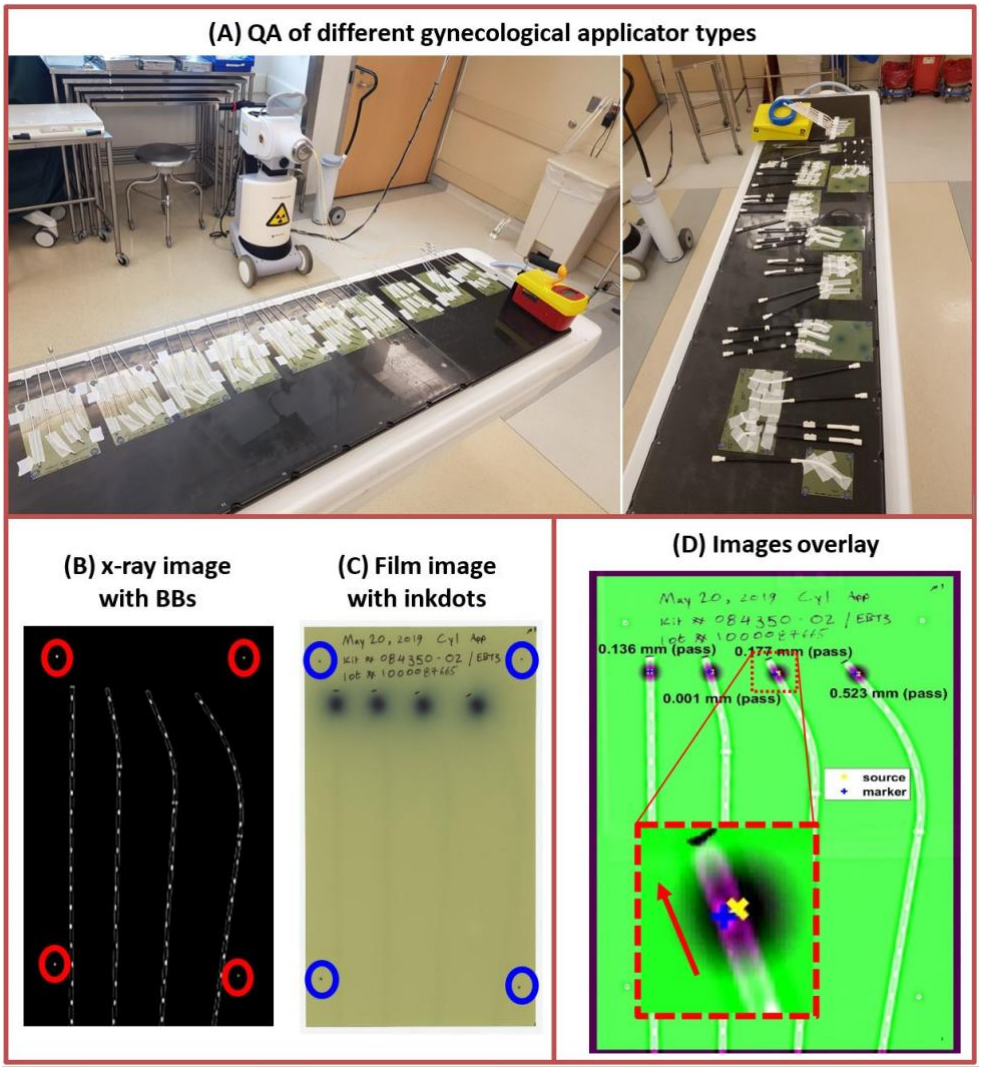

Figure 1: Methods

Results

The difference between the source and marker positions for all applicators in 2019 (59 in total) was (-0.05 ± 0.27) mm. Figure 2 summarizes the statistics per applicator type. A systematic shift of (-0.50 ± 0.34) mm was noticed in 78 applicators tested in 2020 right after the source exchange. The difference decreased afterward to (0.15 ± 0.22) mm based on multichannel cylinder data only. Assuming the error was not detected, the positional difference could have exceeded 1 mm based on a 95% confidence level. Figure 2 also shows that the lunar ovoid of the Venezia applicator provided improved positioning compared to our experience with rings (not included in this study). The Ci·sec nomogram to give a specific dose has the form (Ci·sec =88.2×dose(Gy)×distance(cm)^2), where the distance is between the source and the film. A 3 Gy dose gave adequate color for the analysis using all film models. The QA procedure could be performed with all the included film models since it does not require dose-response linearity.

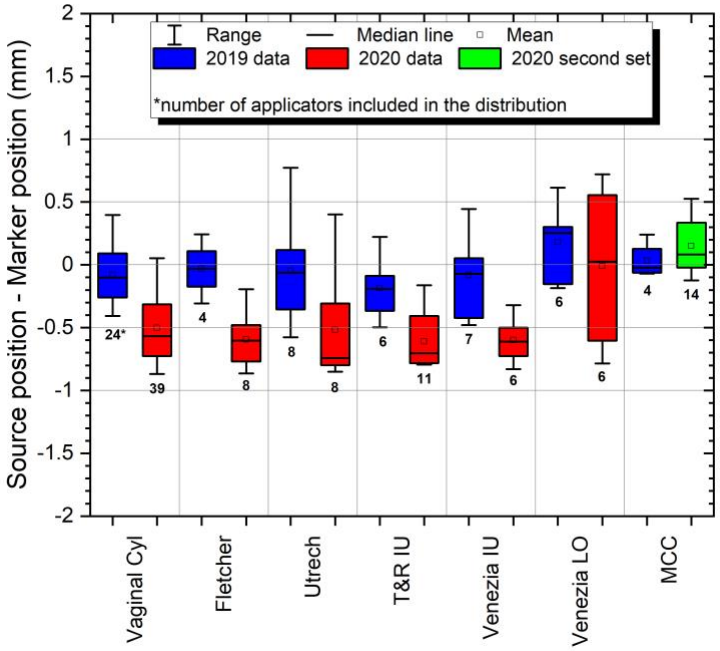

Figure 2: Results. Cyl: Cylinder, T&R: Tandem and Ring, IU: Intra Uterine, LO: Lunar Ovoid, MCC: Multi Channel Cylinder

Conclusion
The tracking/registration model was sensitive to detect, quantify and visualize the displacement of the HDR source with respect to the x-ray marker position which was not the case with standard qualitative QA. The proposed method is capable of advancing applicator QA based on tools already-available in the clinic.

Poster: Prostate

PO-0230 Subdomains of erectile and urinary function after ultrafocal HDR-brachytherapy for prostate cancer

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Purpose or Objective
Focal therapy for localised prostate cancer can lead to durable disease control with the potential to reduce side-effects. We have recently reported the medium term outcomes of our phase I study regarding MRI-guided ultrafocal high-dose-rate (HDR) brachytherapy in which we noticed a significant and permanent decline in erectile function and a transient increase in urinary complaints. We aimed to investigate which subdomains were most affected by ultrafocal HDR-brachytherapy.

Materials and Methods
30 patients with PSA<10ng/ml, T-stage≤T2c and Gleason sum score ≤7 were treated with MRI-guided ultrafocal HDR-brachytherapy from 2013-2016. Multiparametric MRI was used for targeting the clinical target volume (CTV), defined as the gross tumour volume plus a 5mm margin. MR-compatible catheters were implanted under rigidly fused ultrasound/MRI guidance, after which a single fraction of 19Gy was administered to the CTV. As part of the quality of life assessment the 5-item International Index of Erectile Function (IIEF-5, scoring range 1-25) and International Prostate Symptom Score (IPSS, scoring range 0-35) were obtained at baseline and during follow-up (after 1, 3, 6, 9, 12, 18, 24, 36, 48 and 60 months). Median scores with interquartile ranges (IQR) were calculated and differences over time were analysed with the Wilcoxon signed-rank test with $p<0.01$ considered significant to correct for multiple testing.

Results
Median age was 71 years (IQR 68-73) and 13 patients (43.3%) had T2c disease. Median baseline IIEF was 19 (5-22), which systematically decreased to 6 (4-20) at 60 months ($p=0.008$) (i.e. from mild to severe erectile dysfunction). All subdomains involving sexual intercourse or penetration decreased from a median score of 3-4 at baseline (5-point scale), to median 1 (figure 1) except for the confidence in the ability to get and keep an erection. Similar decreases were seen in patients using medication to aid erectile function. IPSS was relatively stable between median 5 (4-8) and median 8 (7-13) during follow-up. In subdomains of the IPSS, significant changes were seen for question 1 (symptoms of urinary retention) and question 4 (symptoms of urge), increasing from median 0 at baseline to median 1 ($p<0.01$). Frequency, intermittency, weak stream, straining and nocturia did not significantly increase (figure 2). Seven patients used alpha blockers during follow-up.

Conclusion
In this cohort with relatively advanced age and a large proportion with bilateral neurovascular bundle irradiation ultrafocal HDR-brachytherapy is accompanied by a relevant decrease in erectile function from mild to severe ED. The influence on urinary complaints is minor, mostly relating to symptoms of urinary retention and urge.
Figure 1: IIEF scores and subdomains.

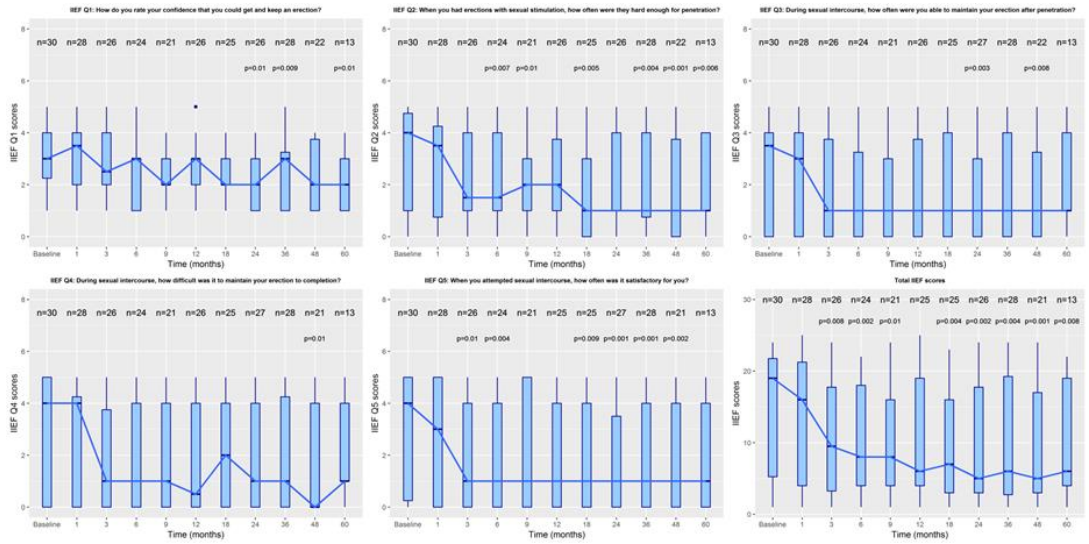
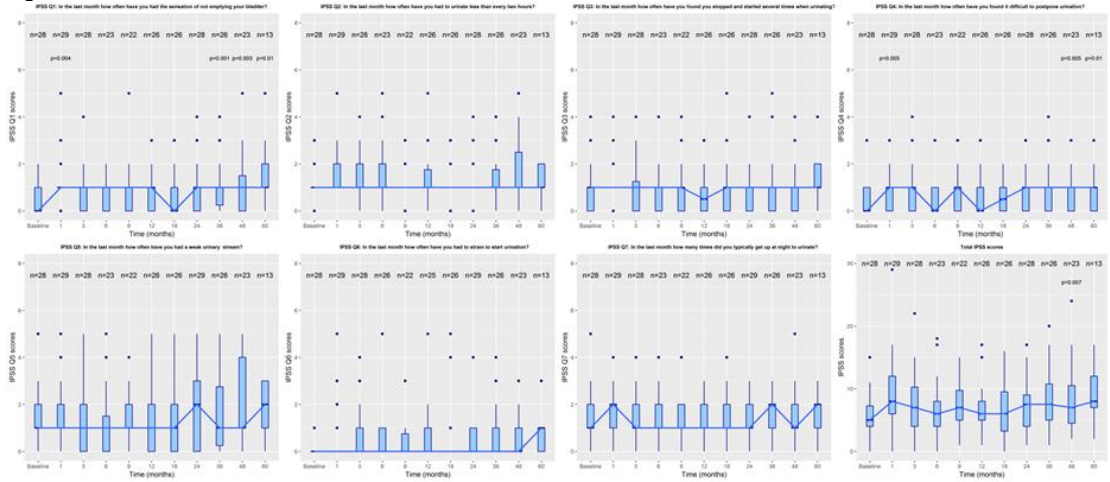


Figure 2: IPSS scores and subdomains.



PO-0231 Using PSA Kinetics to Predict 5-yr Biochemical Failure in Intermediate-Risk Prostate Cancer Patients

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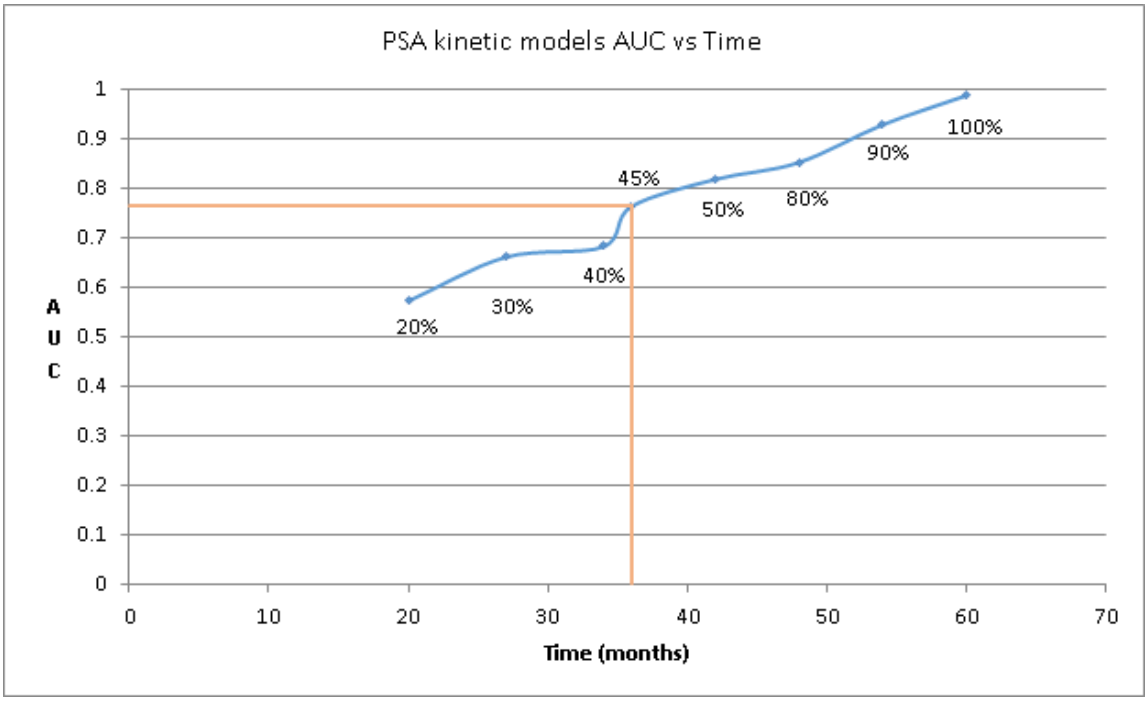
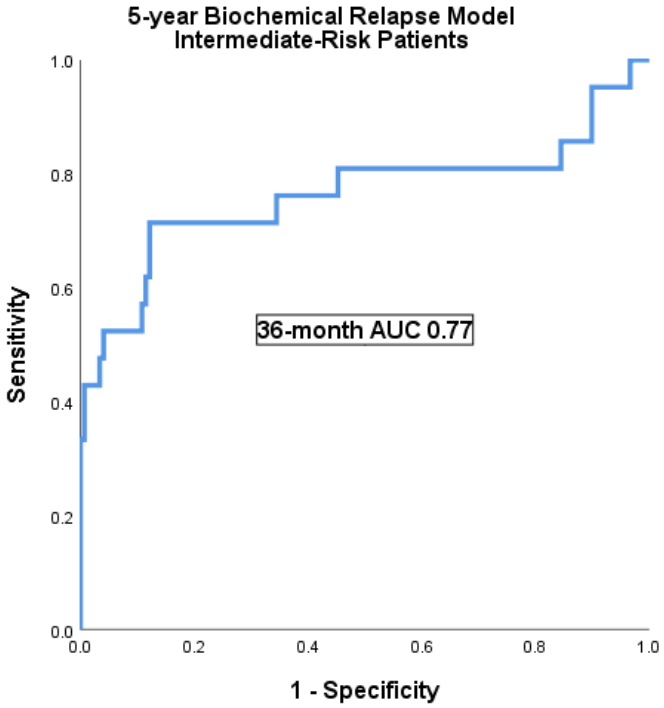
Purpose or Objective
The aim of this work was to test the hypothesis - `"can PSA kinetics be used to predict 5-year biochemical failure in intermediate-risk patients?" Here, biochemical failure was reported according to the RTOG-ASTRO consensus conference definition, and excluded patients who had a transient rise in PSA (PSA Bounce) following treatment.

Materials and Methods
Intermediate-risk disease stratification follows the European Association of Urology (EAU) guidelines. All patients had Brachytherapy as monotherapy, with a prescribed dose of 145 Gy. All patients had a 3-6 monthly interval follow-up for PSA testing.
A model was developed by applying a linear fit to the change in PSA of each patient over time, the output (slope and intercepts for each patient) of which was then used in logistic regression to evaluate how well the model predicted 5-year biochemical failure. Various models were tested for different PSA follow-up times, with values ranging from 0-20, 0-27, 0-34, 0-36, 0-42, 0-48, 0-54, and 0-60 months. The performance of the models was compared using the area under the ROC curve (AUC). Once a suitable model was identified, the data were randomly split into 2/3 training set and 1/3 testing set, where the testing set was used to test if the training set model had any predictive power, which was again evaluated using ROC AUC.

Results

Figure 1 shows the plot of different PSA kinetic models AUC with time, the performance of the models improves with time. The model at the 36-month time point had an AUC 0.76 and has the potential to predict 5-year biochemical failure in up to 55% of patients. The percentage values show the percentage o patients who failed at that particular time point. Figure 2 shows the ROC curve for the 36-month 1/3 testing data set, the model for which was developed with the 2/3 training data set. The 36-month AUC of 0.76 in Figure 1 was reproduced in the testing data set, AUC 0.77, thus demonstrating the robustness of the model. Earlier intervention could be achieved with the ability to predict 5-year biochemical failure in intermediate-risk patients. These patients could be suitable candidates for PET prostate-specific-membrane-antigen imaging, which has the ability to detect small volume disease at very low serum PSA levels. Patients with three or fewer metastases in the bone or lymph nodes could receive stereotactic body radiation therapy, while those patients with local failure alone could be suitable for salvage prostatectomy, or focal salvage Brachytherapy.





Conclusion

A model was developed to predict 5-year biochemical failure in intermediate-risk prostate cancer patients treated with LDR Brachytherapy, which could lead to earlier local curative salvage treatment; however, further validation of the model is required.

PO-0232 Permanent seed prostate brachytherapy : long term results of a large single center

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Purpose or Objective
We started brachytherapy with radioactive seeds for prostate cancer in summer 2005. We hereby present our long-term biochemical control and toxicity results

Materials and Methods
From July 2005 to February 2020, 1617 patients were treated with either permanent seed brachytherapy as single treatment or as a boost. For this present analysis, all 78 patients treated with a boost were excluded from analysis from our institutional database. Biochemical recurrence was calculated using the Phoenix definition (Nadir+2). The log-rank test was used to calculate differences between groups for recurrence-free survival.

Results
Median age was 65 years, 37% had Gleason 7 disease, 7% had a PSA >10 ng/mL and 42% had ≥34% of positive biopsies. While Gleason score 7 accounted for 30% of the first 500 treated patients and 49% of the last 500 treated patients ($p<0.001$).
Out of the 1530, 52 patients had a recurrence, 1087 patients have a documented follow-up of at least 24 months without recurrence. Median follow-up without recurrence was 56 months (IQR 40-84 months). The median PSA at last follow up was 0.08 ng/mL (IQR 0.03-0.23). In 71% <0.2 ng/mL and in 86% <0.5 ng/mL.
The 7-year biochemical recurrence-free survival for all patients was 95%. The rate was 96% in patients with a PSA <6 ng/mL, 95% for a PSA of 6-10 ng/mL and 84% for patients with a PSA >10 ng/mL, $p<0.001$. It was 94% for Gleason 6 and 97% for Gleason 3+4 disease ($p=0.15$). For the first 500 patients, 12 needed self-catheterization, compared to 9 in the last 500 patients. 23 needed a catheter for 5-21 days in the first 500 and 13 (2.6%) in the last 500.

Conclusion
In well selected patients, prostate-seed brachytherapy results in good biochemical recurrence-free survival. In our last 500 patients, long-term urinary retention lasting more than one day was a rare occurrence.

PO-0233 A multi-protocol validation study of automated bi-objective planning for HDR prostate brachytherapy

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Purpose or Objective
An automated bi-objective treatment planning method for HDR prostate brachytherapy that produces many high-quality plans with different trade-offs between target coverage and organ sparing was recently introduced. This allows for a more insightful planning process. Previous retrospective work showed that resulting plans were superior to the, mostly manually optimized, clinically used plans. The method was however constructed and validated only for protocol 1 (Table 1). Our purpose is to show how this method can be improved to straightforwardly support different protocols.

Materials and Methods
In the bi-objective optimization method, clinical criteria are aggregated into two objectives by considering the dose-volume indices (DVIs, also known as DVH-parameters) that deviate the most from the aspired coverage of target volume and sparing of organs at risk, as defined in a clinical protocol. In this work, we scale calculated DVIs relative to their aspiration values to make a meaningful comparison between DVIs with different ranges and different units (dose or volume), as required for the aggregation of DVIs into two objectives. We refer to this as normalization. This normalization enables the use of our bi-objective optimization method for any protocol defined in terms of DVI aspiration values.
For optimization the Gene-pool Optimal Mixing Evolutionary Algorithm (GOMEA) accelerated by an NVIDIA 2080 Ti graphics processing unit was used. Optimization was done on 100,000 dose calculation (DC) points, and all reported DVIs were re-computed on 500,000 DC points (default setting in Oncentra Brachy). A time limit of 3 minutes per patient was used.
Bi-objective planning was done retrospectively using three different protocols for 39 HDR prostate brachytherapy patients, treated using protocol 1 and manual optimization. We first study the effect of normalization by comparing to previously optimized plans for protocol 1. We then show outcomes for all 3 protocols.

Results
Using normalization for protocol 1, all clinical criteria were satisfied for the same 32 patients as without normalization. Table 1 shows the effect of normalization for 3 patients, generally resulting in an increase in ⁂90%, ⁂150%, and ⁂200% for the prostate.
Figure 1 shows results of all 39 patients for all 3 protocols. Plans for protocol 2 marginally violated aspired values of 0% for the bladder ⁂200% and rectum ⁂100% due to re-computation of DVIs, but never exceeded 0.02%. Remaining clinical criteria were satisfied for all 39 patients. Clinical criteria of protocol 3 were satisfied for 38 patients.

Conclusion
The bi-objective optimization method can now be used to optimize plans for any clinical protocol specified in terms of DVI aspiration values, which is an important step towards widespread clinical implementation. For two new protocols, all clinical criteria were satisfied in a majority of cases. Future work will require resulting plans to be compared to clinical plans, and to be further assessed by clinical experts.

Table 1: DVIs for 3 patients that were also highlighted in previous work, when using normalization (Norm.) compared to previously obtained (No norm.) results, and the clinically used plan (Clin.), optimized for protocol 1. Values colored in red violate the clinical protocol. As the outcome of the bi-objective planning method is a large set of plans with different trade-offs, we automatically select the plan with the maximum coverage objective that satisfied all clinical sparing criteria. Reported values are means and standard deviations of the automatically selected plans of 30 optimization runs. Percentages are relative to organ volume or planning-aim dose.

	Protocol	Patient 1			Patient 2			Patient 3		
	1	Clin.	No norm.	Norm.	Clin.	No norm.	Norm.	Clin.	No norm.	Norm.
$V_{100\%}^{prostate}$	> 95%	95.5	97.3±0.1	97.1±0.1	99.0	99.9±0.0	99.6±0.1	98.3	99.1±0.1	99.0±0.1
$D_{90\%}^{prostate}$	> 100%	106.5	107.7±0.5	108.9±0.3	112.3	109.2±0.9	111.8±0.1	108.9	108.9±0.4	110.7±0.3
$V_{150\%}^{prostate}$	< 50%	34.3	27.9±1.1	30.1±0.7	26.3	20.5±1.3	24.4±0.9	28.1	24.2±1.0	26.9±0.9
$V_{200\%}^{prostate}$	< 20%	13.4	11.5±0.5	12.1±0.4	9.9	7.6±0.4	9.0±0.3	9.8	9.3±0.4	9.9±0.5
$V_{80\%}^{seminal\ vesicles}$	> 95%	96.4	97.9±0.4	97.4±0.3	99.7	100.0±0.0	99.9±0.1	95.2	99.3±0.1	99.0±0.2
$D_{1cm3}^{bladder}$	< 86%	85.8	83.4±0.5	83.7±0.5	80.2	84.2±1.1	77.5±1.2	92.5	81.7±0.4	81.9±0.5
$D_{2cm3}^{bladder}$	< 74%	75.3	73.8±0.3	73.7±0.3	69.3	72.0±0.9	66.6±1.0	83.0	73.8±0.2	73.8±0.3
D_{1cm3}^{rectum}	< 78%	70.9	72.4±1.2	72.5±1.2	50.6	57.0±3.0	55.3±1.4	78.6	77.4±0.5	77.4±0.4
D_{2cm3}^{rectum}	< 74%	64.1	66.0±1.1	66.0±1.1	43.9	49.4±2.3	47.9±1.1	69.3	67.9±0.5	67.5±0.5
$D_{0.1cm3}^{urethra}$	< 110%	110.4	109.7±0.4	109.8±0.3	113.1	109.7±0.2	110.0±0.0	109.0	109.6±0.4	109.6±0.4

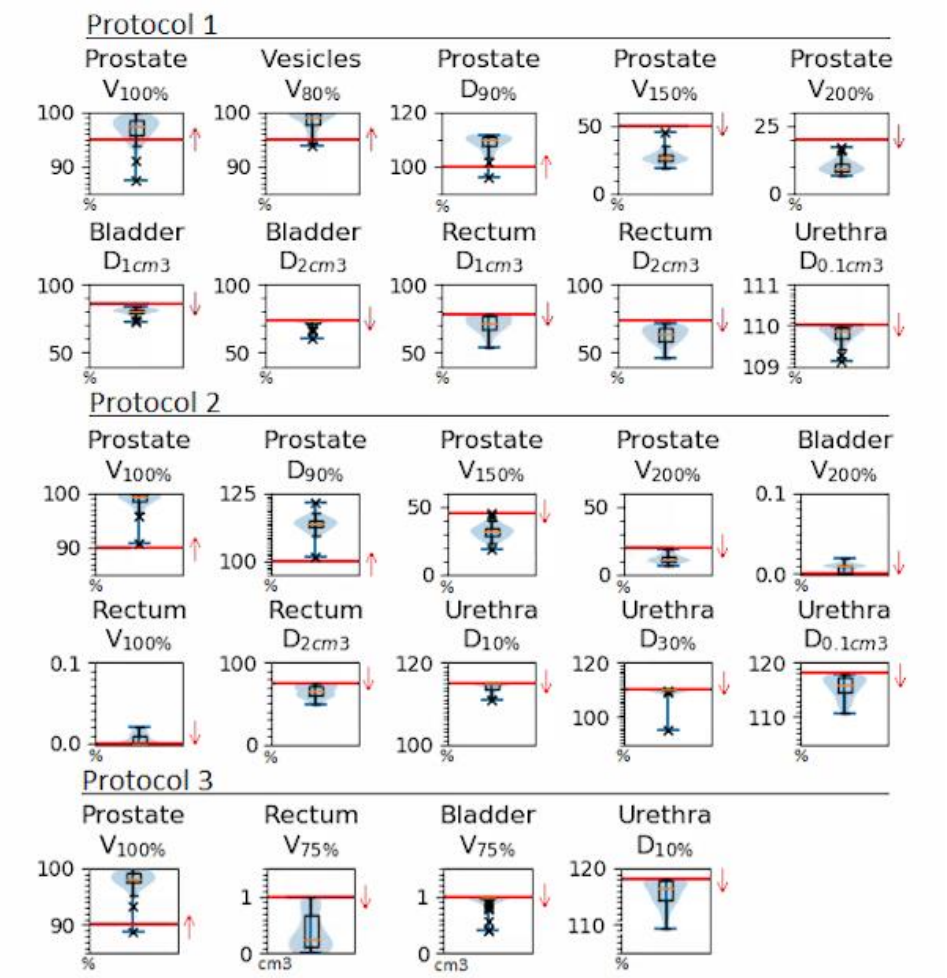

Figure 1: Aggregated values of DVIs of plans optimized for two newly supported, clinically used protocols, for all 39 patients. As the outcome of the bi-objective planning method is a large set of plans with different trade-offs, we automatically select the plan with the maximum coverage objective that satisfied all clinical sparing criteria, taking the median DVIs for 30 optimization runs. Percentages are relative to organ volume or planning-aim dose. The aspired value of a DVI, as described in the clinical protocol, is indicated by a red line, and an arrow indicates minimization or maximization.

PO-0234 Feasibility in using a nomogram as an independent verification process in HDR prostate brachytherapy

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Purpose or Objective
Institutional recommendations indicating the need for an independent check of each clinical patient dosimetry calculation. In case of brachytherapy (BT), this poses several difficulties given the variety of implants. As a compromise, data imported from the TPS are recomputed independently (Carmona el al[1]).
The use of nomograms is very common in the intraoperative planning of Low Dose Rate (LDR) interstitial permanent prostate BT. Some authors (Pujades et al[2]) proposed also its use as well in the already widely spread high dose rate (HDR) technique.
This nomogram has been in use for the past 10 years in our department. The main purpose of this work is to confirm the validity of the adjustment parameters using data we have collected from the high number of implants performed to date, to evaluate a polynomial fit instead a linear one, and to determine whether tolerances can be established.

Materials and Methods
^{192}Ir source with MicroSelectron and Flexitron together with Oncentra Prostate software (Nucletron) have been and are used at our institution.
The doses administered in the HDR implants collected can be of 9.5,10,13.5 or 15 Gy. All implants have been performed by the same radiation oncologist and by three medical physicists following a strict protocol.
From 2011 to 2020, 683 HDR implants have been performed and in all of them the Carmona *et al.* independent calculation has been used. In addition, the nomagram was also evaluated.
The linear function proposed in [2] is:$(TxS_K)/D=axV+b$

Where T is total radiation time(h), S_K is the source Air Kerma Strength ($\mu Gyxm^2xh^{-1}$), D is the prescribed dose(Gy), and V is the target volumen(cm^3). The parameters *a* and *b* obtained in this work were:$a=(6.3\pm0.5)x10^{-2}cm^{-1}$ and $b=(1.7\pm0.14)cm^2$
We have evaluated the potential benefice of a quadratic fit:$(TxS_K)/D=axV^2+bxV+c$
The deviations obtained between the real treatment time and that predicted by the nomogram have also been explored. A tolerance value has been explored from the refined fit (95% confidence).

Results

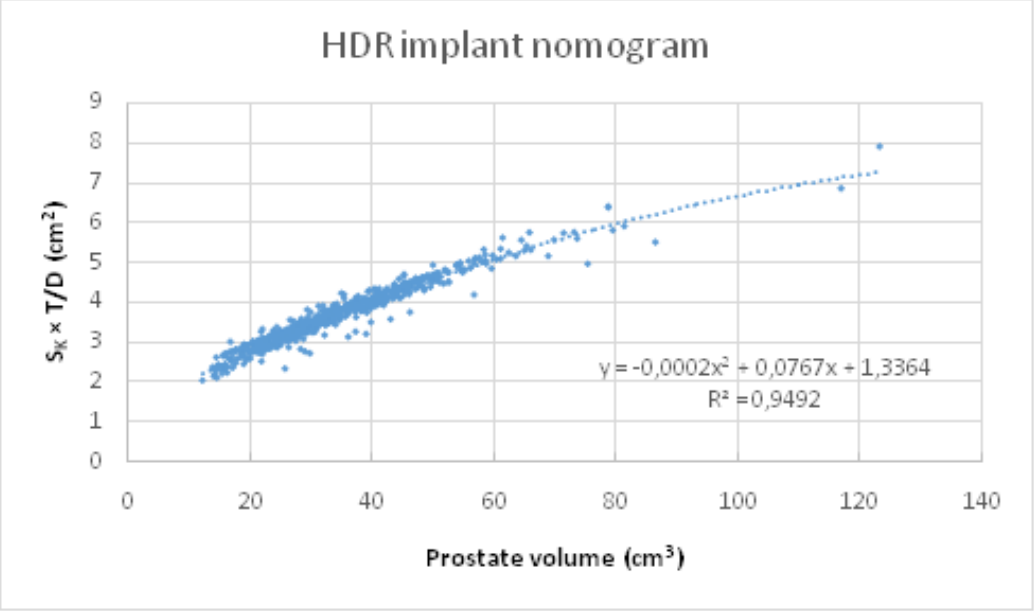

Figure 1 shows the HDR implant nomogram and the new quadratic fit with the new adjusted values for *a*, *b* and *c*.
It has been demonstrated, that the quadratic fit is suitable (R^2=0.9472) and that it fits better than the linear one [2](R^2=0.940).

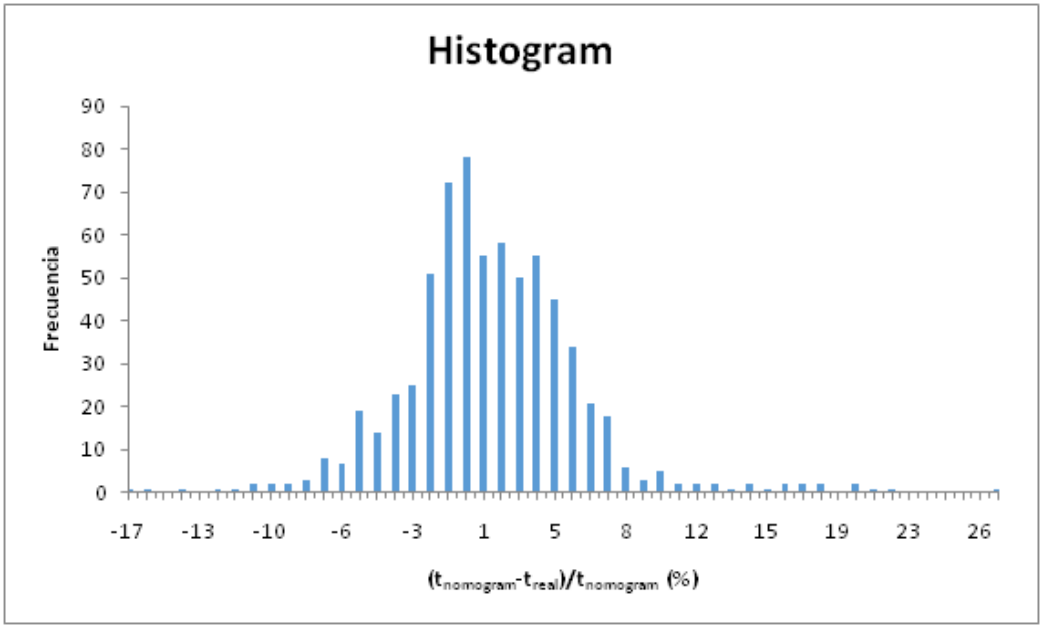

Figure 2 shows the deviations obtained between the real treatment time and that predicted by the nomogram obtained from the quadratic fit.
It has been observed that with the larger number of patients studied (683) and strictly maintaining the technique, deviation values greater than 10% should be reviewed.

Conclusion
Nomograms are a simple additional quality assurance tool which should not replace independent verification.
For the HDR nomogram that we present in this work, the quadratic adjustment improves the linear one.
The deviation threshold from what it is convenient to review the differences between the value predicted by the nomogram and the value obtained in the dosimetry can be set at 10%.

PO-0235 HDR Prostate Brachytherapy – Is 20 needles too many?

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Purpose or Objective
HDR brachytherapy boost to the prostate is used to improve outcomes or as an alternative to EBRT alone for patients with some co-morbidities. During this procedure, the positioning of needles is vital to allow good coverage of the prostate whilst minimising the dose to OARs. Using more needles may improve the quality of the plan, but it is possible that this may also increase acute toxicities. In this study we assessed the plan quality and acute toxicities for 50 patients treated with 20 needles, the maximum possible at our centre, to answer the question – is 20 needles too many?

Materials and Methods
Between October 2017 and September 2019, 50 patients were treated with a 15Gy single fraction boost to the prostate, under TRUS guidance, using 20 implanted needles. Retrospectively, the plans were re-optimised using decreasing numbers of needles and the plan quality of each was assessed in terms of the dose constraints in the UK National Protocol (prostate D_{90}>15Gy, $V_{100}\geq$95%, rectum D_{2cc}<12Gy, V_{100}=0, urethra D_{10}<17.5Gy, D_{30}<16.5Gy) and visual assessment of isodoses. The same patients were reviewed and acute toxicity identified by two parameters: urinary retention post HDR and a hospital stay longer than the usual 1 night. The same toxicity parameters were assessed in all patients during the same time period treated with 16 or fewer needles (25 patients, minimum 13 needles).

Results
In some cases, it was found that plans could be produced that used fewer than 20 needles and still met the clinical dose constraints. However, visual assessment of the isodoses showed the coverage to be often compromised, particularly at the apex, seminal vesicles or the posterior edge of the prostate, and using more needles was found to reduce the likelihood of cold spots in the prostate.
In terms of toxicity, 4 out of 50 patients (8%) treated with 20 needles had an increased length hospital stay following HDR although these were not all directly related to the HDR. 7 out of 50 (14%) went into urinary retention requiring catheterisation following HDR. Of the patients treated using 16 or fewer needles, 2 out of 25 (8%) required an increased length hospital stay due to bleeding (one of these was treated using the minimum 13 needles) and 2 out of 25 (8%) were catheterised due to urinary retention.

Conclusion
Using 20 needles was found to produce treatment plans with optimal prostate coverage, particularly at the posterior prostate edge, apex and seminal vesicles. In our study, increasing the needle number from 16 or fewer to 20 was not associated with an increased hospital stay due to bleeding, however an increased risk of short term urinary toxicity was seen. We conclude that using 20 needles can provide a dosimetric benefit for some patients and in those cases the toxicity risks are acceptable, however this should be taken into consideration when consenting the patient for treatment.

PO-0236 HDR monotherapy for low and intermediate risk prostate cancer in one or two fractions

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Purpose or Objective
The effectiveness of Low Dose Rate Brachytherapy in patients with low risk prostate cancer to date has been proven and confirmed by a number of publications and recommendations. At the same time, there is an increasing interest in the use of High Dose Rate Brachytherapy(HDR-BT) as monotherapy, previously considered only as a part of combined treatment.

Materials and Methods
This study includes 179 patients with localized prostate cancer with low and intermediate risk disease (NCCN), treated in our clinic from April 2016 to December 2019.
Median age was 66,5 years (range 41 - 83). All patients had pathologically diagnosed adenocarcinoma Gleason ≤ 7 (not higher than 2 grade group). Clinical stage ≤ T2b; median PSA 7,22 ng/ml (2,32-18,0); median prostate volume 40,0 cc; maximum flow rate (Qmax) 17.8 ml/sec on average; median IPSS 12. Rectoscopy was performed for all patients to eliminate possible pathology of the rectum.
HDR-BT was performed either 19 Gy as a single fraction (128 patients) or 15 Gy in 2 fractions (51 patients) two week apart. Ir-192 used for HDR-BT. All patients treated with ultrasound control under spinal anaesthesia. Side effects were scored with EORTC/RTOG scale. Biochemical relapse was assessed by the Phoenix (nadir+2) definition.

Results
Median follow-up was 16,5 month (5,9 to 54). PSA decreased more rapidly in 2x15Gy arm: 0.64 ng/ml/month and 0.37 ng/ml/month in 1x19 Gy arm. At the same time, the number of biochemical relapses in the 1x19Gy arm was 7 patients, and in the 2x15Gy arm none. No significant difference in side reactions in the two test groups was observed during the observation period. Although it should be noted 1 urethral stricture in 2x15 Gy arm. GI toxicity rate ≥1 was not reported in both groups.

Conclusion
Despite the prospect of published results of single-fraction HDR-BT, own experience confirms the necessity to make a minium 2 fractions or increase the dose per one fraction using focal booster technique.

PO-0237 HDR monotherapy (2 fractions/13,5 Gy) in LR and favorable IR prostate cancer: analysis of toxicity.

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Purpose or Objective
The purpose of this study was to retrospectively analyze the urinary and gastrointestinal toxicity in low risk (LR) and favorable intermediate risk (FIR) prostate cancer patients undergoing two fractions of high-dose-rate brachytherapy (HDR-BT) as monotherapy.

Materials and Methods
Between April 2013 and January 2018, 49 patients with LR (17, 35%) and FIR (32, 65%) has been treated in our Institution with exclusive HDR BT. Median age 69 years (range 46-80). Median Gleason 6 (range 3-7). Median PSA at diagnosis 7,10 ng/ml (range 2,34-19,75). Median volume of the prostate at diagnostic was 54,09 cc (23,33-103,16 cc). Because of it 24 patients (48%) had neoadjuvant androgen deprivation therapy (ADT) before the HDR BT. Three patients (6%) had a previous transurethral resection (TURP). Five patients (10%) were diabetic, 19 (39%) had hypertension, five (10%) had any cardiac pathology and 7 (14%) were under anticoagulant treatment. All patients were treated with High Dose Rate Brachytherapy (Oncentra Brachy. NUCLETRON/ELEKTA), 2 fractions of 13,5 Gy, 10 days apart. Median D90 for the first implant 107, 25 Gy (range 101,3-111,6) and for the second implant 106,27 Gy (101,4-112,4).

Results
The median follow-up was 42 months (5-85 months). bPFS was at 3 and 5 years 95%. For toxicity analyses, common terminology criteria for adverse events (CTCAE) version 4.0 was employed. Acute dysuria grade 2 was described in 5 patients (10%), acute urinary frequency G2 in 10 patients (20%). Two patients (4 %) had an acute urinary retention G2 needing a catheter during 10 days and in one patient was necessary a surgical resection of the intravesical median lobe because retention (G3, 2%). Chronic dysuria grade 2 was described in 1 patient (2%), chronic urinary frequency G2 in 1 patient (2%), chronic incontinence G2 in two patients (4%) controlled in all cases with medication. There was no grade 4 toxicity. Only 1 patient (2%) had acute proctitis. Acute and chronic gastrointestinal toxicity G2, G3 or G4 has not been described.

Conclusion
HDR monotherapy with 2 fractions of 13,5 Gy is a safe treatment with very low genitourinary and gastrointestinal acute and chronic toxicity despite being patients with a no negligible percentage of associated comorbidities.

PO-0238 LDR-HDR boost in patients with intermediate-risk prostate cancer. A single Institution experience.

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Purpose or Objective
To compare the boost with two BT techniques, LDR/ HDR, performs in a single institution and team, in terms of biochemical progression free survival (bPFS) and toxicity in patients diagnosed of intermediate risk prostate cancer (RI).

Materials and Methods
Between January 2005 and February 2018, 142 patients with RI, treated with a BT boost have been retrospectively analysed. The primary endpoint was to compare the boost with I-125 seeds permanent implants (LDR) and HDR in terms of bPFS. The secondary endpoint after reclassifying patients into “favorable” (FIR) and “unfavorable” (UIR) subgroups was to analyze if there are differences between both approaches, with theory similar treatment intensity. All patients have been treated with EBRT with Intensity Radiotherapy Modulated Radiotherapy (IMRT)/Volumetric modulated arc therapy (VMAT). Prescribed dose was 45 Gy (180 cGy/fraction) when the boost was done with LDR BT and 60 Gy (200 cGy/ fraction) with HDR BT. Prescribed dose with LDR was 100 Gy in 13 patients (26%) and 108 Gy in the remaining 37 (74%). Dose prescription was 10 Gy in 1 fraction when HDR boost was performed under real time TRUS guidance.

Results
SPSS Statistics (Version 18.0) was used for statistical analysis. Median overall follow up for the total cohort was 70,5 months (16-185 months). bPFS was at 5 and 7,5 years 92% for LDR and HDR BT boost respectively (p=0.615). Forty-two patients (30%) were reclassified in FRI and 100 (70%) in URI. There was not significant difference in bPFS, overall survival (OS), cause specific survival (CSS), local failure (LF), lymph node failure (LNF) or distant failure (DF) between LDR or HDR boost. Estimated bPFS at 5 and 10 years was 100 % for FIR patients and 89% and 82 for UIR respectively (p=0.013). For toxicity analyses, common terminology criteria for adverse events (CTCAE) version 4.0 was employed. There was no grade 4 or 5 toxicity. In the multivariate analysis acute dysuria G1 (*p=0.04*), acute urgency G1 (*p= 0.013*) and proctitis G1 (*p=0.00*) are higher in HDR BT. Chronic dysuria G1 (*p= 0. 05*) is higher in LDR BT. Chronic G1 rectal bleeding is superior (*p=0.03*) in HDR BT.

Conclusion
In this mono-institutional and strongly homogeneous study, despite being retrospective, it is demonstrated that BT combined with EBRT is an excellent therapeutic option in patients with IR PCa, with equal results when both LDR and HDR techniques are employed and very low toxicities.
Patients included in UIR, constitute a different entity that should be treated as patients with high risk factors, being of high importance the stratification and identification of both risk groups.

PO-0239 20 Gy HDR brachytherapy as monotherapy for localized prostate cancer: Early outcomes

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Purpose or Objective
To analyze toxicity and early clinical outcomes in patients with low and intermediate risk prostate cancer treated with single session 20 Gy HDR brachytherapy.

Materials and Methods
From January 2015 to October 2019, 62 prostate cancer patients (39 low and 23 intermediate risk) were treated with 20 Gy HDR (Ir192) as single fraction. At diagnosis, mean age was 65.7 years (range 51-77), PSA was 6.74 ng/mL (range 3.98-16) and mean Gleason score was 6 (range 3-7). No patient received previous androgen deprivation therapy. Mean prostate volume was 48.9 cc (range 21.1-93) and all tumors were confined to prostate gland, T1-T2 N0 M0 by MRI.
The procedure was performed under spinal anesthesia and lithotomy position. Needles are inserted into the prostate through the perineum and into the bladder with transrectal ultrasound (TRUS) image guide, using a template. Mean number of needles was 13.2 (range 9-18). After needles implantation 2 mm TRUS images were obtained to the planning system. Prostate was delineated as clinical target volume (CTV). Planning target volume (PTV) included prostate and 5 mm margin except 2 mm margin in the rectal wall. Prostate prescription dose was 20 Gy. Maximum point dose for rectum was less than 70% and for urethra less than 120% of the prescription dose in all patients. Gastrointestinal (GI) and genitourinary (GU) toxicity were evaluated in agreement with Common Terminology Criteria of Adverse Effects (CTCAE v 5.0). For sexual function the International Index of erectile Function Questionnaire (IIEF) was used. It´s an outpatient procedure with a total duration of 2-3 hours and patients leaves the hospital without urinary catheter.

Results
With a median follow-up of 38.7 months (range 12-68) local control rate is 100%. Two patients developed pelvic lymph node relapse as oligometastasis. Mean PSA after 1 year from treatment is 1.07 ng/mL (range 0.05-3.09). Mean dose for D90 was 21.6 Gy (range 20- 23.4) and prostate D100 was 19.4 Gy (range 17.8- 20). The prostate volume irradiated to 20 Gy (V100) was 98.3% (range 95-100%). According to CTCAE v 5.0, acute GU toxicity G1 and G2 was observed in 56.4% and 9.6% respectively. No acute rectal toxicity was described. Chronic GU toxicity G1 was seen in 8.1% of patients. No acute and late GI and GU toxicity G3-G4 were reported. Sexual function is preserved in 89.2% of patients.

Conclusion
In our early experience, single fraction 20 Gy HDR brachytherapy as monotherapy is a safe and well-tolerated treatment with low toxicity in patients with localized prostate cancer. It can be an alternative treatment to watchfull waiting for those patients requesting treatment, and also an alternative treatment to surgery, seed implants and external radiotherapy. Also has the additional advantage of high cost-efficiency.

PO-0240 Prostate radiotherapy rectal sparing: synergy with combo-brachy, gradient optimization, and SpaceOAR

Abstract withdrawn

PO-0241 EAU eligibility criteria for exclusive 125I brachytherapy for intermediate risk prostate cancer

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Purpose or Objective
^{125}I brachytherapy (BT) alone for intermediate risk (IR) prostate adenocarcinoma (PA) is controversial.
The objective was to investigate potential predictive factors including the EAU-ESTRO-SIOG eligibility criteria in selected IR PA patients treated in our center with BT. In addition we performed a comprehensive literature review of IR PA treated with BT as the sole radiotherapy modality.

Materials and Methods
Among 547 patients treated with ^{125}I BT between 2003 and 2013, we isolated 149 IR PA according to National Comprehensive Cancer Network (NCCN) classification after an additional exclusion of patients with PSA > 15ng/ml and ISUP group 3. Relapse was defined as a biochemical failure using ASTRO Phoenix definition or a relapse identified on imaging. A comprehensive literature review on BT for IR PA patients is also presented.
Survival curves were estimated by the Kaplan Meier method. Potential prognostic variables including the EAU-ESTRO-SIOG guidelines eligibility criteria were analysed using univariate and Cox's proportional hazards regression analysis.

Results
Of 149 IR patients, 112 were classified as favorable including 69 eligible to BT according to EAU-ESTRO-SIOG guidelines and 37 as unfavorable according to NCCN. Androgen deprivation therapy (ADT) was received by 6 patients only. No patient received transurethral prostate resection before BT. MRI was available at the initial staging for 89 patients. Percentage of positive biopsy cores were ≤33.0 % and >= 50% for 119 and 11 patients respectively. Median follow-up was 109 months ranging from 1 to 190 months. Follow-up was ≥ 5 years for 136 patients (91.3%). The 10-year overall survival, progression free survival and relapse free survival (RFS) (95% CI) were 84% (75-90%), 66% (56-75%) and 77% (67-84%) respectively. 30 patients experienced a relapse. The median time to relapse was 65 months (7-144 months). An imaging work-up was performed in 21 patients. Local relapse was histologically proven in 8 patients (negative biopsy in 1; biopsies not performed in 3). In addition, 1 patient among the 9 patients who didn't benefit from an imaging exam had a proven prostate relapse after a series of biopsies. Of the 25 patients who died, only one patient died of the metastatic progression of prostate cancer, 14 patients died from other cancers, 7 from intercurrent cause. No patient died of BT toxicity. The cause of death was unknown for 4 patients. Failure to meet the EAU-ESTRO-SIOG criteria was significantly associated with a lower RFS (p = 0.0267, HR (95% CI) = 2.37 (1.10-5.08)).

Conclusion
BT is an effective treatment for selected IR PA. Patients who were not eligible according to EAU-ESTRO-SIOG guidelines had a lower RFS.

PO-0242 Treatment outcomes and toxicity in patients treated with LDR brachytherapy, single institution study

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Purpose or Objective
Low dose rate brachytherapy (LDR BT, permanent implantation) represents an effective treatment modality for localized prostate cancer for many years. In this abstract our retrospectively reviewed treatment results with follow up more than 5 years are presented.

Materials and Methods
Between 2007 and 2019 more than 1200 patients with prostate adenocarcinoma were treated with permanent implantation of iodine-125 (125I) seeds in our institution. Only patients with follow-up more than 5 years are considered here (n=329). Of these, 216, 79, 34 had low, intermediate and high risk disease (EAU) respectively, with median age 64 years (42-82y). Of the patients, 276 presented with Gleason 6 tumours, 45 had Gleason 7 and 8 Gleason 8 and higher disease. Depending on risk group, patients were treated in monotherapy (84%) or in combination with EBRT (16%). Androgen deprivation therapy was administered in 218 patients (mainly by urologists). BT implant procedure consists from single step technique (intraoperative planning), transperineal implantation guided with transrectal ultrasound. Average number of implanted seeds was 49 (14-97 seeds), average prostrate volume at the time of implantation was 31,3 cm3.

Results
With median follow-up of 6,8 years (5,1-16,7y) free of biochemical progression were 94,2% patients in whole cohort (all risk groups), in low, intermediate and high risk group biochemical control was 94,4%, 94,9% and 91,2%. Biochemical failure (RTOG-ASTRO Phoenix) occurs in 19 patients (5,8%), distant failure in 7 patients (36,8%), combined local and regional in 1 patient (5,3%), regional only in 1 patient (5,3%) and local failure only in 7 patients (36,8%). Median time to loco-regional failure was 60 months (21-89m), median time to generalisation was 30 months (7-40m). Salvage treatment was administered as follows: 6 patients with local failure underwent salvage prostatectomy, 2 patients with loco-regional failure salvage EBRT and all other patients salvage ADT.
Overall survival in our cohort was 96,0%, 12 patients (3,7%) died on other causes, prostate cancer specific survival in our cohort was 99,7%. Death from other reason was 12 times more frequent, than from prostate cancer.

Conclusion
Treatment outcomes in our cohort of patients are reflecting published data in the literature. LDR brachytherapy in localized prostate cancer is safe and effective treatment.

PO-0243 HDR brachytherapy as monotherapy or a boost for high risk prostate cancer: 5 year single center data

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Purpose or Objective
to compare efficacy and toxicity of interstitial high-dose-rate (HDR) prostate brachytherapy when it was used as monotherapy or as a boost to external beam radiotherapy for high risk prostate cancer.

Materials and Methods
Material and methods: 119 primary patients with clinically localized high or very high risk prostate cancer that were treated from 1.07.2012 to 01.01.2017 were included in the study. HDR brachytherapy as a monotherapy for high risk prostate cancer was performed in 21 patients ("monotherapy group"). In all cases it was performed as 3 fractions (3 implantations) of 11.5Gy for prostate (with 5mm margins) and seminal vesicles. In 39 men with high and 59 patients with very high risk prostate cancer we performed androgen deprivation with external beam radiotherapy to the prostate and pelvic lymph nodes (46Gy-50Gy in 23-25 fraction) and brachytherapy "boost" to the prostate and seminal vesicles (1 fraction of 15Gy in 17 men; 2 fractions of 10Gy – in another 85 cases) – "boost group". The reported end points were biochemical

control rate according to Phoenix definition and overall/cancer-specific survival. Toxicity was scored according to the RTOG scale.

Results
The median follow-up time was 59.2 months. In "monotherapy group" the 5-year biochemical control was reached in 80.9%. Grade II late genitourinary toxicity detected in 4 (19%) observations. Grade II rectal toxicity mentioned in 2 (9.5%) cases. Grade III was not mentioned neither for rectal nor for genitourinary toxicity. IIEF score before treatment was below 16 points in 28.5% and after brachytherapy – in 51% cases.
In the "boost group" the 5 year biochemical control was mentioned in 30 of 39 (76.9%) high risk and in 39 of 59 (66.1%) very high risk patients (p=0.04). Grade II late genitourinary toxicity detected in 33 (33.6%), grade III – in 1 patient. Grade II rectal toxicity mentioned in 10 (10.2%), Grade III in no case. IIEF score before treatment was below 16 points in 29.6% and after treatment – in 69% cases.
In high risk patients there was no significant difference in biochemical recurrence free survival between treatment groups ("monotherapy" vs "boost").

Conclusion
in patients with high risk prostate cancer high dose rate brachytherapy can be effectively and safely used for monotherapy and as a boost after irradiation of the pelvis.

PO-0244 HDR brachytherapy monotherapy with 2 x 13.5 Gy for localized prostate cancer: short term follow up

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Purpose or Objective
HDR brachytherapy (HDR-BT) monotherapy has been shown an effective treatment for localized prostate cancer with low rates of toxicity and high rates of local control. As recent reports suggest a less favorable outcome after a single fraction, the discussion on HDR monotherapy fractionation restarted. Here, we report our results of acute toxicity, PSA follow up and treatment delivery parameters of a single implant HDR-BT monotherapy with 2 x 13.5 Gy within one day (on an out-patient basis) for localized prostate cancer.

Materials and Methods
Between May 2018 and August 2019, 50 patients with clinical stage ≤T2b and Gleason score 3+3 or 3+4, were treated. The median follow up was 18 months (range 12-30). Under general anesthetics, BT catheters were inserted under US guidance. With the patient still in lithotomy position, a US based treatment plan for the first fraction was calculated and delivered. Before the second fraction (with an interfraction interval of at least 6 hours), a CT scan was made to check migration of the catheters (if needed the catheters were repositioned) and for dose planning of the second fraction. PSA values were prospectively recorded every 3 months. PSA bounce was defined as a ≥ 0.2 ng/ml rise in PSA level with subsequent normalization of PSA values. Biochemical recurrence was defined according to the Phoenix definition: a ≥ 2 ng/ml rise in PSA level above nadir. The CTCAE version 4 was used to report toxicity. The treatment delivery parameters were collected according to the GEC-ESTRO guidelines.

Results
Baseline characteristics are shown in Table 1. The mean number of implanted catheters was 18 (range 13-23). Treatment delivery parameters are shown in Table 2. The differences between first and second fraction are probably due to swelling of the prostate and/or variation in delineation on different images (US or CT-based) and/or a different patient position (legs down versus lithotomy position). Furthermore, the second fraction was delivered without US probe in situ. Fourteen patients showed a PSA bounce. Five patients showed an increase in PSA, for whom further PSA follow up should be awaited to distinguish between PSA bounce and biochemical recurrence. Two patients had a biochemical recurrence. One patient had a biopsy proven residu in the base of the seminal vesicles (outside the PTV), the other patient had regional and non-regional lymph nodes recurrence. Three patients showed a grade 3 acute urinary toxicity, none of the patients had a grade 4 or higher acute urinary toxicity.

	All patients n = 50 Mean (range)
Age (years)	68 (48 – 81)
(clinical) T-stadium	T1c (n = 30)
	T2a (n = 15)
	T2b (n = 5)
Gleason score	3+3 (n=15), 3+4 (n=35)
Initial PSA (ng/ml)	8.6 (3.2 – 17.0)

Table 1: Baseline characteristics

	First fraction Mean (range)	Second fraction Mean (range)
PTV volume (cc)	42 (24 – 60)	48 (25 – 69)
V100 (%)	97.8 (90.3 – 98.4)	95.7 (92.5 – 98.9)
V150 (%)	38.0 (30.6 – 49.7)	36.6 (29.9 – 46.2)
V200 (%)	15.4 (10.0 – 21.5)	16.9 (13.2 – 25.1)
Rectum D1cc (Gy)	9.8 (6.8 – 11.1)	9.5 (6.5 – 11.1)
Rectum D2cc (Gy)	8.8 (5.7 – 10.4)	8.5 (5.7 – 10.2)
Bladder D1cc (Gy)	10.0 (8.5 – 12.3)	9.7 (6.7 – 11.3)
Urethra D0.1cc (Gy)	15.3 (14.6 – 15.6)	15.2 (11.3 – 15.5)
Urethra D10% (Gy)	15.2 (14.4 – 15.5)	14.9 (11.0 – 15.4)

Table 2: Treatment delivery parameters

Conclusion
Treatment delivery parameters and short term follow up of a single implant HDR-BT monotherapy with 2 x 13.5 Gy within one day for localized prostate cancer show promising results regarding first biochemical results and acute toxicity. More patients and longer follow-up are required to justify 2 x 13.5 Gy HDR-BT monotherapy in regard to biochemical disease free survival and late toxicity.

PO-0245 HDR Monotherapy/LDR-EBRT/HDR-EBRT in patients with favorable IR prostate cancer: Long term results.

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Purpose or Objective
To compare three BT techniques, HDR monotherapy, LDR-EBRT and HDR-EBRT, in a single institution and team, in terms of biochemical progression free survival (bPFS) and toxicity in patients diagnosed of favorable intermediate risk prostate cancer (FRI).

Materials and Methods
Between January 2006 and February 2018, 74 patients with FRI, treated with a BT with 3 different modalities (HDR monotherapy, LDR combined with EBRT and HDR combined with EBRT) have been retrospectively analyzed. Median age 70 years (range 53-81). Thirty two (43%) patients received HDR BT monotherapy as two fractions of 13.5 Gy ten days apart. In all patients that were treated with a combined approach EBRT with Intensity Radiotherapy Modulated Radiotherapy (IMRT)/Volumetric modulated arc therapy (VMAT) over a CTV that includes the prostate and seminal vesicles have been employed. Prescribed dose was 45 Gy (180 cGy/fraction) when the boost was done with LDR BT (22 patients, 30%) and 60 Gy (200 cGy/ fraction) with HDR BT (20 patients, 27%). Prescribed dose with LDR was 10 Gy in 3 patients (14%) and 108 Gy in the remaining 19 (86%). Dose prescription was 10 Gy in 1 fraction with when HDR boost was performed under real time TRUS guidance.

Results
SPSS Statistics (Version 18.0) was used for statistical analysis. Median overall follow up for the total cohort was 67 months (5-156 months). bPFS was at 7 years was 83% for HDR monotherapy and 100% for LDR and HDR BT boost (p=0.0,46). There is one local recurrence in apex in a patient treated with HDR monotherapy (T2c, Gleason 6 (3+3), PSA 9,6 ng/ml). There was not significant difference in bPFS, overall survival (OS), cause specific survival (CSS), local failure (LF), lymph node failure (LNF) or distant failure (DF) between the three techniques. For toxicity analyses, common terminology criteria for adverse events (CTCAE) version 4.0 was employed. There are only one chronic hematuria grade 3 in a patient treated with EBRT and HDR. The multivariate analysis has not been performed due to the existence only of a single reflected event.

Conclusion
Combined treatment with LDR or HDR is an excellent therapeutic option in patients with favorable IR prostate carcinoma with a long follow up.

PO-0246 Cost-effectiveness analysis of the use of blood patch as a pre-rectal spacer in brachytherapy.

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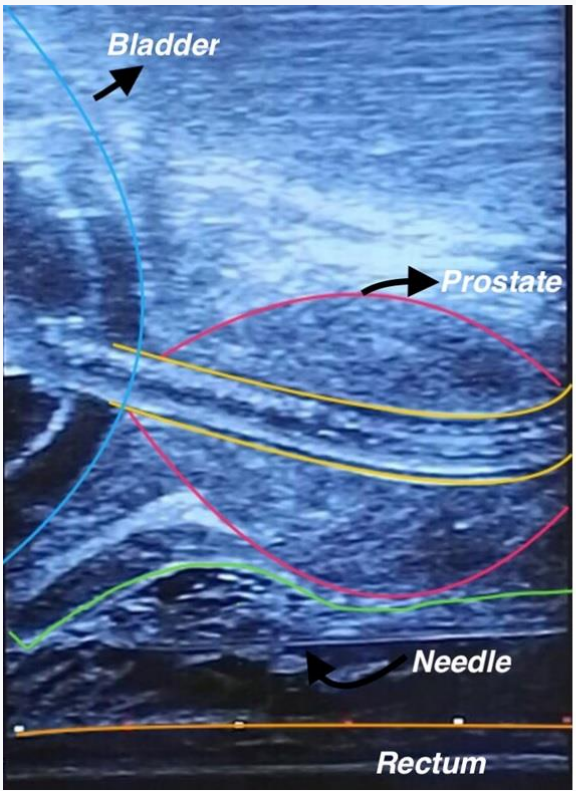
Purpose or Objective
Describe a useful and accessible technique of using blood as a spacer
pre-rectal as an alternative in developing countries with limited resources. Introducing the
Dosimetric analysis of the Latin American experience of Chile, Peru and Colombia.

Materials and Methods
67 patients underwent prostate BATD. Using anesthesia
Continuous epidural and sedation, 16 ml of blood were mixed with 4 ml of contrast. Low
transrectal ultrasound is applied spinal needle 18G x 120 mm, in low prostatic rectum space
Denonvilliers fascia. Instilling the volume into the peri-rectal space as it is
remove the needle. Subsequently, standard insertion of vector needles was performed, planning
It was with CT and fusion with MRI. Change in the anterior peri-rectal space is measured by comparing the
outlines of diagnostic and post-patch CT. The constant dose plan was made by overlapping
the post-patch plan on the contours of the diagnostic CT scan.



Results
It was applied
blood patch adequately in all 67 patients. All dose parameters
rectals above V20 - V80 improved significantly, also DMax
correlating it with the homogeneity of the application. The average pre-rectal space
obtained was 0.83 cm. The thickness decreases by 50% in 10 to 15 days after application. The
Dosimetric advantages in reduction of the mean dose to 0.1 cc of rectum was limited to 57.4% and the
mean dose to 2 cc of rectum was 40%, with improvement in parameters D90 and V100.

Conclusion
The use of the blood patch reduces the integral dose to the rectum, thus reducing possible
late rectal toxicities secondary to prostate treatment. This technique could be
beneficial in patients with a minimum of peri-rectal fat, being a profitable strategy in
in order to improve toxicity outcomes in resource-limited countries.

PO-0247 Prostate HDR boost: urethra V110 constraints correspond to low adverse effects

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Purpose or Objective
To retrospectively assess the urethra V110 values and correlate with rates of urethral adverse effects

Materials and Methods
For our prostate HDR boost cases a dose of 13Gy is delivered as a single fraction before or after administration of EBRT. HDR brachytherapy catheters are inserted under transrectal ultrasound guidance. A Foley balloon is placed in the bladder and filled with diluted contrast. The prostatic urethra is contoured following the contrast in the Foley catheter, from the bladder neck through the penile bulb. The HDR planning is performed in Brachyvision using the following DVH criteria: Prostate V100≥95%, V150≤40%, V200≤14%; Urethra D0.1cc≤125%Rx, D10%≤118%Rx, V125≤ 1cc, and V110<1 cc soft goal (added in April 2018). A cumulative EQD2 form is also generated and finalized when the EBRT plan becomes available. The EQD2 tolerances are based on the GEC-ESTRO guidelines: Urethra D10%/D30%/D0.1cc≤120/105/120, respectively. Sixty five HDR prostate boost cases treated from 2015 to date were included in this study (36 cases were treated before April 2018, when UV110 was not originally computed).

Results
Urethra UV110/UV125 and urethra+1mm U_01 V110/V125 were computed and a statistical analysis performed for 2 groups – before/after April 2018. Urethra dose for the HDR boost plans and CUM EQD2 were evaluated against our DVH criteria. Follow-up information was analyzed to assess for urethral symptoms and corroborate with the dosimetric results. Histograms generated for the 2 groups showed an improvement in UV110 after April 2018. In the 1st group: 53% of cases had UV110>1cc and 47% >1.1cc; max UV110 1.87cc. In 2nd group: 34% of cases had UV110>1cc and 17% >1.1 cc; max UV110 1.55 cc. Urethra criteria for the HDR boost plan and the CUM EQD2 values were met for all patients. A linear dependence was found between U_01 V110/125 and UV110/125. Follow-up results were analyzed for 50 patients. The others do not have follow up yet or were transferred to another hospital. 3 patients had acute grade 2 urethral symptoms which resolved. 1 patient from the first group needed temporary catheterization.

Conclusion
The UV110 values decreased after April 2018 when the UV110 < 1cc criteria was added for plan quality check. The correlation between U_01 V110/125 and UV110/125 can be used to understand what DVH criteria would be appropriate for the anatomical urethra structure. The follow up data demonstrate that the urethral constraints used for these patients are appropriate and result in a low rate of urethral adverse effects.

PO-0248 The one-hundred most-cited publications in prostate brachytherapy

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Purpose or Objective
The aim of this study was to identify the leaders in publications on low-dose rate (LDR) and high-dose rate (HDR) prostate brachytherapy (PB) through a bibliometric analysis of the top 100 most cited publications in the field.

Materials and Methods
The broad search-term “prostate brachytherapy” was searched in the Web of Science database to generate wide-ranging results. Successively, we selected individually the top 100 most cited publications by reading the abstracts and if necessary the publications.

Results
The median total citation count was 187 (range 1464 – 132), median citation per year index (citations/year since publication) was 13.5 (ranging from 379.0 - 6.3). The top publishing countries of the first author included the USA (78 publications), Canada (6), the UK (5) and Germany (4). The journal that published the most publications was the *International Journal of Radiation Oncology Biology Physics* (n=38) and 2 in Brachytherapy. There were 2.7 times more low-dose rate (LDR) than high-dose rate (HDR) publications (43 versus 16). Only one first author in HDR had 3 publications, compared to 4 first authors, each with 3 publications publishing on LDR. The United States was the leading country in 43.8% of HDR publications (n=7) and 88.4% of LDR publications (38). Most were clinical studies (47), then guidelines (21 publications). HDR had only 2 first authors with more than 1 publication in HDR, Hoskin and Galalae. In LDR 4 authors published three times (Nag, Potters, Stock and Zelefsky).

Conclusion
This bibliometric analysis of the top 100 most cited publications clearly demonstrates the North American dominance in the publications of PB, especially in LDR. However, it is important to note that European first authors were more frequent in HDR publications.

PO-0249 Comparison of two different Low Dose Rate (LDR) Brachytherapy techniques - a retrospective analysis

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Purpose or Objective
To analyse the impact of a new 125I brachytherapy prostate implant technique in terms of dosimetry, robustness and conformity.

Materials and Methods
Royal Marsden Hospital (RMH) used Elekta® Seed Selectron® (SS) after loading system with Oncentra Prostate® Treatment Planning System (TPS). Due to discontinuation of seed supply RMH switched to the 4D Brachytherapy (4DB) technique from BXTAccelyon®.
This technique uses peripheral pre-loaded needles plus fully customisable central needles; both housing seeds and spacers inside a plastic sleeve (Isostrand®). Peripheral needles distribution and loading is given by BXTAccelyon, based on an ellipsoid model of the prostate using five measurements taken the week before implant using TRUS. Seed delivery is tracked dynamically using also TRUS and the plan can be interactively modified at any stage during the procedure.
RMH is the first centre to combine Oncentra Prostate and BXTAccelyon 4DB systems.
Paddick conformity index was used for evaluating the spatial quality of dose distributions:
CIpaddick = V100^2/(Vprostate*Vpi)
where VProstate is the volume of the 3D prostate contour on ultrasound and VPI is the volume of the prescribed isodose.
This index reaches a maximum of 1 when V100 = VProstate and prescribed isodose is fully contained inside the prostate.

Results
Implant day and FU-CT dosimetric parameters are presented for comparison on Table 2.
Both techniques comply with GEC-ESTRO recommendations.
At FU-CT, SS has higher D90 and V100 than 4DB but D100 is higher for 4DB. V150 is lower for 4DB.
A two sided t-test was performed on the FU-CT data between techniques which showed statistically significant differences only on D90 ($p = 0.006$) and V150 ($p = 0.00000002$).
For SS all needles were placed at the beginning of the implant and loading was done at the end when some oedema could have occurred. When oedema resolves the prostate gland contracts and seeds (which are loose) might be dragged closer to each other. This could result in higher changes for SS on the periphery (D100) and high dose regions (V150).
The 4DB plan can be interactively adapted at any point during the implant, including prostate shifts. Needles are placed and delivered sequentially: peripherals first, centrals afterwards. Seeds are tracked to their exact location with seed trains enclosed inside the Isostrand, which constrains their potential movement. The combination of these factors might explain the smaller changes of 4DB at FU-CT.
The average (SD) Paddick indexes at FU-CT for SS and 4DB are 0.63 (0.07) and 0.53 (0.05), respectively. The lower value for 4DB may be due to the non-conformity of dose delivered by the proposed pre-loaded needles in some cases.

Conclusion
Both 4DB and SS comply with GEC-ESTRO recommendations with SS achieving better conformity and dosimetry (except D100 and V150) and 4DB being more robust overall. A learning curve is always expected with the implementation of a new technique but 4DB has achieved comparable results already.

PO-0250 MRI-Guided Robotic Prostate Biopsy and Brachytherapy: Update from the EU-funded CoBra Project

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Purpose or Objective
The Interreg 2 Seas (EU)-funded CoBra research initiative is a five-year project to develop a novel device for MR-guided robotic biopsy and brachytherapy for prostate cancer. We report on research achievements at three years into the work. We present details from several of the work packages: 1) MRI-safe I-125 seed delivery module, and evaluation of MR seed artefact of the MR-guided robot; 2) MRI-safe biopsy system; 3) novel steerable needles developed to improve access to all parts of the prostate; 4) prototype trajectory planning for ideal needle paths from an optimal number of insertion points; and 5) phantoms designed to test MR image quality in the presence of needles and seeds.

Materials and Methods
For the work streams detailed in this report the lead developers are 1) the University of Lille, 2) Demcon, 3) TUDelft, 4) University of Portsmouth, and 5) Portsmouth Hospital University Trust. Project milestones and progress are reviewed bi-weekly via web conference and every six months at a steering meeting, led by the University of Lille.

Results
The prototype MR-LDR brachytherapy module automatically loads stranded Bebig seeds. Testing seed artefact in the presence of motors (active, non-active, parallel and perpendicular to the MR field) for SE and GRE sequences, showed no change in the artefact size. However, the artefacts were significant (with or without the motors present), demonstrating the need to develop an algorithm that can detect seed positions accurately for clinical use (< 1 mm vector displacement from combination of uncertainty in 3D between planned and delivered position).
A novel technique has been developed for the robotic biopsy module, alongside unique methodology to automatically remove prostate core from the needle.
Steerable needles have been manufactured comprising of a steerable inner needle, bent by a pull-push mechanism, and a compliant outer catheter. The steerable needle is attached to the robotic brachytherapy module and allows for active omnidirectional steering up to 15 mm over a 125 mm distance in a porcine gelatin phantom.

Prototype software to plan trajectory needle paths to optimise the number of insertion points has been developed for the current steerable needle design.
Phantom designs are modular. Components can be exchanged enabling testing of brachytherapy seed and needle tip spatial positional accuracy and artefacts. Guide tubes hold needles at fixed angles and depths, and the seed patterns chosen test clinically relevant distributions.

Conclusion
At this three-year point in the programme, we present key outcomes and deliverables, on the MRI-guided robotic brachytherapy and biopsy system, prototype parts and software that have been developed and initial test results. The CoBra project is generating new knowledge of benefit to brachytherapy and biopsy, with broader applications in the medical field.

PO-0251 clinical outcomes of radiation therapy for high-risk prostate cancer

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Purpose or Objective
The aim of our study was to conduct a tolerance and toxicity analysis of combinatorial RT involving conventionally and non-conventionally fractionated conformal EBRT in the treatment of PCa.

Materials and Methods
Between April 2016 and December 2019, 342 patients with PCa received combinatorial RT including a course of conformal EBRT with conventional fractionation. The median follow-up was 26.3 months (range, 10–51,7 months). The mean age was 65 (range, 46–82) years. The median pretreatment PSA was 19.5 ng/ml (range, 1.8–232 ng/ml). At time of diagnosis, 125 (36.5%) patients had cT2N0M0 disease and 217 (63.5%) patients had cT3N0M0 disease.
After having evaluated tolerance and immediate effects of combinatorial conventionally fractionated RT, we decided to examine the feasibility of hypofractionated RT treatment modality for PCa patients. From April 2018 to December 2019, 82 patients were treated with moderately hypofractionated RT using a dose of 2.5 Gy per fraction to a total tumor dose of 37.5 Gy. The median follow-up time was 12,8 months (range, 10 –29.3 months). The mean age was 65,5 years (range, 52–81). The median pretreatment PSA was 17.2 ng/ml (range, 3.2–165 ng/ml). At time of diagnosis, 17 (20.7%) patients had cT2N0M0 and 65 (79.3%) patients had cT3N0M0 disease.
The brachytherapy was performed using the Ir-192 HDR brachytherapy source from GammaMed Plus machine under ultrasound guidance. The patients received one single fraction of 15 Gy.

Results
All PCa patients completed the scheduled course of combinatorial RT. Conventionally fractionated RT induced acute grade 1 reactions of the lower urinary tracts (UT) in 92 (26.9%) patients, acute grade 2 reactions of the lower UT in 11 (3.2%) patients and acute grade 3 reactions of the lower UT in 7 (2%) patients; acute grade 1 reactions of the lower gastrointestinal tract (GIT) in 47 (13.7%) and acute grade 2 reactions of the lower GIT in 5 (1.5%) patients. Among the late radiation-induced lower UT complications, 37 (10.8%) were grade 1, and 11 (3.2%) were grade 2. Six (1.8%) patients developed the urethral stricture. Among the late radiation-induced lower GIT complications, 24 (7%) were grade 1, and 7 (2%) were grade 2.
Hypofractionated RT induced acute grade 1 reactions of the lower UT in 24 (29.3%), acute grade 2 reactions of the lower UT in 3 (3.7%) and acute grade 1 reactions of the lower GIT in 19 (23.2%) patients, acute grade 2 reactions of the lower GIT in 1 (1.2%) patient. Among the late radiation-induced lower UT complications, 8 (9.8%) were grade 1, and 1 (1.2%) were grade 2. There were no late radiation-induced lower GIT complications.

Conclusion
The results of our study showed that PCa patients tolerated conventionally fractionationated and moderately hypofractionated regimens of combinatorial RT quite well. Most patients have mild reactions with limited impact on their quality of life. Currently, we provide follow-up care to all patients.

PO-0252 Technical Evaluation of 3D printed Disposable Seed Loader for LDR Cs-131 Prostate Brachytherapy

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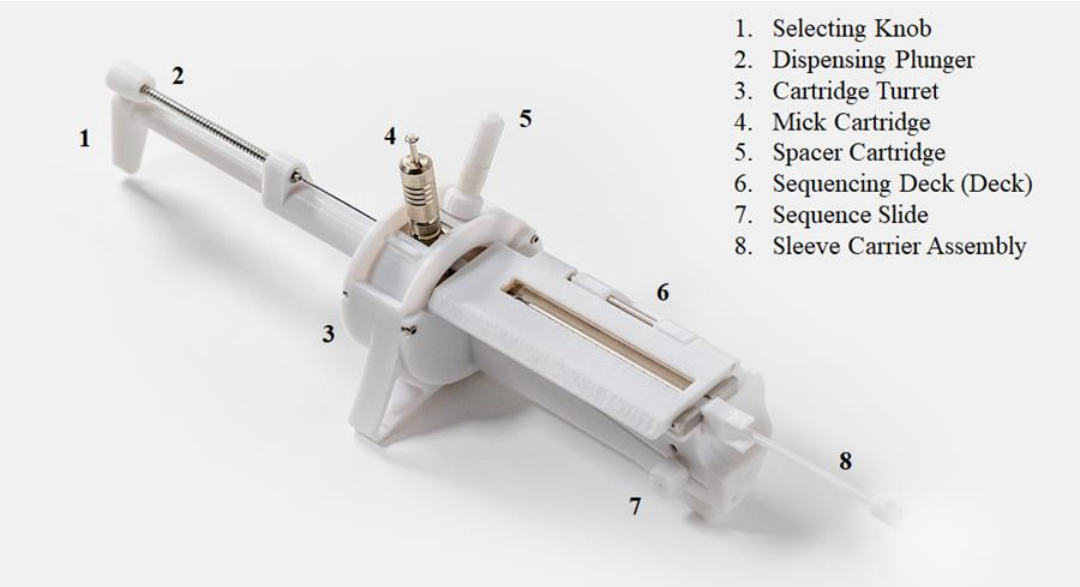
Purpose or Objective
Seed preparation and delivery is one of the crucial steps in seed delivery techniques in Low Dose-Rate Prostate Brachytherapy (LDR PB). The aim of this study is to evaluate the efficacy, robustness, and repeatability of the disposable 3D printed Build-BluTM Seed Delivery System (SDS) (IsoRay, Inc., Richland, WA) used in needle construction process of LDR PB.

Materials and Methods
The SDS is a disposable seed stranding real time loader intended for a single patient LDR PB case. The device uses Cs-131 seeds and spacers to build custom sequences. The accessories include shielded Mick-spacer cartridges, and sleeve carriers. Both cartridges are inserted in a stainless-steel slot and non-metal slot, in the cartridge turret. Seed-spacers are selected by the selecting knob and dispensed into a shielded visible sequencing deck. Created desired sequence is then translated into the sleeve carrier and inserted into the needle. To assess the SDS clinical functionality, 3 mick cartridges containing

15 dummy seeds, 2 spacer cartridges with 20 spacers each, and 60 sleeve carriers were used. For the evaluation, 2 treatment plans were generated with the Oncentra Prostate treatment planning system. The intended use, repeatability, and robustness of the SDS was tested by building 60 needles using 16 different seed-spacer sequences; each sequence was built at least twice.



Results
The construction of each needle took approximately 1 minute by an experienced user. Creating each sequence strand was faster compared to similar devices. This may be because only one type of spacer is used. The SDS produced the intended result of its use in 56 out of 60 built needles with no issues. The approximate 7% failure of the SDS in needle construction was due to jammed seeds at the gateway during translation into the sleeve carrier, and failure of the user to retract the sequence slide before creating the next strand.

Conclusion
The device demonstrated acceptable level of robustness and repeatability in the needle construction process for LDR PB. The technical evaluation revealed its conformance to manufacturer specification and its intended use. Number of failures of this system is within the same range with other clinically used systems in seed loading based on 87 LDR PB cases performed in 2018 and 2019 using a similar device. The SDS was shown to be safe in the clinical setup. Greater number of needles generated with the SDS is required for further detailed statistics and comparison to other similar devices available at the market.

PO-0253 Real-time intraoperative-planning reduces toxicity in LDR-brachytherapy-boost in prostate cancer

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Purpose or Objective
This is a retrospective study conducted to report the tumor control and toxicity outcomes of patients with intermediate-risk prostate cancer treated with EBRT and LDR-PB.

Materials and Methods
88 patients(p)(years 2009-2018) received 44-46Grays(Gy) of EBRT to the prostate and seminal vesicles and a LDR-PB transperineal prostate implant of I125(110 Gy). Every patient received 6months of androgen deprivation therapy. Toxicity was graded using CTCAEv4.0. We analyzed bPFS and overall survival(OS) with Kaplan Meir. Analysis of acute-late toxicity (bleeding, frequency, pain, TURP..) with SPSSv25.

Results
Median follow-up was 3.1years.
The bPFS and prostate cancer-specific survival at 5 years were 100%. The incidence of acute and late toxicity is in table3. Only 3p (3,4%) had late GU-G3 toxicity (TURP or urethral dilatation)
Median D1ccUrethral:138Gy, median D2ccrectal: 66,08Gy

Conclusion
LDR-PB boost with real-time intraoperative planning is a safe and effective option for treatment patients with intermediate-risk prostate cancer.

Poster: Miscellaneous

PO-0254 A systematic review of intraluminal HDR brachytherapy in the management of cholangiocarcinoma

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Purpose or Objective
To conduct a systematic review evaluating the role of high dose rate intraluminal brachytherapy (HDR-ILBT) in the palliative management of cholangiocarcinoma in terms of clinical outcomes and toxicities.

Materials and Methods
A review of all published articles up to December 2019 was conducted using Medline, Embase and Cochrane databases using the following search terms: “bile duct carcinoma” or “cholangiocarcinoma” or “bile duct neoplasms” in combination with “brachytherapy” or “high dose rate brachytherapy” or “HDR brachytherapy”. Any additional studies identified within the references section were also screened for inclusion. Two authors (AT & PM) independently completed screening. Studies published in English and those reporting outcomes for more than10 patients were included in the final analysis and review. If same group of patients was included in multiple publication, only the most recent experience was selected for review. Primary questions addressed within this review include: the duration of stent patency or re-occlusion rate, toxicity of HDR-ILBT as well complete or partial response, local control and overall survival, if reported.

Results
518 studies were identified with the pre-specified search criteria and 1 additional study was found within reference review. Seventeen studies met the final inclusion criteria for full review. Significant heterogeneity was observed in treatment regimens, that included use of palliative surgery, external beam radiation (EBRT), intra-arterial and intravenous chemotherapy in conjunction with ILBT. Among all 17 studies, use of ILBT appeared to result in longer duration of stent patency: 10 months in patients who received ILBT compared to 4-6 months in those who didn’t. Significantly Higher CR/PR rates were observed with ILBT if the dose was more than 14Gy (p=0.05) or when it was combined with EBRT. Weighted mean overall survival of patients treated with ILBT alone was 11.8 months compared to 10.5 months for those who received EBRT +/- chemotherapy in addition to ILBT. The primary toxicity attributable to ILBT was duodenal ulcer (up to 23%, single study) and cholangitis; the high rate of ulceration was observed in patients receiving higher than 37.5Gy of intraluminal HDR dose.

Conclusion
Brachytherapy can be an effective tool in management of malignant biliary tract obstruction in combination with stenting. Both retrospective and prospective studies have suggested improved outcomes with HDR ILBT is combined with percutaneous stenting..

PO-0255 CT-guided high-dose interstitial brachytherapy vs. SBRT in hepatocellular carcinoma

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Purpose or Objective
This planning study evaluates normal liver tissue exposure of CT-guided high-dose interstitial brachytherapy (BT) in comparison to liver SBRT in patients with HCC.

Materials and Methods
Treatment plans of 38 patients (m:f 32:6; age 67+/-12 years) who received high-dose BT between 07/17 and 02/19 were analysed. Patients received local ablation of up to 3 lesions (max diameter <6cm) in a single treatment session with a prescribed dose of 15Gy. Virtual SBRT plans with a prescribed dose of 37.5Gy (65%-Iso) in 3 fractions were planned using the BT planning CT. Regarding clinically relevant liver exposure, the V10Gy of the single BT treatment was compared to the V20Gy of SBRT. Conformity index (CI), healthy tissue conformity index (HTCI) and conformation number (CN) were calculated.

Results
A total of 46 lesions were evaluated. 25 patients had one lesion treated at a time, 17 patients had two lesions, and 4 patients received treatment of 3 HCC lesions. The mean GTV diameter was 2.9 +/-1.0cm and the mean GTV volume was 10+/-13ccm. The corresponding mean PTV volume for SBRT planning was 31+/-28ccm, after adding a margin of 6mm. The mean total liver volume was 1637+/-493ccm.
Using interstitial BT, a mean D98=18.1Gy and D50=41.6Gy was delivered; CI: 0.99+/-0.02; HTCI: 0.18+/-0.16; CN: 0.17+/-0.16. In contrast, in virtual SBRT plans a mean D98=50.8Gy and D50=54.3Gy was achieved; CI: 0.94+/-0.09; HTCI: 0.59+/-0.30; CN: 0.56+/-0.29. Regarding normal liver tissue exposure, the liver volume exposed to 10Gy was 93+/-73ccm in BT and correspondingly 134+/-100ccm V20Gy in SBRT plans. Thus, normal liver sparing with BT was superior to SBRT in 38/46 cases.

Conclusion
Compared to SBRT, high-dose interstitial brachytherapy offers an excellent dose coverage in patients with hepatocellular carcinoma while sparing normal liver tissue exposure for a majority of patients.

PO-0256 Episcleral Brachytherapy for Uveal Melanoma - Reference Center experience

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Purpose or Objective
Uveal melanoma is the most common intraocular tumor in the adult age, and the second most common after skin melanoma, with an annual incidence rate of 4-10 per million people. Portuguese patients with uveal melanoma were sent abroad for treatment until November 2013.
Different therapeutic approaches include enucleation, proton therapy, episcleral brachytherapy (EBT), with similar outcomes.
The purpose of this work was to evaluate treatment response in patients with uveal melanoma submitted to EBT as well as overall survival (OS), recurrence free survival (RFS) and metastasis free survival (MFS).

Materials and Methods
Included all patients with uveal melanoma treated in our institution by the Radiation Oncology Department in co-operation with the Ophthalmology Department, between November 2013 and March 2019. Plaques with low energy photon seeds (^{125}I) were used. Dose prescription was 85 Gy to the tumor apex. Response was evaluated by ophthalmic ultrasound with serial lesion measurements and treatment side effects were recorded. OS, RFS and MFS were estimated using Kaplan-Meier method. A type I error of 0.05 was considered for inferential statistics.

Results
113 EBT procedures were done in 113 patients, with a median age of 61 years, female gender (57,5%) and right eye (51,3%) predominance.Initial median diameter and thickness were 11,54 mm (3,10-18,70 mm) and 6,06 mm (2,00-12,67 mm), respectively. No distant metastatic disease was present at the time of diagnosis.Staging was: Stage IIA 43,4%, Stage IIB 40,7%, Stage I 14,2%, Stage IIIA 1,8%.
Median treatment time was 116,0 hours, median prescribed dose of 86,75 Gy. A notched eye plaque (ROPES15n) was used in 21,2% of cases and a COMS 14 plaque in 21,2%.No complications during implant procedure or treatment period were registered.
Median follow-up was 18 months (1-60 months).During this period, a significant reduction in thickness (median difference of 1,88 mm, p<0,001) and diameter (median difference of 1,96 mm, p<0,001) was recorded. Radiation retinopathy was observed in 15,9% of patients, treated by intra-ocular anti-VEGF in all cases.
At 24 months the RFS was 95,2%, MFS 86,0% and OS 92,4%.

Conclusion
EBT is an effective and well tolerated eye sparing method to treat patients with uveal melanomas. A progressive significant reduction in tumors diameter and thickness was observed with no severe late side effects registered.

PO-0257 Perioperative Radiation with/without High Dose Rate Brachytherapy for High-risk Soft Tissue Sarcoma

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Purpose or Objective
Evaluation of the therapeutic ratio of maximal perioperative radiation therapy (MRT = external beam radiotherapy with interstitial high dose rate brachytherapy boost) versus standard radiation therapy (SRT) in the form of external beam radiation therapy (EBRT) in patients with high risk soft tissue sarcomas (STS).

Materials and Methods
Retrospective review of STS patients treated between 2009 and 2017 with definitive perioperative radiotherapy with or without interstitial brachytherapy boost. Multidisciplinary evaluation was used to select the highest risk patients for MRT. Chi-square analysis was used to compare MRT and SRT groups, Kaplan-Meier estimates were used for survival and control analysis, and logistic regression was used to evaluate factors predictive of brachytherapy use in our cohort.

Results
Fifty eight patients were identified, 23 (40%) treated with MRT and 35 (60%) SRT. The majority (59%) had grade 3 disease, and 91% had close or positive surgical margins. Median tumor size was 10.5 cm for patients treated with MRT and 6.2 cm for patients treated with SRT. Median brachytherapy dose was 13.5 Gy in 3 fractions over 2 days. After median follow up of 39 months, local control was similar (83%) with MRT and SRT, and no significant difference was observed in distant failure (35% MRT vs 29% SRT, p=0.62). Grade 3+ acute toxicity was higher with MRT, 11 (48%) vs 2 (6%) (p<0.01), respectively, including 16% (n=9) requiring surgical management. There was no significant difference in grade 3+ chronic toxicity between cohorts, 2 (9%) vs 0 (0%) (p=0.39), and no Grade 5 toxicities.

Conclusion
Adding interstitial brachytherapy boost to perioperative external beam radiotherapy for patients with STS did not result in excessive chronic toxicities compared with EBRT alone. Local control was similar with MRT and SRT despite selection of patients with larger tumors in the MRT cohort. The overall impact of interstitial brachytherapy warrants prospective evaluation.

PO-0258 How to design, fabricate, and validate a customized COMs-style eye plaque

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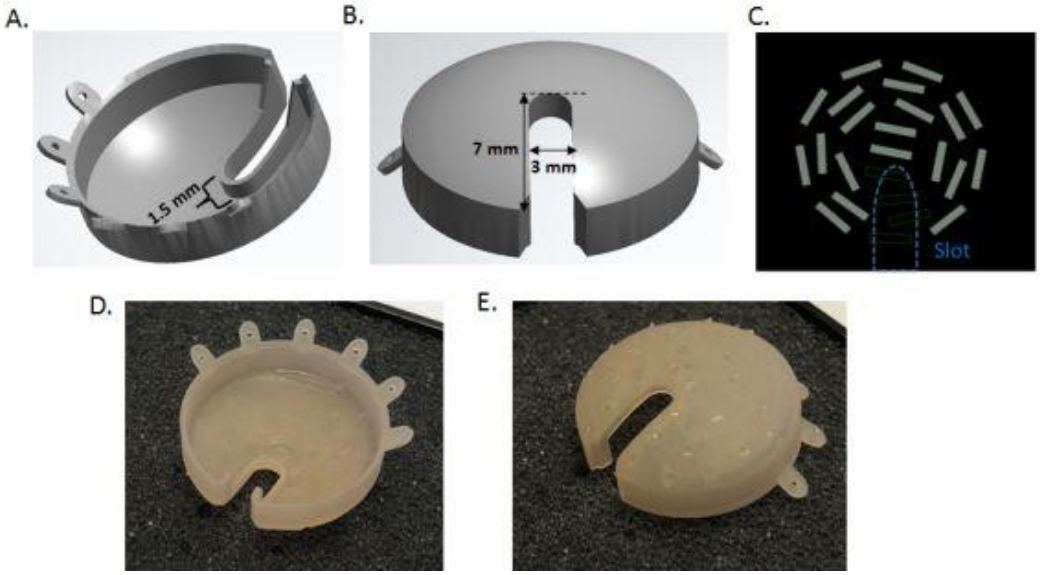
Purpose or Objective
A customized COMS-style eye plaque may provide superior dosimetric coverage compared with standard models for certain intraocular tumor locations and shapes. This work provides a recipe for developing and validating such customized plaques. To date, the publications regarding customized COMS-style plaques have emphasized the customization results, namely the plaque design and dosimetry, and have by and large minimized their description of the methods for creating the customized plaque. The purpose of this paper is to provide a detailed description of the process for creating a customized eye plaque, that is to say a recipe that the reader can follow for the design, prototype, fabrication, and quality assurance tasks.

Materials and Methods
The concept-into-clinical treatment process for a customized COMS-style eye plaque begins with a CAD model design (Figure 1 A, B, C) that meets the specifications of the radiation oncologist and surgeon, as well as a heterogeneity-corrected dose prediction to model the dose distribution. Next, a 3D printed plastic prototype is created and reviewed (Figure 1 D, E). After design approval, a Modulay plaque is commercially fabricated. Quality assurance is subsequently performed to verify the physical measurements of the Modulay and Silastic as well as dosimetric measurement of the calibration, depth dose, and dose profiles. Sterilization instructions are provided by the commercial fabricator. This customization procedure and quality assurance is demonstrated with a narrow-slotted plaque that was recently constructed for the treatment of a circumpapillary ocular tumor.

Figure 1. Computer Aided Design (CAD) modeling and 3D printed prototype of a customized eye plaque. (A) and (B) The CAD modeling for the Mayo Slotted Plaque incorporated a 7mm long and 3mm wide slot into the standard 20 mm COMS eye plaque to accommodate the optic nerve. (C) A standard COMS 20 mm Silastic insert design could be modified to include a slot. The slot was designed to minimize the number of seed slots (4) that would be eliminated from the 20 mm Silastic insert. (D) and (E) A 3D printed prototype of the Mayo Slotted Plaque. A 3D printed model was generated for verification before the Modulay plaque was fabricated.



Results
The production of a customized COMS-style eye plaque is a multistep process that requires requird approximately 30 hours and a cost of $1500. CAD and dosimetric modeling is recommended to ensure that the design will meet the patient's needs, and quality assurance is essential to confirm that the plaque has the proper dimensions and dose distribution. The customized narrow-slotted plaque presented herein was successfully implemented in the clinic, and provided superior dose coverage of juxtapapillary and circumpapillary tumors compared with standard or notched COMS-style plaques. For the Mayo Slotted Plaque, the fabricated Modulay is shown in Figure 2A. The Modulay plaque was tested on two cadaveric eyes to ensure that the plaque would conform to a human optic nerve without damaging the nerve (Figures 2B,C).

Figure 2: Modulay fabrication and cadaveric testing. (A) The Modulay plaque and Silastic insert loaded with twenty ^{125}I seeds. The Modulay plaque was fabricated by Trachsel Dental Studios. (B) and (C) The Modulay plaque was tested on two cadaveric eyes to ensure that the plaque would conform to a human optic nerve without damaging the nerve.

Conclusion
Customized eye plaques may be used to treat intraocular tumors that cannot be adequately managed with standard models. The procedure by which a customized COMS-style plaque may be designed, fabricated, and validated was presented along with a clinical example.

PO-0259 Single-fraction adjuvant electronic brachytherapy after resection of conjunctival carcinoma

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Purpose or Objective
To analyze the outcomes and toxicity profile of a single-fraction ad-juvant electronic brachytherapy (e-BT) approach for patients with squamous cell conjunctival carcinoma (SCCC).

Materials and Methods
Patients with T1-T3 SCCC were retrospectively assessed. All patients underwent surgery followed by a single-fraction adjuvant e-BT with a portable 50-kV linear accelerator. Depending on margins, e-BT do-ses ranged between 18 to 22 Gy prescribed at 2 mm depth, re-sembling equivalent doses of 2 Gy per fraction (EQD2) of 46-66 Gy (α/β ratio of 8-10 Gy and a RBE of 1.3). Endpoints included median progression-free survival (PFS), adverse events rates (CTCAE v.4.03) and relationship between variables and toxicity.

Results
Forty-seven patients were included. The median age was 69 [29 – 87] years. Most of the tumors were T1 (40.4%) or T2 (57.5%) with a median size of 7 mm [1.5–20]. Margins were positive in 42.6% and negative in 55.3%. The median time from surgery to e-BT was 9 weeks [0–37]. After a median follow-up of 24 [17 – 40] months recurrence occurred in only 2 patients (6 and 7 months after e-BT), yielding a median PFS of 24 [6 – 40] months and an estimated PFS rate at 2 years of 95.7%. Acute grade 2 conjunctivitis occurred in 25.5% and was managed with a short course of topical steroids. No toxicity-determining factors were identified.

Conclusion
E-BT is a safe and effective for SCCC treatment, with clinical and lo-gistic advantages compared to classical methods. Longer follow-up and prospective assessment is warranted to confirm these findings.

PO-0260 INTERBOARD: a dedicated tumor board to deal with personalized medicine in interventional oncology.

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Purpose or Objective
Interventional oncology offers less and less invasive procedures allowing a personalized management of the patient in the framework of personalization of the treatment and using a "tailor made" approach. Aim of this study is to assess potential

advantages and to measure benefits from the creation of a dedicated multidisciplinary tumor board for interventional oncology.

Materials and Methods
Our interventional oncology tumor board (INTER-BOARD) is composed of radiation oncologist experts in interventional radiotherapy, radiation oncologist experts in external beam focal radiotherapy, interventional radiologists, endoscopists, geriatrician oncologists and radiation technicians. We conducted a retrospective analysis of all the patients managed at our institutional INTER-BOARD from January 2018 to June 2019. Outcome measurements were number of patients managed in each semester, median interval time between initial assessment and admission to the hospital, total number of procedures, number of procedures by type, adverse events and days of hospitalization due to complications.

Results
A total amount of 438 patients (mean age 64 years; range 27-92) were discussed and managed by the INTER-BOARD during the study period. Overall, 203 procedures (46.3%) were performed in patients > 65 years and 49 (11.2%) in patients > 80 years. Number of patients discussed progressively increased over time: 82 patients (18.7%) were discussed during the first semester, 120 (27.4%) during the second semester, and 236 (54.1%) in the third semester. Discussed patients were affected by 33 different primary cancers and 22 different procedure types were proposed. 47.9% of all procedures was represented by Interventional Radiotherapy (brachytherapy). Both the mean intervals from the board discussion to the pre-hospitalization and from the pre-hospitalization to the hospital admission were 11 days. Mean hospitalization time was 4 days (progressively decreasing over time from 5 days during the first semester to 3 days in the third semester). Adverse events occurred in 4% of cases, with a progressively decreasing rate over time: 16%, 5%, and 3% for 1st, 2nd, and 3rd semester, respectively.

Conclusion
In our experience, a dedicated interventional oncology multidisciplinary tumor board allows the optimization of patient care progressively reducing the hospitalization time of the patient and, in terms of adverse events, reducing the waiting time to procedures.

PO-0261 Adjuvant HDR contact brachytherapy for localized penile cancer: long-term toxicities and outcomes

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Purpose or Objective
The purpose of this study was to evaluate the outcomes of patients diagnosed with penile cancer and treated with High-dose rate (HDR) brachytherapy (BT) in our institution, with focus on local control rates and acute and late toxicities.

Materials and Methods
According to our institution protocol, after conservative local excision, adjuvant HDR BT was offered in multidisciplinary tumor board as alternative to amputation for pT1-2N0-2 M0 penile squamous carcinoma if positive or close resection margins (< 5 mm).
Between February 2005 and July 2011 we retrospectively identified nine patients treated with HDR BT, having refused penile amputation.
The median dose was 36Gy (range: 15-54), with 3Gy/fr bid through flexible catheters attached to a personalized applicator. The treatment dose was prescribed at a depth of 5mm, while the urethra's dose constraint wasn't exceeded. In 2019, the files were retrospectively analyzed and patients were evaluated using the RTOG/EORTC Common Toxicity Criteria and the International Prostate Symptom Score.

Results
The median follow-up period was 55 months (range 8-114 months). Estimated overall survival was 131 months (CI 95%: 110.1-151.9). The mean disease-free survival (DFS) was 98 months (CI 95%: 55.3-140.7). The survival rate at 5 years was 100%, at 9 years 77%, and the recurrence rate at 5 years was 33%. Two patients (22%) were diagnosed with local relapses and one (11%) had loco-regional relapse.
Most patients presented with acute skin toxicities, mostly G2 to G3 mucositis, and one patient developed soft tissue necrosis. Two patients experienced dysuria. Late skin and urinary toxicities varied from G1 to G4. In 2019, at the 9 years follow-up, late lasting effects varied from mild to moderate urinary disfunction, and moderate to severe skin reactions. In 2020, the patients were recontacted and no changes to their toxicity grades was reported.

Conclusion
HDR contact BT is a valid option in penile cancer treatment for selected patients with good local control, excellent 5 year survival and acceptable toxicity profile.

PO-0262 Brachytherapy for paediatric pelvic tumours – sole local therapy modality and combined with surgery

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Purpose or Objective
Brachytherapy (BT) is an appealing option in the treatment of children as it delivers a localised radiation dose with rapid drop off. Due to the potential long term effects on growth, development and the risk of second malignancies, external beam radiation is not ideal in infants and extensive surgery may be an unacceptable option.

In 2012 a paediatric BT program began between Westmead Hospital and The Children's Hospital at Westmead (CHW). This is an intensive treatment requiring extensive planning and collaboration and presents both technical and practical challenges. We describe our experience using BT in children with pelvic tumours.

Materials and Methods
Between 2012 and 2020 referrals from CHW or from elsewhere in Australia and New Zealand were assessed and pre-plans created to determine the likely implant or mould to deliver treatment to the target area and whether surgical resection would be a component of local therapy.

All BT implants were performed under general anaesthetic with both surgical and BT teams present. Assessment of the primary tumour was performed via cystoscopy and/or directly via Pfannenstiel incision. BT implants and surgical resection were performed in complimentary fashion to ensure optimal tumour coverage.

Post-operative imaging was used to create individual BT treatment plans. Organ at risk planning dose aims were adjusted from paediatric protocols and adult BT literature with attention to bones, growth plates, bladder, urethra, rectum and bowel. Quality assurance, safety protocols and workflow were adapted depending on the implant used.

Children remained sedated and ventilated for duration of BT treatments and were transferred from CHW paediatric intensive care unit for BT twice daily.

Results
Eleven children were treated with BT for pelvic tumours comprising 7 boys and 4 girls with a median age at time of BT of 17 months (range 11m – 16yrs). Six were rhabdomyosarcoma of the prostate and/or bladder, 3 undifferentiated sarcoma, 1 Ewings-like sarcoma and 1 pelvic recurrence of Wilms tumour. All had prior chemotherapy and one prior external beam radiation therapy. BT techniques included trans perineal interstitial implants performed with ultrasound guidance (9 patients), trans abdominal implants (5) and customised 3-dimensional applicators (2). Surgical interventions included organ-preserving tumour resection (7 patients), ureteric transposition (5) and relocation of other structures away from the treatment area (2). Ten received HDR BT with doses of 5-6.5Gy over 5 fractions delivered to 95% of the CTV. One child received LDR BT. 9 of 11 children are alive and without disease at median follow up 48 months (range 15-98 months). Two died from distant metastatic disease without local recurrence.

Conclusion
BT both with and without surgical resection is a treatment option in paediatric patients with pelvic tumours that may preserve function and minimise side effects. It requires a collaborative approach between surgical and radiation therapy colleagues.

PO-0263 A Matlab toolkit for Ru-106 eye plaque QA, dose calculation, reference table and report generation

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Purpose or Objective
Ru-106 eye applicators are the standard of care for the conservative treatment of uveal melanomas of smaller thickness. As treatment requires collaboration of different specialties in different departments, efficient communication and reporting on delivered dose is required. Tools to bundle both acceptance of new sources, treatment planning and communication to ophthalmologists are however lacking. Our aim was to develop an 'all-in-one' toolkit to perform depth-dose rate fits during acceptance of new plaques, pre- and post-treatment planning, including generating reports for efficient documenting, and generate reference tables used for operating room time planning. The provisional treatment times in these tables serve as a guide for ophthalmologists to estimate expected treatment times for newly presenting patients.

Materials and Methods
A GUI toolkit was developed in Matlab (2017b) consisting of 3 modules: quality assurance (QA) reporting, treatment planning and reference treatment time calculation.

QA reporting Depth-dose rates along the central axis are measured during acceptance of new eye plaques (BEBIG). The program performs a cubic polynomial fit (per vendor recommendations) of the discrete point measurements and checks this against the certificate fit. The fit is stored for later retrieval by the other modules, such as treatment planning.

Treatment planning Patient and applicator details are entered into a form after which the system performs a 1D treatment time calculation. The user can opt to use a radiobiological dose rate correction factor. The module consists of two parts: pre-treatment treatment time calculation based on the prescribed dose, and post-treatment calculation of the administered dose based on the actual insertion and removal time of the plaque (fig 1).

Reference tables For each applicator the program generates an overview table with treatment times for our standard prescribed dose, at variable depths and for 12 months following acceptance.

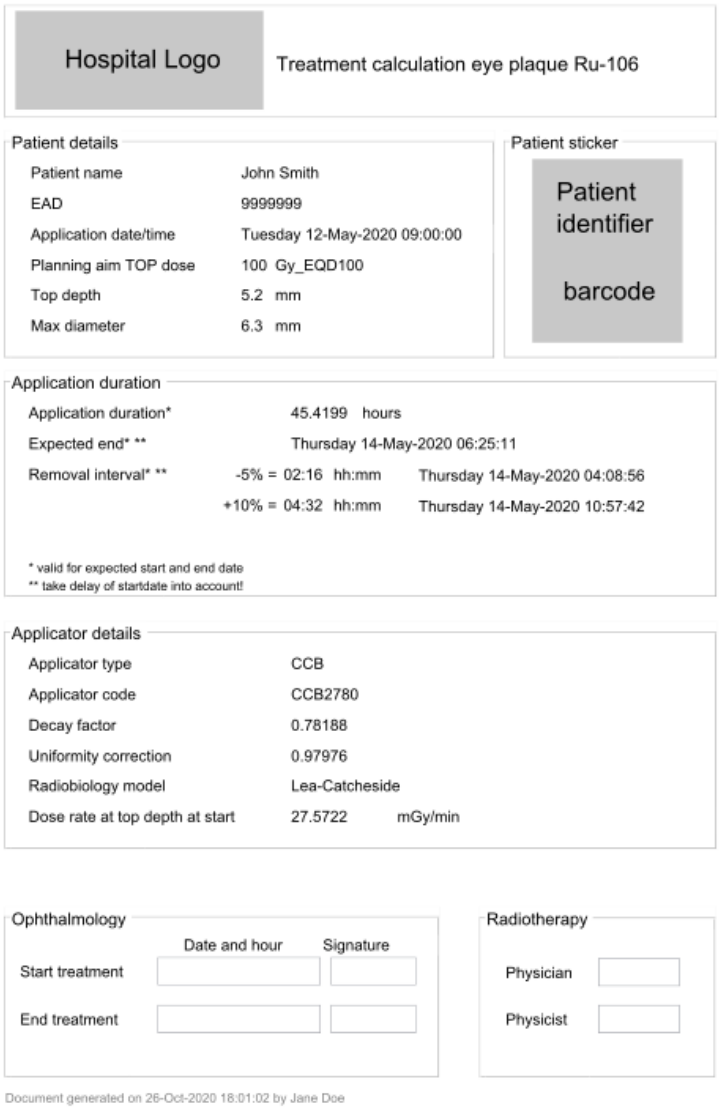

Figure 1: Treatment calculated report. The hospital logo has been censored. A patient identifier can be added on the printed report for unique identification. Prior to distribution to the ophthalmologist, a radiation oncologist and medical physicist sign off on the treatment. The true insertion and removal date/time is manually entered by the ophthalmologist.

Results

QA reporting For each plaque a report in pdf-format is automatically generated summarizing the acceptance measurements, including the in-house diode measurements of depth dose curve, fit details, uniformity measurements and comparison to the vendor's certificate.

Treatment planning A single page pre-treatment report with the prescribed dose and planned treatment time is generated for easy communication to the ophthalmology department. In addition, a comprehensive post treatment report, including all patient and source details, is generated for storage in the hospital information system (HIS).

Reference tables After acceptance of the sources, overview reference tables are created for each plaque. The table cells with treatment times exceeding an adjustable, predefined limit are shown in a different color (fig 2).

Source CCB2780

without radiobiological correction

Depth (mm)

	Feb-2020	Mar-2020	Apr-2020	May-2020	Jun-2020	Jul-2020	Aug-2020	Sep-2020	Oct-2020	Nov-2020	Dec-2020	Jan-2021
0.5	0d13h	0d14h	0d15h	0d15h	0d16h	0d17h	0d18h	0d19h	0d20h	0d22h	0d23h	1d0h
1	0d15h	0d16h	0d16h	0d17h	0d18h	0d19h	0d21h	0d22h	0d23h	1d0h	1d2h	1d3h
1.5	0d17h	0d18h	0d19h	0d20h	0d21h	0d22h	0d23h	1d1h	1d2h	1d4h	1d5h	1d7h
2	0d19h	0d20h	0d21h	0d22h	0d24h	1d1h	1d3h	1d4h	1d6h	1d7h	1d9h	1d11h
2.5	0d22h	0d23h	1d0h	1d2h	1d3h	1d5h	1d6h	1d8h	1d10h	1d12h	1d14h	1d16h
3	1d1h	1d2h	1d4h	1d5h	1d7h	1d9h	1d11h	1d13h	1d15h	1d18h	1d20h	1d23h
3.5	1d5h	1d6h	1d8h	1d10h	1d12h	1d14h	1d17h	1d19h	1d21h	2d0h	2d3h	2d6h
4	1d10h	1d12h	1d14h	1d16h	1d18h	1d21h	1d23h	2d2h	2d5h	2d8h	2d11h	2d15h
4.5	1d16h	1d18h	1d20h	1d23h	2d2h	2d5h	2d8h	2d11h	2d14h	2d18h	2d22h	3d2h
5	1d23h	2d2h	2d5h	2d8h	2d11h	2d14h	2d18h	2d22h	3d2h	3d6h	3d11h	3d16h
5.5	2d8h	2d11h	2d15h	2d18h	2d22h	3d2h	3d7h	3d11h	3d16h	3d22h	4d3h	4d9h
6	2d20h	2d23h	3d4h	3d8h	3d13h	3d18h	3d23h	4d5h	4d10h	4d17h	4d23h	5d6h
6.5	3d10h	3d15h	3d20h	4d1h	4d7h	4d13h	4d20h	5d2h	5d9h	5d17h	6d1h	6d10h
7	4d5h	4d11h	4d17h	4d23h	5d6h	5d14h	5d22h	6d6h	6d15h	7d0h	7d10h	7d21h
7.5	5d5h	5d12h	5d20h	6d4h	6d13h	6d22h	7d8h	7d18h	8d5h	8d17h	9d5h	9d16h
8	6d13h	6d21h	7d7h	7d17h	8d4h	8d16h	9d4h	9d17h	10d7h	10d21h	11d12h	12d5h

Figure 2: Part of a reference table for a specific source without radiobiological dose rate correction as distributed to OR planning. Expected treatment times are displayed for the 15th of every month. The duration is color coded according to the American Brachytherapy Society guidelines. If treatment times become prohibitively long, such as for large tumors at the end-of-life of the source, patients can be excluded from Ru-106 eye plaque treatment, prior to detailed treatment planning and operating room booking.

Conclusion
We have presented a Matlab tool which can be used in any step in the preparation and treatment of ocular melanomas with Ru-106 plaques. The software generates pdf-documents for storage in the HIS.

PO-0264 orbital mold brachytherapy for recurrent orbital mesenchymal sarcoma: a contemporary approach

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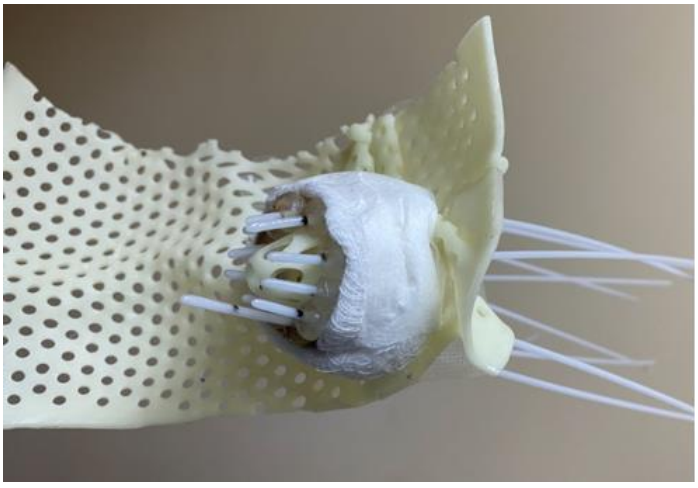
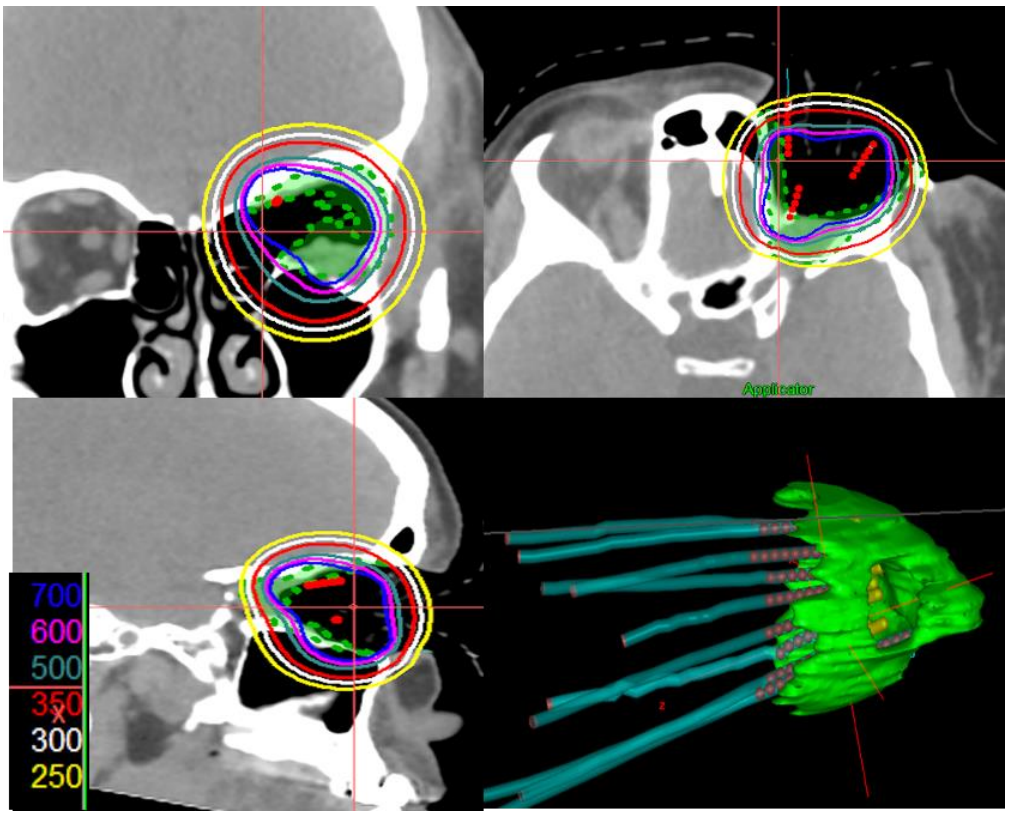
Purpose or Objective
To report the technical details of a contemporary approach for orbital brachytherapy that can be used in low-resource settings

Materials and Methods
A 43-year old female diagnosed with recurrent orbital mesenchymal chondrosarcoma of the left orbit presented with her third local recurrence. The patient proceeded with conservative surgery with planned adjuvant high dose rate brachytherapy 2 weeks post-surgery. Brachytherapy mold applicator was fabricated through the use of thermoplastic mask, ProGuide catheter needles, catheter fixation buttons, and a strip of gauze. Optimal catheter placement was done through the use of CT simulation planning.



Results
The clinical tumor volume-high risk (CTV-HR) corresponded to the gross tumor residual. The clinical tumor volume-intermediate risk (CTV-IR) corresponded to the whole orbit. Flexitron Iridium-192 high dose rate (HDR) brachytherapy plan was generated using Oncentra brachytherapy planning system. The planned dosimetry was CTV-HR D90≥ 3.5-4Gy and CTV-IR D95≥3-3.5Gy to be done in 14 twice-daily 4Gy fractions. The accepted plan had a CTV-HR D90 of 3.97Gy/fraction, which resulted to a total dose of 55.6Gy and an EQD2 of 96Gy. The CTV-IR D95 was 3.25Gy/fraction with a total dose of 45.5Gy and an EQD2 of 70Gy. The plan was evaluated using the dose volume histogram and dosimetric parameters, which showed adequate irradiation of the tumor volume and at-risk areas. The patient underwent orbital brachytherapy without any adverse events except for mild skin erythema.



Conclusion
The reported approach for orbital brachytherapy is feasible even in low-resource settings and it is effective in the local treatment of tumors of the orbit especially for previously irradiated sites.

PO-0265 Intraluminal HDR brachytherapy as a component of induction chemoradiotherapy for esophageal cancer

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Purpose or Objective
to evaluate efficacy and toxicities of intraluminal high dose rate brachytherapy (HDRB) when it was used as a stand-alone radiotherapy method in preoperative chemoradiotherapy (CRT) for patients with oesophagal cancer

Materials and Methods
66 patients with cT1-3N0-2M0 squamous cell carcinomas of the thoracic oesophagus were included in this prospective non-randomized study. Standard examinations included CT with contrast, endoscopy with EUS and MRI. HDR brachytherapy was performed as 3 fractions of 7Gy on days 1, 8 and 15. Cisplatinum (80 mg/m^2) was intravenously injected on 1 and 29 days; 96 hrs infusions of 5 FU (850 mg/m^2) was done on 1-4 and 29-32 days. Assessment of clinical response was performed 4-6 weeks after the end of CRT. Radical oesophagectomy with 2D lymph node dissection and simultaneous esophageal reconstruction was performed 6-7 weeks after induction CRT in 61 of 66 patients.

Results
Radical surgery with 2D lymph node dissection and simultaneous oesophageal reconstruction was performed in 61 of 66 patients. R0 resection was obtained in all cases. Postoperative complications detected in 31.1% of patients (mainly grade 1-2). Only 1 patient died because of complications (1.7%). Inconsistency of anastomosis revealed in 3 of 61 cases (4.9%). Complete pathomorphological response (pCR) was obtained in 22.9% (14/61), downstaging was reached in 59% (36/61) cases. 5 pCR of primary tumour was combined with remained positive lymph nodes (pT0N+). Conversion of nodal status

after CRT was reached only in 3 of 33 patients with clinically N+, remained 28 observations nodes were still positive on postoperative histology. After 9-15 months follow-up lymph node progression was detected in 8 cases (14%), distant metastases – in 23 patients (40,3%), a combination of both – in 6 cases (10.5%). 2- and 5- year disease-free survival was 42.1% and 17.5%, overall survival – 52.6 % and 22.8%.

Conclusion
Intraluminal high dose rate brachytherapy for operable oesophageal cancer is effective and well-tolerated preoperative treatment option. Unfortunately, 2 cycles of concurrent chemotherapy can't control lymph node disease and this fact must be considered during treatment planning.

Poster: Skin

PO-0266 Dosimetric comparison of brachytherapy and tomotherapy for a large SCC on the scalp

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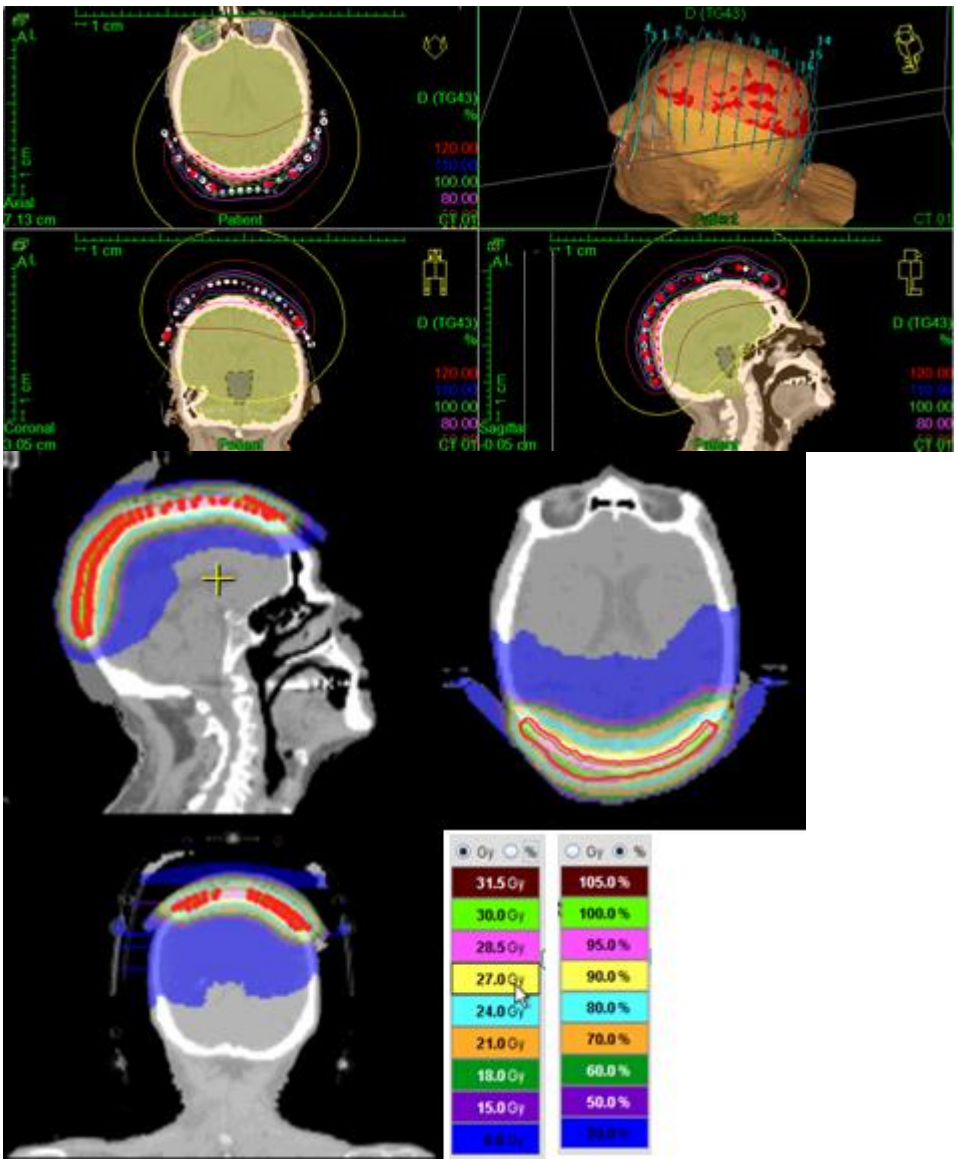
Purpose or Objective
An 86 year old male patient was referred to the radiotherapy department at Guy's Cancer Centre presenting with large ulcerated squamous cell carcinomas (SCC) involving the scalp from the frontal to the occipital region. [JEl1] Due to the extent of the lesions the patient was deemed unsuitable for surgery. MeV electrons were also discarded due to the potential of further development of ulcers that may have arisen from matched electron field hot spots. Ir^{192} HDR superficial brachytherapy and 6MV Tomotherapy planning modalities were explored as the only viable options. The planning target volume (PTV) was 111.6cm^3, with the lenses, optic nerves, retinas, pituitary fossa, optic chiasm, brainstem and brain considered to be organs at risk (OAR). The prescription was 30Gy/10#.

Materials and Methods
For HDR brachytherapy a custom made shell was engineered using thermoplastic and PETg on to which a Freiburg flap was attached and catheters introduced to form an applicator. CT images of the patient and applicator were acquired. Catheter reconstruction and treatment plan optimisation was performed on the Oncentra Brachytherapy treatment planning system (TPS) using the TG43 algorithm. From 32 available catheters 17 were activated. Graphical optimisation was used to achieve a PTV coverage V80 ≥ 95% while maintaining D2cc < 120% and Dmax < 105% to the skin.
For Tomotherapy a 1cm thick custom made bolus was produced covering the whole of the scalp, enabling 100% coverage to the skin by reducing skin sparing. A Tomotherapy plan was produced using 2.5cm field width, pitch of 0.287, modulation factor of 2.000 on a fine dose calculation grid. The plan was optimised for 95% coverage of PTV and maximum dose of 107%, prescribing to median dose, with dose to OAR reduced through the use of a directional block on the 'brain-ptv' planning structure.

Results
With comparable PTV coverage the Tomotherapy plan provided superior dose reduction to all OAR. OAR less than 30cc[DI1] received on average mean dose reduction of 5.3Gy. Whereas the mean dose reduction was 3.5Gy for the brain. The volume of brain receiving 50% of the dose was 9.4% less.

	Tomo (Gy)			HDR (Gy)			Diff (Gy)		
	Max Dose	Mean Dose	V(50%)	Max Dose	Mean Dose	V(50%)	Max Dose	Mean Dose	V(50%)
Brain	28.7	8.3	17.6	22.8	11.8	27	5.9	-3.5	9.4
Brainstem	3.6	1.5		9.2	6.5		-5.6	-5	
Chiasm	1.1	1		7.1	6.7		-6	-5	
Lenses	0.9	0.8		6.3	5.8		-5.4	-5	
Retinas	1.75	0.95		7.6	6		-5.85	-5.05	
Optic Nerves	1	0.95		6.7	6.4		-5.7	-5.45	
Pituitary	1	1		7.1	6.7		-6.1	-5.7	



Conclusion
For this patient Tomotherapy provided superior OAR sparing with comparable PTV coverage compared to HDR brachytherapy.

PO-0267 Contact Skin Radiotherapy for advanced non melanoma skin cancer during COVID-19 pandemic.

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Purpose or Objective
In the context of the SARS-CoV-2 pandemic, it is of paramount importance to ensure the quality of cancer treatment as well as patients and health professionals' safety. Individual-based treatment option has to be considered in patients suffering from non-melanoma skin cancer (NMSC), who are more critical because typically older and frail. The aim of this study was to assess the feasibility and the safety of Contact Skin Radiation Therapy (CSRT) to treat NMSC during SARS-CoV-2 pandemic.

Materials and Methods
Patients with advanced BCC and SCC who had an indication to CSRT, as assessed by the Multidisciplinarty Tumor Board, were enrolled and treated from February 21 to May 4 2020 (Phase 1 of the Italian Pandemic – lockdown period) at the Interventional Oncology Center (IOC), Fondazione Policlinico Gemelli, Rome, Italy. The prescription was: total dose 40Gy at 5Gy/fractions, twice a day. Treatment success indicators, such as treatment acceptance and completion, were identified to evaluate the feasibility of CSRT. Therefore, a psychological assessment regarding patient's safety perception was performed after treatment.

Results
Ten patients were available for CSRT. Four patients asked to postpone the treatment for personal reasons and were rescheduled. Six patients were therefore treated including 3 patients with advanced BCC and 3 with advanced SCC. All six patients were males, with a median age of 80 years (range 62–92 years). The ECOG Score was 0-1 in 3 patients and 2 in the remining 3 patients. The most frequent treatment sites were the face (47%), lower and upper extremity (26%), nose (16%) and ear (11%). All patients completed the treatments as prescribed. After a median follow-up of 7.5 months (range 6-9 months), complete response was achieved in 5/6 patients (83.4%) and partial response in 1/6 patients (16.6%). Median time from discussion of the tumor board to simulation was 8.5 days (range: 7-25 days); median time from simulation to treatment was 4 days (range: 3-10 days). Before treatment initiation, patients declared that they felt worried (50%) or scared (16.7%) dealing with the risk of being infected with SARS-COv2 (66.7%) or because of possible treatment interruption (33.3%). During the treatment period, patients answered to feel protected (100%), quiet (66.7%) and reassured (33.3%). No patients developed symptoms attributable to SARS-CoV-2 infection according to triage clinical evaluations.

Conclusion
CSRT represents a non-invasive, safe, and feasible treatment option even during the pandemic emergency period. Hypofractionation could be an option to reduce overall treatment time and infective risk exposition.