6 Reporting in Brachytherapy: Dose and Volume Specification
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1 Introduction

Exchange of information and clinical results between radiation oncology centres requires uniformity and agreement on the methods used to specify the doses and the volumes to which these doses have been delivered. This requires an agreement on definitions of terms and concepts necessary to report irradiation techniques.

The ICRU recognised the importance of uniformity in reporting: it has been involved for several decades in an effort to harmonise the concepts, definitions of terms, dose and volume specification and dose determination in radiation therapy. Several reports have been published for external beam therapy (ICRU 42,44,47). "Dose and volume specification for reporting intracavitary therapy in gynecology" was published in 1985 (43) (a revision is at the moment in preparation). „Dose and volume specification for reporting interstitial therapy“ was published in 1997 (45).

This chapter is based mainly on the recommendations of the International Commission on Radiation Units and Measurements (43,44,45,47,48) and the recent GEC-ESTRO recommendations (86).

1.1 From prescribing to recording and reporting

1.1.1 Treatment prescription

The prescription of a treatment is the responsibility of the radiation oncologist (or the radiation oncology team) in charge of the patient. It is not the aim of this chapter (nor the role of the ICRU) to make recommendations about the treatment prescription, i.e., about the general rationale of the treatment, dose level or technical aspects of the treatment.

In fact, different methods of treatment prescription are used at present by different radiation oncologists or in different radiotherapy centres, depending on local tradition, personal training and experience, and local conditions.

For example, for cervix brachytherapy, some centres prescribe the treatment in terms of the TRAK (or mg.h which is its “historical” equivalent). Many prescribe the dose at point A, while more recently, some centres orientate their prescription towards volume evaluation. The maximum “tolerable” dose to organs at risk is also used as a prescription method.

In interstitial therapy, some centres prescribe the minimum dose to the CTV, others the “Mean Central Dose”, others the dose on the envelope surface encompassing the CTV, etc.

In endoluminal brachytherapy, the dose is prescribed at different distances from the centre of the source or at different depths in the tissues. For example, in endovascular brachytherapy, the dose is prescribed at 2 mm from the source axis, or at 1 or 2 mm from the tissue surface, etc.

1.1.2 Recording the radiation treatment

Recording the treatment parameters as completely and accurately as possible in the patient chart must be performed in a radiation therapy department for several purposes:

- to ensure further care and follow-up of the patients,
- to keep treatment conditions reproducible, safe and constant,
- to build up progressively clinical experience in the department progressively resulting in improved techniques,
- to be able to exchange information on treatment conditions with other centres,
- to be able to “reconstruct” the treatment conditions when needed: interpretation of the treatment outcome(s), accident, implementation of a quality assurance program, or a research and development program, etc.

It is important that sufficient information be exchanged, and agreement be reached, between the medical, physics and radiographer staff, on the methods of recording the treatment parameters. The terms and concepts to be used should be clearly defined.

The amount of information to be recorded depends on (1) the technique and the purpose of the treatment (cure or palliation), and (2) the situation of the department as far as equipment and staff is concerned.

### 1.1.3 Reporting the treatment

**Prescribing** the treatment is the responsibility of the radiation-oncology team in charge of the patient, **recording** the treatment parameters is the responsibility of the department, but harmonisation in **reporting** is mandatory for the reliable exchange of information between centres.

Harmonisation in reporting implies an agreement on (1) concepts and definitions of terms, and (2) a general approach on how to report a treatment. Agreement must also be reached on the (minimum) information that should be contained in the report. Because, however, of the huge amount of information now available in some situations, the part of this information, which is relevant for reporting, must be selected.

Comparison of treatments performed in different centres using different treatment conditions implies agreement on a certain number of reference parameters. As a first basic option, reference points must be selected and the dose to these points can be compared. Alternatively, fixed dose levels can be selected and the dimensions of the corresponding volumes can be compared. In brachytherapy, the reference points can be related to anatomy or to the source and/or the applicator. In the past, selection of reference points was the most common approach for comparison. With advancing imaging and dosimetric techniques, the volume concept becomes a realistic option. For the future, the volume concept will probably be a major factor in the development of brachytherapy (as in external beam therapy) and will become more and more clinically relevant.

**Recommendations for improving harmonisation in reporting** interstitial, intraluminal and intracavitary brachytherapy therapy are presented in this chapter on “reporting in brachytherapy”. However for the future, and without interfering with the prescription itself, nor with the local policy for recording the treatment parameters, it is obvious that all procedures would be simplified and faster, and the risk of confusion and accident would be reduced if the same definitions of terms and concepts and the same methods for specifying the doses and the volumes were used for prescribing, recording and reporting. This would also facilitate multi-centre research and cooperative clinical trials.
1.2 The three levels of dose and volume evaluation for reporting

Different levels of completeness and accuracy can be identified for reporting. Three levels have been identified for conventional photon beam therapy (44, 47); they are proposed in the present report for brachytherapy (90).

**Level 1**

This implies reporting the minimum of data that are required to perform brachytherapy in an efficient and safe way.

These data should be available in all centres, whatever their situation regarding staff and equipment. In well staffed and equipped centres, reporting at Level 1 may be sufficient for certain treatment techniques.

**Level 2**

Reporting at Level 2 must contain all the information of Level 1.

In addition, reporting at Level 2 contains the information needed to perform a state of the art treatment. It allows the exchange of more complete and relevant information between different centres. The conditions for reporting at Level 2 usually require a well equipped and staffed centre.

It implies that the relevant volumes (p. 158) and organs at risk (p. 163) can be defined with modern imaging techniques under reliable conditions (typically, a series of CT and/or MRI sections, but other imaging techniques, such as ultrasound or PET, may bring additional relevant information). At Level 2, it is also assumed that 3-D dose distributions are available; dose-volume histograms can then be derived from these two sets of information.

Depending on local conditions, target and organ reconstruction is based on a full CT examination or a limited number of CT images (sections). Interpolation between images is therefore sometimes needed; the accuracy of the reconstructed target and organ dimensions depends on the number of sections available.

**Level 3**

Reporting at Level 3 is characterised by individualised, usually very complex and often evolving techniques (e.g., “3-D image based intensity modulated brachytherapy”). Reporting at Level 3 contains all information from Levels 1 and 2. No additional reporting requirements are established yet, but comprehensive information should be given.

All radiation therapy techniques are continuously evolving and more sophisticated equipment and software continue to be commercially available. Therefore, with time, the boundaries between the three levels, as defined above, may change.
2 Clinical Aspects – Volumes

It is difficult to report a treatment correctly without a clear idea about the prescription. An accurate and complete view of the aim of the treatment, rationale and prescription is needed to understand the choice of treatment parameters and thus to report the treatment in a relevant way.

The clinical status of the patient should be reported as completely as possible, including tumour location and extent, pathology, general status, etc. This information should be reported according to recognized international classification (3,102,103,117). The definition of volumes is of utmost importance, both in external-beam planning and in brachytherapy planning, and the process consists of several steps.

Different volumes are defined in this section. The GTV and CTV (44,47) are pure oncological concepts and are thus independent of the treatment strategy, discipline or technique.

The Planning Target Volume (PTV) (section 2.3) is in general of lower importance in brachytherapy compared to external beam therapy because the radioactive sources and the target volumes are usually fixed to each other and one does not need to deal with the problem of day to day treatment set up variations.

The concepts of Treated Volume and Irradiated Volume are discussed in sections 2.4 and 2.5, respectively. Lastly, the organs at risk in brachytherapy are presented in section 2.6.

2.1 Gross Tumour Volume (GTV)

2.1.1 Definition

The Gross Tumour Volume (GTV) is the gross palpable, visible or demonstrable extent and location of the malignant growth. The shape, size and location of the GTV may be evaluated by various diagnostic methods: clinical examination i.e., inspection and palpation, endoscopy, and imaging techniques such as radiography, CT, MRI, PET, ultrasound, or other techniques, depending on the location and type of pathology.

The GTV may consist of:

- the primary tumour (GTV-T),
- metastatic lymphadenopathy (GTV-N), or
- distant metastases (GTV-M).

In brachytherapy applications, the GTV is mainly the primary tumour, thus GTV-T.

According to the above definition, there is no GTV after complete ‘gross’ surgical resection. There is no GTV when there are only a few individual cells or ‘subclinical’ involvement, even histologically proven.

2.1.2 Recommendations for reporting

The methods used to determine the GTV should meet the requirements for scoring the tumour according to the TNM (102,103) and American Joint Committee on Cancer (3) systems, and the definition of the GTV is then in full agreement with the criteria used for the TNM classification.
Fig 6.1: The figure illustrates the superiority of MRI compared with CT for discrimination between different types of tissues for a patient with cervix carcinoma III AB.

A: Transversal CT showing a large soft tissue mass at the level of the uterine cervix, infiltrating into both parametria. No discrimination between GTV and uterine tissue is possible.

B: Transversal MRI showing a high signal intensity mass indicating macroscopic tumour infiltrating into both parametria and into the left sacrouterine ligament. A clear distinction is possible from normal uterine tissue (arrows).

C: Sagittal MRI showing a high signal intensity mass at the level of the cervix in the midsagittal plane extending mainly posteriorly with clear distinction from the uterine corpus (two contiguous sections are presented in Fig A, B and C).

The GTV may appear to be different in size and shape, sometimes significantly so, depending on what examination technique is used for evaluation (e.g., palpation versus mammography for breast tumours, CT versus MRI for some brain tumours, CT versus MRI/ultrasound for prostate cancer). Therefore, the radiation oncologist should, in each case, indicate which method has been used for the evaluation and delineation of the GTV. Figure 6.1 illustrates the specific contribution of MRI for discrimination between different types of tissues.
A GTV may be confined to only part of an organ (e.g. T2a in prostate cancer), or involve a whole organ (e.g., T2b in prostate cancer, IB2 in cervix cancer). The GTV may or may not extend outside the normal borders of the organ tissue involved.

For reporting, the GTV should be described in standard topographical or anatomical terms, e.g., “18 mm x 12 mm x 20 mm tumour in the left lobe of the prostate adjacent to but not reaching the capsule”, cT2a.

In many situations, a verbal description might be too cumbersome and, therefore, for the purpose of data recording and analysis, a classification system is needed. Several systems have been proposed for coding the anatomical description, some of them are mentioned in ICRU Report 50 (44).

Careful identification of the GTV is as important in brachytherapy as in external beam therapy, for at least three reasons: (1) accurate description of the GTV is needed for staging (e.g., TNM), (2) identification of the GTV is necessary to permit recording of tumor response in relation to dose and other relevant factors, which may be used (carefully) as a prognostic factor. (3) an adequate dose must be delivered to all parts of the GTV to obtain local tumour control in radical treatments.

2.2 Clinical Target Volume (CTV)

2.2.1 Definition

The CTV is the volume which contains the “gross” and “subclinical” disease. Clinically, it thus contains the GTV and a “safety margin” around the GTV (CTV-T) to take into account (probable) subclinical involvement. The CTV may also include other anatomical areas, e.g., regional lymph nodes (CTV-N) or other tissues with suspected (or proven) subclinical involvement (CTV-M).

“Subclinical involvement” may consist of individual malignant cells, small cell clusters, or micro-extensions, which cannot be detected during staging procedures by the methods mentioned above.

The cell density is high in the GTV (typically 10^6/mm^3); it decreases in the safety margin from the edge of the GTV towards the periphery of the CTV. The different parts of the CTV thus have to be treated at adequate dose levels (and time-dose patterns) to achieve the aim of therapy, either cure or palliation.

If the GTV has been removed by radical surgery, and radiotherapy is needed to residual tissue close to the site of the removed GTV, this volume is also usually designated as CTV-T (e.g., in breast-conserving procedures).

Delineation of a CTV requires consideration of factors such as the local invasive capacity of the tumor and its potential to spread, for example, to regional lymph nodes (based e.g. on histology).

The definition of CTV boundaries requires a clinical decision (31,62). In some cases, this decision is based on probability evaluation (when data are available), but it often implies an arbitrary choice (e.g., endovascular brachytherapy (86)). The final decision rests on the clinical experience and judgement of the radiation oncologist.

2.2.2 Recommendations for reporting

The CTV (like the GTV) is a purely clinical-anatomical concept: it should therefore be described in terms of the patient’s anatomy and the tumor extent, independently of any dose distribution. As a
minimum recommendation, its physical dimensions should be reported in terms of maximum diameters, in mm (or cm) in three orthogonal directions. The CTV must be defined in plain topographic terms and/or according to a code which conforms with the recommendations for the GTV.

2.2.3 GTV and CTV: pure oncological concepts

It must be stressed that the GTV and CTV are purely oncological concepts, and are thus independent of the therapeutic approach. In particular, they are not specific to the discipline of radiation therapy. For example, in surgery, a safety margin is taken around the GTV according to clinical judgement, and this implies the use of the same CTV concept as in radiation therapy. In brachytherapy, as in external-beam therapy, volumes to be irradiated are defined, and thus the same concept of CTV is applied. Furthermore, the CTV concept can be applied to other modalities, e.g., regional chemotherapy, hyperthermia, and photocoagulation.

The definitions of GTV and CTV in brachytherapy are thus identical to the definitions given for external-beam radiotherapy in ICRU Report 50 (44) and Supplement to Report 50, ICRU Report 62 (47).

2.3 Planning Target Volume (PTV)

2.3.1 Definition

The PTV is a geometrical concept used for treatment planning. The aim is to ensure that the prescribed dose is actually absorbed in the whole CTV, taking into consideration the net effect of all the possible variations of position of the CTV relative to the irradiation source.

In external beam therapy, the PTV is defined to enable selection of appropriate beam sizes and beam arrangements. In brachytherapy, the PTV is defined to select appropriate source arrangement, positioning and/or movement control. The dose distribution to the PTV has to be considered as representative of the dose distribution to the CTV.

2.3.2 PTV in external beam- and in brachytherapy

In external-beam therapy, to ensure that all tissues included in the CTV receive the prescribed dose, one has, in principle, to plan to irradiate a volume geometrically larger than the CTV: the PTV. The additional safety margin results from a number of factors:

(1)-the Internal Margin is intended to take into account the expected physiological movements (e.g., respiration) and variations in size, shape, and position (e.g., stomach, bladder, rectum) of the CTV;

(2)-the Set-Up Margin is intended to take into account all variations and uncertainties in beam geometry and patient-beam positioning.

The situation is quite different in brachytherapy because the source (or source applicator) is, in general, fixed to the target volume. Therefore, in brachytherapy, the PTV is often considered to be identical to the CTV.

There are however exceptions. For instance, in intraluminal brachytherapy, a safety margin is added around the CTV to compensate for inaccuracies or uncertainties in the position of the radioactive
source(s) relative to the patient's organ. Such inaccuracies can be due to displacement of the source (in the longitudinal or radial direction), patient motion, etc.

The width of this safety margin should, ideally, be based on systematic evaluation of the uncertainties. It may differ according to the organ being treated, the clinical target volume and also the type of applicator and technical devices used. With some techniques, there are uncertainties about consistency of source position (moving sources, fractionated techniques) or alteration of source or applicator position (intracavitary applications, permanent implants) during the application.

Remarks:

1°) In external therapy, the two steps (localisation of CTV and treatment planning) can always be dissociated and therefore checked separately. However, in interstitial therapy, a better evaluation of the tumour extent (and regression after external beam therapy) may often be obtained by the clinician at the time of application (due e.g. to general anaesthesia). The final decision on the CTV may then be modified.

2°) Due to the high density of the cancer cells in the GTV (about $10^6$/mm$^3$), a high irradiation dose must always be delivered to all parts of the GTV in radical treatments.

3°) A CTV may be treated by 2 (or more) PTVs (e.g., external and brachytherapy). In particular, because the cancer cell density is higher in the GTV compared to tissues with only subclinical disease, different dose levels may be prescribed and thus several PTVs be identified.

This is the case, for example, in 'boost' therapy where the 'higher-dose' volume (often containing the GTV) is located inside the 'lower-dose' volume. For example, 50 Gy may be prescribed to a large PTV followed by an additional 35 Gy to a smaller PTV ("boost") corresponding to the GTV only. These two PTVs may be referred to as PTV-50 and PTV-85, respectively.

Another example is the treatment of cervix cancer where the central part of the PTV is mainly treated with high-dose brachytherapy and the lateral extensions by external beam and a lower dose contribution from brachytherapy.

2.4 Treated Volume

The treated volume is the volume of tissue which, according to the implant as actually achieved, receives a dose at least equal to the dose selected and specified by the radiation oncologist as being appropriate to achieve the goal of the treatment.

The Treated Volume is thus encompassed by an isodose surface corresponding to that dose level, which is the Minimum Target Dose (section 6.3.2, 7.4.3). This isodose surface should ideally match the PTV as closely as possible, it should entirely encompass the CTV/PTV, but may be larger depending on the available sources and source arrangement. The Treated Volume (and the PTV) thus depends on the irradiation technique.

2.5 Irradiated Volume

The Irradiated Volume is the tissue volume, larger than the Treated Volume, which receives a dose considered to be significant in relation to normal tissue tolerance.
The dose considered to be significant must be clearly stated:

- in absolute dose value (in Gy),
- as a percentage (e.g., 50%) of the prescribed dose or of the dose at a reference point.

The dimensions of the Irradiated Volume should be reported. The Irradiated Volume depends on the technique and may be used as an optimization parameter.

2.6 Organs At Risk (OAR)

2.6.1 Definition

Organs At Risk (OAR) ("critical normal structures") are normal structures that, because of their radiosensitivity and/or their location close to the target volume, may significantly influence the treatment planning and/or the prescribed dose level (ICRU Report 62) (47).

The probability of side effects depends on several factors of the irradiation: dose level, fraction size and dose rate, irradiated volume, but also probably a complex dose-volume combination (7,18,23,73,77,78,84,85,87).

2.6.2 PTV and Organs At Risk

In brachytherapy, as indicated in ICRU Report 50 (44) for external-beam therapy, when delineating the PTV, a compromise is always necessary due to adjacent radiosensitive normal tissues (Organs At Risk), as well as to other factors such as the general condition of the patient.

Delineation of the PTV which requires judgement and experience is the responsibility of the radiation oncologist.

For example, in brachytherapy for cervix cancer, the PTV is limited in the AP direction by the presence of the bladder and the rectum. The treatment is frequently planned to the maximum tolerable dose to these organs at risk.

3 Reporting the Technical Aspects of the Brachytherapy Treatment

3.1 Description of the radioactive sources

The description of the sources should include complete information on:

- radionuclide;
- type of source, i.e., wire, needle, tube, seeds, seed ribbon, hairpin, radioactive stent, liquid or gas filled balloon, etc;
- physical characteristics of the sources: dimensions (core dimensions and outer dimensions), chemical composition, filtration (if relevant);
- length of each source line (if line sources are used): physical and active length.
Active source length

The active source length is defined as the distance from the most proximal to most distal end of the radioactive material contained in the source line: e.g., (physical) length of wire, seed train, ribbon source. For a moving source, the length is defined as the distance between its extreme positions.

- strength (activity) of the sources, specified according to the recommendations of section 4.
- distribution of the activity within the source(s) (uniform or differential loading, etc.) (10,22,58).

3.2 Source pattern

- number of sources or source lines;
- separation between source lines and between planes, or separation between the guides, if a single moving source is used;
- geometrical pattern formed by the sources (e.g., triangles, squares), for interstitial implants or utero-vaginal source spacing, where relevant;
- the surfaces in which the implant lies, i.e., planes or curved surfaces;
- whether crossing sources are placed at one or more ends of a group of linear sources.

3.3 Applicator

- catheter, material of the inactive vector used to carry the radioactive sources (e.g., flexible or rigid);
- dimensions (diameter and length);
- whether rigid templates are used at one or both ends;
- centering device for the catheter (e.g., for intrabronchial or endovascular applications);
- fixation;
- shielding (high atomic number material, e.g., for the rectum in cervix treatment, or the mandibula in lip or oral cavity interstitial applications);
- for cervix treatment, fully rigid applicator (or not), consequently fixed known geometry (or not) of the complete applicator device;
- rigid uterine source with fixed curvature (or not);
- connection between vaginal and uterine applicators, i.e., fixed, loose (semi-fixed), free;
- type of vaginal sources: ovoids (size and separation), line sources (number and orientation), special sources (box, ring, mould, etc.).

3.4 Type of afterloading and source movement

- manual afterloading;
- remote afterloading;
  (sufficient relevant information should be given on the mechanical system of afterloading) (1,36,49,50,110,112,113);
- stepping source;
- oscillating source
  (an accurate description of the source movements is necessary to derive the time-dose pattern at the different points in the PTV or organs at risk, see section 5, p. 168).

NB: Description of the source(s), applicator and technique is facilitated when the types/models have been published. The complete reference of the publication is then often sufficient. When appropriate,
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the manufacturer should be mentioned. However, any variation between the published conditions and that actually used should be mentioned. If new types of sources, applicators or techniques are used, a full description is needed.

3.5 The “Systems”

The term “system” (ICRU, Report 38,(43)) denotes a set of rules taking into account the source strengths, geometry and method of application in order to obtain suitable dose distributions over the volume(s) to be treated.

For reporting, the system includes recommendations for specifying the application and possibly, as in the Manchester System, for calculating the dose rate (or the dose) at specific points.

The “historical” systems mentioned in the present chapter were developed in a period where computer treatment planning and dose computations were not yet available.

In brachytherapy applications, a “system” ensures safety insofar as it implies application rules and is based on clinical experience. If a system is followed, it must be followed for (1) prescription, (2) application of the sources in space and time and (3) reporting.

If a standard system has been followed, it must be specified and this facilitates reporting. If it is not the case, the source pattern should be described completely and unambiguously.

Development of computers and easy availability of complete dose distribution (which is per se a benefit) tends to increase the use of “no system” applications.

4 Specification of the Source “Strength” (Intensity) in Brachytherapy

A clear distinction should be made between specification of the sources, dealt with in this section, and specification of the doses to the patient organs or tissues, dealt with in sections 6, 7 and 8.

4.1 Reference Air Kerma Rate (RAKR)

As a general recommendation (ICRU, Reports 38 and 58 (43,45)), the “strength” (intensity) of photon emitting radioactive sources for brachytherapy should always be specified in terms of the quantity “Reference Air Kerma Rate” (RAKR).

The problem of specification of sources in brachytherapy is an important one. A new concept has been introduced with the aim of replacing the activity (contained or “apparent”) in a source by the “output” from the source. This concept has been discussed by several authors, and the quantity Reference Air Kerma Rate has been increasingly adopted by different organizations and commissions (2,4,9,11,15,17,21,41,60,61,69,71,72,98,114).

4.1.1 Definition

The Reference Air Kerma Rate (RAKR) of a brachytherapy source is the air-kerma rate, in vacuo, at a reference distance of 1 meter from the source centre, on its transverse axis due to photons of energy greater than δ.
4.1.2 Units

The quantity reference air kerma rate is expressed in Gy s\(^{-1}\) at one meter, or a multiple of this unit (in a convenient way, e.g. for low dose-rate brachytherapy, in microgram per hour, \(\mu\text{Gy h}^{-1}\), at 1 m).

4.1.3 Energy cut-off, \(\delta\)

The energy cut-off is intended to exclude low-energy or contaminant photons (e.g., characteristic x rays originating in the outer layers of steel or titanium source cladding) that can significantly increase RAKR without contributing significantly to absorbed dose at distances greater than about 1 mm in tissue.

4.1.4 Air kerma rate constant \(\Gamma_\delta\)

The relation between RAKR of a given source and other quantities used to specify the radioactive sources in brachytherapy is based on the physical quantity „air kerma rate constant“, \(\Gamma_\delta\) (14, 45, 46).

\[
\text{For a gamma emitting radionuclides, } \Gamma_\delta \text{ is the kerma rate, for a point source, at a reference distance of one meter, per unit activity, due to photons of energy greater than } \delta, \text{ in the „in vacuo“ conditions defined above.}
\]

For the gamma energies emitted by the radionuclides used in brachytherapy, one may consider that the numerical values for dose and kerma are equal.

\(\Gamma_\delta\) is expressed in Gy per second at one meter, or multiples. Some numerical values are given in Table 2.2 in Chapter 2 / p. 26 [ICRU, Report 58 (45)].

4.2 Total Reference Air Kerma (TRAK)

4.2.1 Definition

The Total Reference Air Kerma (TRAK) is the sum of the products of the Reference Air Kerma Rate and the irradiation time for each source.

4.2.2 Practical application of the TRAK

The TRAK is an important quantity which should be reported for all brachytherapy applications, for the following reasons:

1. It is an unambiguous quantity that is simple to calculate (on condition that the strengths of the sources are expressed in RAKR (4.1).

2. The conversion of the quantity mg.h to the TRAK is easy and straightforward : 1 mg.h radium equivalent (0.5 mm Pt filtration) corresponds to 7.2 \(\mu\text{Gy}\) at 1 m.
The TRAK, corresponds in terms of the “modern” SI units, to the „historical“ quantity mg.h. It implies that the extensive and long standing clinical experience of the use of mg.h can be exploited for today’s protocols and studies.

(3) The doses to all organs, and thus the integral dose to the patient, are directly proportional to the TRAK.

(4) In addition, the use of TRAK provides, as a first approximation, an indication of the absorbed doses delivered during treatment at distances from the sources down to 20 - 10 cm (i.e., in the pelvis or abdomen). The dose at 10 cm from the centre of the sources is roughly 100 times higher than the TRAK. It is indeed easy to verify that when the distance of a point P from the centre of the volume (C) occupied by the sources is larger than 2.5 times the largest dimension of that volume, the dose rate obtained at P from the actual distribution of the sources differs by less that 4% from that obtained by assuming that all the sources are located at C (20). However, the TRAK does not allow one to derive, even approximately, the absorbed dose in the immediate vicinity of the sources (i.e., in the tumour or target volume).

(5) The TRAK, or the sum of the RAKR of all sources, can serve as a useful index for radiation protection of the personnel and nursing staff in charge of the patient (kerma -or dose- rate at 1 meter from the patient, neglecting, as a first approximation, the attenuation and scattering phenomena).

4.3 Additional specification of photon sources used for intraluminal applications

In addition to the RAKR and TRAK, for photon sources used in intraluminal brachytherapy, the following recommendation is made (48).

For intraluminal brachytherapy applications, it is also recommended to report the dose rate (and dose) at 10 mm from the source axis at the centre of the source (section 7, p. 181).

This recommendation is partly justified by the fact that several authors have reported their data using the above source specification.

4.4 Specification of beta-ray sources used for endovascular brachytherapy

The following recommendation is made for beta-ray sources used in intravascular brachytherapy (48).

The intensity of the beta-ray emitting sources should be specified in terms of the Reference Absorbed Dose Rate at a distance of 2 mm from the source centre (axis).

NB:

As can be seen from the recommendations above, all sources for brachytherapy applications are specified in terms of their “output” (dose rate) at reference distances and/or in different conditions. The quantity “activity” is used only for regulatory and protection purposes.
5  Reporting the Time-Dose Pattern in Brachytherapy

5.1  Description of the time-dose pattern

The description of the time-dose pattern should include the type of irradiation with the necessary data on treatment and irradiation times (49). The information on dose and time should provide the necessary data to calculate instantaneous and average dose rates.

- The overall treatment time should always be recorded.
- Continuous irradiation: dose rate.
- Non-continuous irradiation: the total irradiation time should be recorded.
- Fractionated and pulsed irradiation: the fraction size and irradiation time of each fraction, the interval between fractions, and the overall treatment time should be recorded.
- When the irradiation times of the different sources are not identical, they should be recorded.

For moving sources:

- Stepping sources: step size, dwell location and dwell time should be recorded. Variation of the dwell times of a stepping source can be used to manipulate the dose distribution. This can be achieved either by manual adaptation of the source positions in relation to the Target Volume, or by a computer optimisation programme. If such a dose optimization is applied, this should be specified (e.g., optimization at dose points defined in the implant, or geometrical optimization (52)).

- Oscillating sources: speed in different sections of the vectors should be recorded.

5.2  Biologically weighted dose

For comparing applications performed using different dose rates, doses per fraction or other differences in time-dose patterns, weighting factors, \( W_{\text{rate}} \), must be introduced. The product of the (physical) absorbed dose, \( D \), by these weighting factors, \( W_{\text{rate}} \), is the biologically weighted dose, \( D_{\text{rate}} \), for dose rate, dose per fraction or other differences in time-dose pattern.

When evaluating the "radiobiological equivalence" between treatments performed with different time-dose patterns, the radiobiological model used (e.g., \( \alpha/\beta \), repair function, ...) as well as the numerical values of the parameters applied, must be indicated. In addition, the conditions for evaluation of radiobiological equivalence must be stated (e.g., late or early effects, type of tissue, dose and dose rate range, etc.) (35,56,66,113,115,116).

For reporting, the biologically weighted dose \( D_{\text{rate}} \) alone cannot be given, but the (physical) absorbed dose and the complete time-dose pattern should be given together with the weighted dose. This will avoid confusion when comparing treatments and will allow, eventually, re-evaluation of "radiobiological equivalence" when new and better radiobiological data becomes available.

An important issue when evaluating "radiobiological equivalence" is the selection of the reference dose rate or time-dose pattern. As a general rule, and unless otherwise stated, "historical" continuous low dose rate irradiation is taken as the reference (i.e., typically with radium, 60 Gy in 6 days or about 0.5 Gy per hour, at the specification point).
At present, reliable and universally accepted methods of evaluating radiobiological equivalence between brachytherapy applications performed with different time-dose patterns are not available; great care must therefore be taken when comparing different treatment schedules.

6 Interstitial Therapy: Definition of Concepts, Doses and Volumes for Reporting

6.1 Some “historical” systems in interstitial therapy

Some historical systems are briefly recalled to facilitate interpretation of the definitions and concepts developed in this section.

6.1.1 The Paterson-Parker System

The Paterson-Parker System (Manchester System) was developed to deliver a reasonable dose uniformity (+/- 10 %) throughout a region implanted with radium needles (64,75,76).

The system specifies rules for the geometric arrangement of the sources, and for the linear activity needed to cover a PTV with a sufficiently homogeneous dose (Fig 6.2). The system includes tables of milligram-hour (mg.h) needed to deliver specified doses for different sizes of implants (or moulds). The proportion of activity on the periphery is specified according to the size of the implant: it is larger for smaller implants. The system is still used for single-plane implants and double-plane implants in many centres.

Fig 6.2: Manchester System for application of radioactive sources with different loading. Fig A shows the localisation film. Fig B and C give the distribution of dose rate for a single-plane implant with iridium wires of unequal linear activity in order to ensure dose uniformity throughout the implanted region. Wires 1, 4, 5 and 6 (peripheral) contain a linear activity of 60 MBq per cm; wires 2 and 3 contain a linear activity of 37MBq per cm. Wires 1, 2, 3 and 4 are 6 cm long; wires 5 and 6 are 3.5 cm long. Fig B gives the dose rates in the plane containing the wires,. Fig C in a perpendicular plane. (From Wambersie and Battermann [115])

6.1.2 The Quimby System

The Quimby System is characterised by uniform source spacing and uniform source activity (91). Consequently, this arrangement of sources resulted in a non-uniform dose distribution, higher in the central region of the implant (as in the Paris System: see Fig 6.3). This system was particularly used in US centres.
6.1.3 The Paris System

Fig 6.3: Iridium-192 wire implant according to the Paris system (single-plane implant). The wires are of equal linear activity, parallel, and arranged in such a way that their centres are in the same plane perpendicular to the direction of the wires (i.e. the central plane, see Fig 6.4).
(From Wambersie and Battermann [115])

Fig 6.4: The central plane. In an implant where the source lines are rectilineal, parallel, and of equal length, the central plane is perpendicular to the direction of the source lines and passes throughout their centres. The Mean Central Dose ($D_m$) is the mean of the local minimum doses $D_i$ ($i = A, B, ...$) in the plateau region. (A) A single plane implant; (B) a two-plane implant; (C) an actual single-plane implant where sources are not rectilinear: the central plane can be defined as in (A).
(From ICRU Report 58 (45).)
The Paris System of implant planning was developed mainly with iridium-192 wire sources (20,80,81,82). The sources are of equal linear activity, parallel, placed at equal distances, and arranged in such a way that their centres are in the same plane perpendicular to the direction of the lines (Fig 3A and B). This plane, called the "central plane" is the midplane of the application (Fig 6.4 A, B and C).

Fig 6.5A. and B : Dose planning for implants with iridium-192 wires contained in two parallel planes, following the Paris system. Examples of a breast implant in two planes. (A) The 7 wires are equidistant and arranged in triangles (length of the wires 7 cm for the upper row and 8 cm for the lower row), linear activity 52 MBq cm\(^{-1}\), application time 43.32 h for a reference dose of 20 Gy. (B) The 6 wires are equidistant and arranged in squares (length of the wires 6 cm for the upper row and 7 cm for the lower row), linear activity 52 MBq cm\(^{-1}\), application time 42.91 h for a reference dose of 20 Gy. (From Wambersie and Battermann [115])

If the volume to be treated is large, more than one plane containing wires is used. Again, equidistance of the radioactive lines is required. This means that their intersections with the central plane are arranged according to the apices of equilateral triangles or squares (Fig 6.4B and 6.5 A and B). This regular distribution of the wires results in a slight overdosage at the centre of the target volume.

The dose rate at a point in the middle of a group of sources is called the basal dose rate (BD). This BD is always calculated from the position of the sources in the central plane and is the minimum dose rate between a pair or group of sources. The value of the isodose curves are expressed as a percentage of the BD.

The reference dose rate is derived from the BD and is equal to 85% of the BD. It is used for calculating the total treatment time of the implant.

Because the ends of the active wires are not crossed, as in the Manchester System, the active sources should be 20 - 30% longer than the target volume at both ends. The minimum thickness of a treated volume is 50 - 60% of the source separation for single planes and 120 - 150% for 2 planes.
6.1.4 Need for a common language

With the development of computer based dose calculation, there is more freedom for prescribing and performing brachytherapy applications. It is therefore important that a common language is available to report treatments and make exchange of information possible and reliable.

6.2 Dose distribution in interstitial therapy

6.2.1 General description

In interstitial therapy, the dose distribution is non-homogeneous and includes steep dose gradients and regions of high dose surrounding each source. The doses (and the dose gradients) decrease with the distance from the sources.

6.2.2 Local minimum doses

Within the volume of the implant, however, there are regions where the dose gradient approximates a plateau (Fig 6.6).

"1° In an interstitial implant, the regions of plateau dose are equidistant between adjacent neighboring sources, for sources of identical activity. They are regions of "local minimum doses".

2° Variations between these local minimum doses can be used to describe the dose uniformity of an implant.

3° A region of plateau dose is the place where the dose can be calculated most reproducibly and compared easily by different departments.

Fig 6.6: Plateau dose region between radioactive sources. The dose distribution shows a plateau region of low dose gradient. In this example of three sources, 6 cm long and with 1.5 cm spacing, the dose varies by less than 2% in the grey region between the sources. (From Dutreix et al., [20])
6.2.3 Central plane

To give the necessary information about the dose or dose rate distribution, isodose curves must be calculated in at least one chosen plane. If only one plane is used for isodose calculation, the “central plane of the implant” should be chosen. In order to assess the dose distribution in other areas of the implant, multiple planes for isodose calculation can be chosen, either parallel or perpendicular to the central plane.

In source patterns in which the source lines are straight, parallel, of equal length and with their centres lying in a plane perpendicular to the direction of the source lines, this plane is defined as the central plane (see Fig 6.4A and B) (45).

In an actual implant, all source lines may not necessarily be straight, parallel, and of equal length. In such cases, the central plane should be chosen perpendicular to the main direction of the source lines and passing through the estimated centre of the implant (see Fig 6.4.C).

For more complex implants, it may be necessary to subdivide the target volume into two or more subvolumes for dose evaluation. In this event, a central plane may be defined for each of these subvolumes (Fig 6.7). The calculation of dose distributions in multiple planes throughout the target volume shows that a variation of a few millimetres in the position of the central plane is not critical.

\[
D_{ma} = \frac{D_A + D_B + D_C + D_D}{4} \quad (a)
\]

\[
D_{mb} = \frac{D_E + D_F + D_G}{3} \quad (b)
\]

Fig 6.7: Central planes in a complex implant. It is sometimes necessary to plan the treatment in terms of two or more sub-volumes. In the example shown, where all source lines are not of equal length, two central planes are identified: (a) for the long source lines and (b) for the shortest ones. Two Mean Central Doses are determined in the two sub-volumes \( D_{ma} \) and \( D_{mb} \) respectively. Open circles are the intersections of the sources with the central planes, and closed circles are the points where the local minimum doses are calculated. (from ICRU Report 58, [45]).
6.3 Reference points (dose levels) for reporting interstitial therapy

6.3.1 Mean Central Dose (MCD)

In interstitial therapy, the Mean Central Dose is defined as the arithmetic mean of the local minimum doses between sources in the central plane (or in the central planes if there are more than one) (45).

In the case of a single-plane implant, the Mean Central Dose is, in the central plane, the arithmetic mean of the doses at mid-distance between each pair of adjacent source lines, taking into account the dose contribution, at that point, from all sources in the pattern (see Fig 6.4A).

![Diagram of a two-plane implant with source lines and dose profiles](image)

**Fig 6.8A and B: Evaluation of dose profiles.** Three profiles (B) are drawn along two orthogonal directions through a two-plane implant (A) with eight parallel line sources, 10 cm long, 1.8 cm spacing. The profiles are calculated in percentage of the Minimum Target Dose (thick line) along axes XX, YY and Y'Y' in the central plane. The profile along the axis YY is the most representative to estimate the Mean Central Dose (MCD), which is the mean of the local minimum. The Mean Central Dose is equal to 118% of the peripheral dose (from ICRU Report 58, [45]).

In the case of an implant with line sources in more than one plane, the Mean Central Dose is the arithmetic mean of the local minimum doses between each set of three (triangles) or four (squares) adjacent source lines within the source pattern (see Fig 6.4B). For triangles, the minimum dose lies at the intersection of perpendicular bisectors of the sides of the triangles (geometric centre) formed by these source lines. This point is equidistant from all three source lines. For squares, the minimum is at the intersection of the diagonals.

In some complex implants, a single central plane may not bisect or even include all the sources. In these cases, a Mean Central Dose based on one plane can be misleading and it is advisable to subdivide the volume and to choose a separate central plane for each subvolume (see Fig 6.7).

Three practical methods are acceptable for determining the Mean Central Dose:
1. **Evaluation of triangles**: If parallel lines are used, one can identify triangles consisting of three adjacent source lines for all the sources, so that the triangles formed constitute as many acute triangles as possible. The intersection points of the perpendicular bisectors of each triangle are determined and the local minimum doses are calculated at each of these points. The mean of these local minimum doses is the Mean Central Dose. This method is the most precise when parallel lines are used.

2. **Evaluation of dose profiles**: the dose profiles are calculated for one or more axes through the center of the implant passing through as many local minima as possible. The local minimum doses are determined by inspection. The mean of these local minimum dose values is the Mean Central Dose (Fig 6.8).

In a single surface implant performed following a curved surface, a profile may lead to an underestimation of the Mean Central Dose.

In a complex implant, it may be difficult to find axes passing through the minima, and profiles may lead to an overestimation of the Mean Central Dose. However, experience shows that the error lies within acceptable limits. This method is sometimes preferred for seed implants. In a seed implant, the dose should be calculated along several random profiles passing through the implant. (Fig 6.9) (115).

---

**Fig. 6.9**: Seed implant with 68 iodine-125 seeds of 19.2 MBq i.e. a, total activity 1310 MBq (35.4 mCi). Fig B: dose distribution in the central plane perpendicular to the Z axis. (From Wambersie and Battermann [115]).

**Fig. 6.10**: Determination of Mean Central Dose (MCD) from inspection of dose distribution. Dose distribution in the central plane of an implant with six parallel iridium-192 line sources, 6 cm long, 1.5 cm spacing, reference air kerma rate 14.5 μGy h⁻¹ at 1 m. the dose varies by 5% between plotted isodose lines in the region of interest. The isodose values are 16, 19, 22, 24, 26, 28, 30, 31.5, 33, 35, 40 and 45 cGy h⁻¹. The local minima, A, B, C and D, can be easily estimated by inspection $D_A$ and $D_D$ approximate 31 cGy h⁻¹ and $D_B$ and $D_C$ approximate 34 cGy h⁻¹. The estimated Mean Central Dose is $D_m = 32.5$ cGy h⁻¹ (from ICRU Report 58, [45]).
3. Inspection of dose distribution: the dose distribution is plotted in the central plane. With isodose lines varying by 5% (at most 10%) of the local dose in the central region, the local minima can be determined by inspection. The mean of these local minima is the Mean Central Dose (Fig 6.10). This method is often preferred for complex implants with line sources.

6.3.2 Minimum Target Dose

The Minimum Target Dose is the dose selected and specified by the radiation oncologist as adequate to treat the PTV. It corresponds to the prescribed dose in many instances. It is related to the source arrangement and is the dose delivered at the periphery of the PTV. The application is planned in such a way that all points of the PTV receive a dose (at least) equal to the Minimum Target Dose.

The Minimum Target Dose is known in some American centers as the ‘minimum peripheral dose’ (19). It is equal to about 90% of the prescribed dose in the Manchester System for interstitial therapy. It is known as the ‘reference dose’ in the Paris System, where it is equal to 85% of the Mean Central Dose (MCD).

6.4 Volumes for reporting in interstitial therapy

6.4.1 Treated Volume

As defined in section 2.4, the Treated Volume is the tissue volume that, based on the actual implant, receives at least a dose selected and specified by the radiation oncologist as appropriate to achieve the purpose of the treatment (e.g., tumour eradication or palliation).

Following the definition of the Minimum Target Dose (see above), the Treated Volume is encompassed by an isodose surface, the value of which is the Minimum Target Dose. The Treated Volume should, in principle, entirely encompass the CTV (however, this may not necessarily always be the case).

6.4.2 High-dose regions

In order to correlate radiation dose with late damage, the high-dose regions around sources should be assessed (Fig 6.5 and 6.11)
There will inevitably be a high-dose zone around each source. Although this zone is often small and well tolerated, the exact tolerance dose and volume for interstitial therapy are not known yet. However, for intercomparison, there must be agreement on how to describe the high-dose volumes. A dose of approximately 100 Gy is likely to be significant in determining late effects. In those patients who receive 50 - 60 Gy as Minimum Target Dose or 60 - 70 Gy as Mean Central Dose (MCD), 100 Gy corresponds approximately to 150% of the MCD. It is therefore recommended in ICRU-Report 58 (45) that the size of the region receiving more than 150% of the MCD should be reported.

The high-dose region should be defined as that encompassed by the isodose corresponding to 150% of the Mean Central Dose (MCD) around the sources in any plane parallel to the central plane where a high-dose region is suspected. The maximum dimensions of all regions, in all planes calculated, should be reported.

6.4.3 Low-dose regions

A low-dose region is defined as a region, within the CTV, where the dose is less than 90% of the prescribed dose. The maximum dimension of the low-dose region in any plane calculated should be reported.

In implants for which the CTV is included within the Minimum Target Dose isodose, the occurrence of a low-dose region is exceptional. If the CTV is not covered by the Minimum Target Dose isodose, there will be low-dose regions due to geographical miss. Low-dose regions should be reported in order to correlate the local recurrence rate with the dose distribution.

6.4.4 Reference Volume

The Reference Volume is the volume encompassed by an isodose defined in relation to the Mean Central Dose.

Fig 6.12: Dose and volume reporting in interstitial brachytherapy for breast cancer. The Minimum Target Dose was defined at ~ 10 mm from the outer needles and was 20 Gy for LDR. When the Mean Central Dose was calculated after treatment, this was 28 Gy. For comparison with published data, the “85% of the Mean Central Dose” was chosen. 85% of the Mean Central Dose was 24 Gy, the mean reference volume was 73 cm³, and the homogeneity index
Fig. 6.12 (continued): 0.72. By this approach the technique could finally be characterised as intensive treatment in terms of dose and volume compared to commonly reported practice in literature. A similar conclusion was reached for the consecutive HDR brachytherapy experience with a Minimum Target Dose of 10 Gy and a “85% of Mean Central Dose” of 13 Gy.
(From Resch, Pötter, Van Limbergen et al. [92])

At present, there is no general agreement on how to relate reference volume and Mean Central Dose. For example, in the Paris System, the reference dose is 85% of the Mean Central Dose.

In using a reference volume for reporting, the relation of the reference dose to the Mean Central Dose should always be given (e.g. 90%, 80%, 75%).

A relevant comparison must use the same relationship between the Mean Central Dose and the dimension of the reference volume. If this is done, it is possible to compare dose and volume between different treatments for a fixed relation between the reference isodose and the Mean Central Dose. If this is not done, an apparently similar prescribed dose and volume may correspond to totally different implants (Fig 6.12).

The reference isodose level for reporting should be that commonly used in literature reports (e.g. 85%).

6.5 Dose uniformity parameters

Several indices quantifying the homogeneity of the dose distributions have been proposed (see, for example (74,96,118).

Two parameters describing dose uniformity for interstitial implants are recommended in ICRU Report 58 (45). They can be derived directly from the concepts of Minimum Target Dose and Mean Central Dose:

1. The spread in the individual minimum doses used to calculate the Mean Central Dose in the central plane expressed as a percentage of the Mean Central Dose;
2. The dose homogeneity index, defined as the ratio of Minimum Target Dose to the Mean Central Dose.

6.6 Additional representation of the dose distribution

To appreciate fully the dose distribution of an implant, the use of volume-dose calculations has been advocated (13,63,70).

For this purpose, the CTV (or a larger volume including an additional margin) is divided into subvolumes (e.g., voxels) and the dose rate calculated at the centre of each subvolume. The volume receiving at least a specified dose is then defined as the sum of all subvolumes where at the centre at least that dose is received.
Fig 6.13: Natural Dose-Volume Histogram (NDVH) of the tongue implant shown in figure 6.11. Treatment dose rate of 1 Gy h\(^{-1}\) was chosen to deliver 60 Gy in 60 h.
(From Anderson [6]).

Because of high dose gradients, significant differences in calculated volumes may be observed, depending upon the size of the elementary subvolumes. The size of the grid and of the elementary subvolumes used in dose and volume calculations should be clearly stated.

Volume-dose data can be represented by means of histograms showing the distribution of fractions of the CTV receiving doses within chosen intervals, especially the Natural Dose-Volume Histogram (NDVH) as published by Anderson (5,6) (Fig 13). With this model, even small differences between implants can be shown. The main characteristic of the NVDH is the peak that occurs with a regular implant of several sources. In fact, the peak dose reflects the basal dose of the Paris System (106). If the implant is less uniform, the peak is wider. So, the NVDH can be used for intercomparison between planned and actual source arrangements (65,106). An example of a Cumulative Dose-Volume Histogram (CDVH) is presented in Fig 14 (105).

The value of these alternative representations of the dose distribution as a possible prognostic factor for treatment outcome has still to be established in clinical research.
6.7 Recommendations for reporting interstitial therapy—Summary

The following data are recommended by the ICRU (Report 58) (45) for reporting interstitial therapy. Reporting at level 2 (and 3) shall always include all data that should be reported at level 1.

* Description of the clinical conditions, including GTV, CTV (sections 2.1 - 2.6, p. 158)\(^{(a)}\)
* Description of the technique (is the application performed following a "system"?) (section 3, p. 163)\(^{(b)}\)
* Source specification, including RAKR and TRAK (section 4, p. 165)\(^{(c)}\)
* Complete description of time-dose pattern (section 5, p. 168)\(^{(d)}\)
* Treatment prescription (section 1.1, p. 155)\(^{(e)}\)
* Mean Central Dose (MCD), Minimum Target Dose, Homogeneity Index (sections 6.3.1, 6.3.2, 6.5)
* Volumes and their dimensions, including PTV, Treated Volume (2), high-dose regions, low-dose regions, reference volume, irradiated volume\(^{(f)}\).
* Organs at risk (section 2.6, p. 163)

\(^{(a)}\) The clinical conditions should be described as completely as possible when reporting at level 1, completely at level 2. Reporting should include the description of the GTV and CTV.

\(^{(b)}\) The treatment technique should be described in detail. In particular, it should be clearly indicated whether -or not- a "system" is followed for prescribing, recording and reporting.

\(^{(c)}\) A clear distinction should be made between specification of the sources and specification of the doses to the patient. The TRAK should (and can) always be reported at Level 1.

\(^{(d)}\) The time-dose pattern at any point depends on the technique, particularly when a moving source is used. Description of the technique and of the time-dose pattern should then be closely correlated.

If biological “equivalence” is sought for comparison with treatments performed with other time-dose patterns, the radiobiological models and the “weighting factors” should be clearly indicated. In any case, reporting “weighted doses” should \textit{complement but not replace} reporting of the (physical) absorbed doses and the actual time dose-pattern.

\(^{(e)}\) The prescribed dose, as specified here for interstitial therapy, is the dose that the radiation oncologist intends to give and which is entered in the patient’s chart. Depending on the system used, the approach for dose prescription in interstitial therapy may differ from centre to centre. If the prescribed dose is not the Minimum Target Dose nor the Mean Central Dose (MCD), the method for dose prescription should be reported.

If, for clinical or technical reasons, the dose actually delivered differs from the prescribed dose, this should be reported.

\(^{(f)}\) Reporting dimensions of volumes is typically part of reporting at level 2. In addition to the Treated Volume, the dimensions of the high- or low-dose region(s), any dose uniformity data, and additional representation of dose distribution if available should be reported.
7 Intraluminal Brachytherapy: Definition of Concepts, Doses and Volumes for Reporting

7.1 Introduction

This section deals with recommendations for reporting intraluminal brachytherapy applications for bronchus, oesophagus, vagina, biliary duct tumours and endovascular brachytherapy.

Intraluminal applications consist of the insertion of one or several linear sources, contained in appropriate applicator devices, in natural cavities (or lumina). Other types of sources/applicators may be used such as ovoids or moulds in the vagina. This technique allows delivery of high doses to the CTV, while sparing organs at risk. The linear (or quasi linear) sources may be simulated by several point sources (seeds) or a moving source.

7.2 Dose distribution in intraluminal brachytherapy

In intraluminal brachytherapy, the radioactive material is inserted in the (anatomical) lumen, limited by the mucosa, the usual site of origin of the tumour. Due to the (physical) inverse square law:

(a) the dose is decreasing dramatically as a function of distance to the linear source, and
(b) the dose gradient is steepest close to the source and decreases with distance.

7.2.1 Dose at the luminal surface

The highest tissue dose is obtained at the level of the luminal surface; it depends on the applicator diameter. The luminal surface dose is critically related to tumour control and the risk of complications. In contrast, the highest (physical) dose is within the applicator volume or in the lumen where it is obviously not clinically relevant.

7.2.2 Dose gradient

Dose inhomogeneity in the tissues, over a given radius (e.g., 5 mm), is high close to the source (i.e., when a small diameter applicator is used); the dose becomes more homogeneous at a distance from the source (i.e., when a large diameter applicator is used). These situations are illustrated in figures 15 and 16 for different diameter applicators. Dose homogeneity is better with a large applicator (when clinically possible); it can be expressed by comparing the dose variation between the mucosal/tumour surface, the dose at the reference point in tissues and the external border of the PTV (see the definitions below).
Fig 6.15: Dose gradient in intraluminal brachytherapy. The dose variation is expressed relative to the dose at 10 mm from the source axis.

Fig 6.16: Dose gradient in intraluminal brachytherapy. Influence of the applicator diameter on the dose variation for three particular types of clinical situations. Dose variation between the applicator surface and at 5 mm depth in the tissue is indicated.

Because of the steep dose gradient, there is no obvious choice for a reference point for reporting based (at least partly) on dose distribution (as in external beam therapy). Therefore, it is recommended that two sets of reference points should be selected related (1) to the source(s) and (2) to the tissues/organs. These two sets of information should be clearly distinguished from one another.
7.2.3 Shape of volumes

The volume encompassed by an isodose close to the sources (see below Treated- and Reference Volumes, section 6.7.5) has a “cigar” or cylindrical shape, depending on the distribution of radioactivity in the source. For a wire source with homogeneous linear activity, or for a series of seeds with equal activities, the diameter decreases as the extremities are approached (“cigar” shape). This can be deliberately compensated for by increasing the activity near the end of the linear source (e.g., seeds of different activities, moving source with different dwell times, etc.).

7.3 Clinical aspects

The definitions and general recommendations for reporting from section 2 (p. 158) are applicable (compare for more details Chapter 24 on Oesophagus. However, the organs suitable for intraluminal brachytherapy have a central lumen containing the applicator. The dose to the volume occupied by the lumen and the applicator is obviously not relevant. Therefore, the main dimensions to evaluate and to report are the length and the tissue depth (thickness).

7.3.1 Length and depth of the GTV, CTV, PTV

The lengths of the GTV, CTV, and PTV should be reported (see Fig 24.3, 24.6, 24.8; 32.4).

The lengths of the GTV, CTV and PTV are defined at the level of the mucosa (in contrast to the Treated- and Reference Volume, which are defined at the reference depth, see section 7.5).

The depths of the GTV, CTV and PTV are defined in relation to the luminal surface.

As discussed previously (see Section 2), delineation of the CTV and PTV depend on the judgement and experience of the radiation oncologist.

7.3.2 Lumen - Lumen diameter

The organs suitable for intraluminal brachytherapy have a lumen and, depending on the site, the lumen diameter may be measured using appropriate diagnostic procedures, such as radiographs with contrast medium, endoscopy, CT, MRI, US. If the lumen is completely filled by the applicator, the lumen diameter becomes identical to the applicator diameter (vagina, oesophagus, see 7.4.2). The reference lumen diameter is defined in the central plane (see section 7.4.1). If this is not relevant (e.g., due to the presence of tumour stenosis which is maximal distally or proximally), an average lumen diameter should be chosen around the central plane.

7.3.3 Specific clinical aspects in endovascular brachytherapy

Although the concepts defined above for intraluminal brachytherapy are in general applicable to endovascular brachytherapy, some of them need modification and new definitions have been introduced by the GEC ESTRO (86).

Lesion length

The lesion length is defined as the stenotic or occluded length of the vessel segment. Its proximal and distal ends must be specified according to strict criteria (e.g., >50% reduction of the lumen diameter as seen on the angiogram).

The lesion length must be reported so that patients can be compared related to their prognosis.
Interventional length

The interventional length is defined as the angioplasty length or the distance covering any part of the vessel where the intervention took place. The interventional length must be reported so that patients can be compared in relation to the efficacy of endovascular brachytherapy (Fig 32.4). The concept of interventional length may have some analogy with the concept of GTV in oncology.

Length and depth of the Clinical Target Volume

In endovascular brachytherapy, the length and depth of the Clinical Target Volume (CTV) is the length or depth to irradiate: it should include the whole injured part of the vessel wall (Fig 32.4). The length of the injured vessel wall is larger than the interventional length because dissection may occur in the vessel wall beyond the inflated balloon length.

7.4 Reference points for reporting intraluminal brachytherapy

Following the ICRU (48), a clear distinction should be made between specification of the sources (at a distance from the source (section 4.3, p. 187) and specification of the dose to the patient (see Fig 6.19 and 6.20B,C).

For reporting irradiation of the patient (or the Target Volume), a set of 3 reference depths/points (independent of the treatment technique) are defined:

► the surface (mucosa) itself (Fig 6.18-20);
► the Minimum Target Dose.
► a reference depth of 5 mm in the tissues, from the surface (mucosa) (Fig 6.18-20);

Before defining the reference points, lengths and volumes to be reported, it is necessary to define the “central plane” of the application to which these points, lengths and volumes are referred.

7.4.1 Central plane

The central plane of an intraluminal application is the plane perpendicular to the axis of the organ lumen, half way between the proximal and distal ends of the PTV. This definition is analogous to the definition of the central plane of an interstitial implant (see section 6.2.3).

The central plane is used for prescribing and reporting. The reference points, lengths and volumes to be reported should be defined in the central plane.

The central plane is also used to define the average lumen diameter, as indicated in section 7.3.2).

7.4.2 Dose at the luminal surface

The dose at the mucosa represents the highest (maximum) dose in the PTV, and is thus clinically relevant in relation to tumour effects and/or complications.

Reporting the dose at the luminal surface, in the central plane, is therefore recommended. If, because there is a large irregular tumour, the mucosal dose in the central plane itself is not representative, an average mucosal dose around the central plane may be more relevant to report.
NB:
(1) For oesophagus and vagina, where large applicators can be introduced into the cavity, the mucosa is totally dilated and the external contour of the applicator coincides with the inner mucosal surface. The applicator and the lumen diameter then become identical, and the reference depth can be measured from the external surface of the applicator (Fig 6.19, 20C-H).

(2) When a non-centered device is used (e.g. frequent in bronchus and with some systems in endovascular brachytherapy), it is difficult to specify the actual dose at the mucosa or at the reference depth. The best estimation of the maximum and minimum doses should then be reported (Fig 6.17, 18).

7.4.3 Minimum Target Dose
The Minimum Target Dose is the minimum dose to the PTV. It should be (at least) equal to the dose defined by the clinician as adequate to treat the PTV.

The Minimum Target Dose should be reported; this requires information about the depth and the length of the PTV. The Minimum Target Dose should be reported as absolute dose value (in Gy) and as a percentage of the dose at the reference point.

7.4.4 Reference depth – Reference point

A Reference depth of 5 mm, from the surface in the organ wall, in the central plane, is recommended for oesophagus, bronchus and vagina (Fig 6.19, 20).

In endovascular brachytherapy (Fig 6.20A), a reference depth of 1 mm, from the endothelium (surface wall) in the artery, is recommended for reporting dose to the patient, for coronary arteries. For peripheral arteries, a depth of 2 mm is recommended.

The reference point for reporting is located at the reference depth. Prescribing and reporting doses at the same depth certainly simplifies the procedures and reduces the risk of confusion and accidents (compare experience in postoperative vaginal brachytherapy) (Fig 6.20F).
Fig 6.17: Influence of centering on dose distribution at the lumen surface and at the reference depth. For reporting intraluminal brachytherapy with non-centred applicators minimum and maximum doses should be given for the reference depth and the lumen surface.

A: Centered source with a symmetrical radial dose distribution.

B: Non-centered source and its influence on the dose at the lumen surface and at the reference depth (modified from Pötter et al. 2001 (86)).
**Fig 6.18**: Small diameter applicator (6mm) in a wide oesophageal lumen with moderate stenosis. Position of the applicator is either concentric or eccentric. Dose prescription is at 5 mm from the applicator surface or at 10 mm from the source axis.

A: Position of the applicator is concentric. The reported dose is at 5 mm from the applicator surface (100%). However, this does not correspond to a certain dose at a certain depth in the oesophageal wall. Therefore, the maximum and minimum dose in the oesophageal wall should be reported in addition. In this case, this variation is between ~ 80% to 290% (factor 3.7). The dose at the applicator surface is 290%. However, this dose does not correspond to a certain dose at a certain point on the luminal surface. Therefore, in addition to the maximum, the minimum dose should also be reported. In this case this is 100% (factor 2.9).

B: If the applicator is eccentric, the dose at the mucosa/tumour surface varies between ~ 60% to 290% (factor 4.8), the dose within the oesophageal wall varies between ~ 45% to 290% (factor 6-7).

C: Concentric position of the applicator. Dose prescription is 10 mm from the source axis. The dose to be reported at 5 mm from the applicator surface is 130%. In this case dose variations are as follows: mucosa/tumour surface: 130% to 370% (factor 2.9), within the oesophageal wall: 100% to 370% (factor 3.7).

D: Eccentric position of the applicator. Dose prescription is at 10 mm from the source axis. The dose to be reported at 5 mm from the applicator surface is 130%. Dose variations are as follows: mucosa/tumour surface : ~80 % to 370% (factor 4.6); within the oesophageal wall : ~ 60% to 370% (factor 6.2).
Fig 6.19 A,B: **Large diameter applicator in a wide oesophageal lumen with moderate stenosis**

Fig 6.19A: Large diameter applicator (15mm) in a wide oesophageal lumen with moderate stenosis and tumour load. **Dose is prescribed at 5 mm from the applicator/lumen surface (100%).** Dose prescription is identical with the dose to be reported. The dose at the applicator surface is 180%. Higher isodose lines are inside the applicator i.e. outside the tissue. The dose at the mucosa/tumour surface is evenly distributed (180%), because the applicator surface and mucosa/tumour are directly attached to each other. Dose variation within the oesophageal wall (thickness 4 - 5 mm) is from ~100% to 180% (factor of 1.8).

Fig. 6.19B: Large diameter applicator (15mm) in a wide oesophageal lumen with moderate stenosis and tumour load. **Dose is prescribed at 10 mm from the source axis (100%).** The dose to be reported at 5 mm from the applicator/lumen surface is 80% of the prescribed dose; the dose at the applicator surface is 140% of the prescribed dose i.e. 180% of the reported dose. The dose at the mucosa/tumour is 140%, the variation within the oesophageal wall (thickness 4 - 5 mm) is from ~90% to 140% (factor of 1.8).

Fig 6.19C, D **Small diameter applicator in a narrow oesophageal lumen with extensive stenosis**

Fig 6.19C: Small diameter applicator (6 mm) in a narrow oesophageal lumen with extensive stenosis and tumour load (tumour thickness as measured from the lumen surface maximum 16 mm). The applicator is directly attached to the mucosa and the tumour surface. **Dose is prescribed at 5 mm from the applicator/lumen surface (100%).** Doses to be

Fig 6.19D: Small diameter applicator (6 mm) in a narrow oesophageal lumen with extensive stenosis and tumour load (see above). **Dose is prescribed at 10 mm from the source axis (100%).** The dose to be reported at 5 mm from the applicator surface is 130%, and at the applicator surface (tumour/mucosa) 370%. 
Fig 6.19C (continued)
reported are at 5 mm (100%) and at the applicator/lumen surface 290%. This surface represents mainly the macroscopic tumour and only partly the mucosa. The lowest dose within the oesophageal wall and within the GTV is < 50%.

7.5 Dimensions of volumes for reporting (Fig 6.20)

7.5.1 The reference volume

**Definition**

The reference volume, in intraluminal brachytherapy, is defined as the tissue volume encompassed by the isodose corresponding to 90% of the dose at the reference point (see section 6.7.4.4).

**Length of the reference volume**

The length of the reference volume is defined parallel to the (main) lumen axis or source axis, at the reference depth, i.e. 5 mm from the mucosa (1 and 2 mm for intravascular brachytherapy) as defined in section 7.4.2. (Fig 6.20)

The lengths are defined along the direction of the (main) axis of the source (or source line). However, the lengths measured on the axis or the lumen themselves are obviously irrelevant.

NB: The length of the reference volume was called reference isodose length in the EVA GEC ESTRO Report (86) (Fig 6.20A).

7.5.2 Treated Volume

The Treated Volume is encompassed by an isodose surface corresponding to the Minimum Target Dose. (compare 2.4)

The length of the Treated Volume is measured along the direction of the main axis at the depth of the CTV. The diameter of the Treated Volume may vary along the axis dependent on the shape of the CTV.

7.5.3 Active source length and length of the Treated- and Reference Volume

A distinction has to be made between the active source length, as defined in section 6.3.1, which is a technical characteristic of the source itself and the lengths of the resulting Treated Volume and reference volume, which are clinical and dosimetric concepts (Fig 6.20). For the same active source length and total activity, the lengths of the Treated Volume and reference volume, and the dose distribution may be different for a (solid) linear source and a set of point sources. These differences are even greater when the point sources have different activities and/or different spacings to improve dose distribution (20). The same is true for a moving source with different dwell times.

The ratio between the active source length and the length of the PTV or Treated Volume length (measured at a given depth) may be different, sometimes significantly, depending on the dose fall-off around the extremities of the source. This in turn depends on the source characteristics and the lumen diameter.
Fig 6.20 Reporting Intraluminal Brachytherapy

Reference Lumen Diameter (RLDi) is 3 mm, radius (r) is 1.5 mm. Prescribed Dose (PD) is at 2.5 mm. Reference Depth is at 1 mm (RD). Reference Lumen Dose Point (RLDP) and Reference Depth Dose Point (RDDP) are also indicated. In this case PD and RDDP are identical. For peripheral arteries RD is at 2 mm. For non-centred applicators minimum and maximum doses should also be given (for details see Fig 6.17 and Fig 32.3B). The Length of the Reference Isodose (RIL) is defined as the length of the 90%-isodose at the reference depth of 5 mm.

Fig 6.20A: Reporting in Endovascular Brachytherapy (coronary artery).
Reference Lumen Diameter (RLDi) is 3 mm, radius (r) is 1.5 mm. Prescribed Dose (PD) is at 2.5 mm. Reference Depth is at 1 mm (RD). Reference Lumen Dose Point (RLDP) and Reference Depth Dose Point (RDDP) are also indicated. In this case PD and RDDP are identical. For peripheral arteries RD is at 2 mm. For non-centred applicators minimum and maximum doses should also be given (for details see Fig 6.17 and Fig 32.3B). The Length of the Reference Isodose (RIL) is defined as the length of the 90%-isodose at the reference depth of 5 mm.

Fig 6.20B: Reporting in Endobronchial Brachytherapy (small diameter applicator)
Applicator Diameter (AD) is 2 mm, radius (r) is 1 mm. Prescribed Dose (PD) is at 10 mm from the source axis. Reference Depth (RD) is at 5 mm from the Applicator Surface (AS). Reference Depth Dose is given at the the RD (6 mm (5+1) from the source axis). Dose at the Applicator Surface (AS) is also given. For non-centred applicators minimum and maximum doses should also be given (for details see Fig 6.17 and Fig 32.3B). In order to clearly indicate the doses at the reference depth (RD) and at the Lumen Surface (different from the Applicator Surface) the diameter of the (bronchus) lumen has to be reported, which is from ~18mm for the trachea to ~9mm for the tertiary bronchi (for details of the dimensions and the topographical anatomy see Fig 26.1; for an example of a calculation with minimum and maximum doses based on Computed Tomography see Fig 5.7). The Length of the Reference Volume (RVL) is defined as the length of the 90%-isodose at the reference depth of 5 mm.
Fig 6.20 Reporting Intraluminal Brachytherapy (continued 1)

Fig 6.20C-E: Reporting in Endo-oesophageal Brachytherapy (centred, concentric applicator)
Dose reporting for different Applicator Diameters (AD) 6, 10, 15 mm (C,D,E) and different prescription practice (at 10 mm from Source Axis; at Applicator Surface (AS) +5mm). The Depth of the Prescribed Dose (PD), of the Reference Dose (RD) and the AS are indicated, in addition AD and the radius of the applicators (r: 3, 5, 7.5 mm).

The Length of the Reference Volume (RVL) is defined as the length of the 90%-isodose at the reference depth of 5 mm. Independent of the varying individual dose prescription (C-E), for reporting the reference dose should always be given at the RD, which is 5 mm from the AS. Dose at the AS should also be reported (compare for details Fig 5.9 and 26.3-8).
Fig 6.20 Reporting Intraluminal Brachytherapy (continued 2)

Fig 6.20F: Prescription and reporting point are identical at 5 mm from the Applicator Surface.

Fig 6.20G: Prescription and reporting point are not identical: Prescription point is at 3 mm from the Applicator Surface (depth of the vaginal wall), Reference Point remains at 5 mm from the AS.

Fig 6.20H: Prescription different at the vaginal vault (at 10 mm from the AS) and along the vaginal wall (at 5 mm from the AS). Reporting at 5 mm for the vaginal wall and at 10 mm for the vaginal vault.

Fig 6.20F-H Reporting in Endovaginal Brachytherapy
Dose Reporting for a given Applicator Diameter (AD) for different prescription practice. Prescription Depth and Prescribed Dose (PD); Reference Depth (RD), Reference Volume Length (RVL), Active Source Length (ASL). Reference volume width (RVW) and thickness (RVT) are not in the diagram.
Fig 6.20 in summary shows in detail the essential parameters for reporting intraluminal brachytherapy with concentric source and applicator position. Typical situations for endovascular (Fig 19A) bronchial (Fig 19B) and oesophageal (Fig 19 C-E) as well as typical intravaginal applications are shown (Fig 19 F – H). For the oesophagus and the vagina differences in the prescribed depth are illustrated. For the oesophagus three difference applicator diameters are compared.

7.6 Recommendations for reporting intraluminal brachytherapy – Summary

<table>
<thead>
<tr>
<th>It is recommended reporting the following data in intraluminal brachytherapy (^{(a)}):</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Complete description of the clinical conditions (see section 2 and 7.3, p. 183)</td>
</tr>
<tr>
<td>* Description of the technique including the applicator dimensions (see section 3, p. 163)</td>
</tr>
<tr>
<td>* Full time-dose pattern (see section 5, p. 168)</td>
</tr>
<tr>
<td>* Treatment prescription (see section 1.1, p. 155)</td>
</tr>
<tr>
<td>* Specification of the sources (see section 4, p. 165)</td>
</tr>
<tr>
<td>* Dose specification at 3 different depths in the organs, within the patient :</td>
</tr>
<tr>
<td>► dose at the surface/mucosa (^{(b)})</td>
</tr>
<tr>
<td>► Minimum Target Dose (^{(b)})</td>
</tr>
<tr>
<td>► dose at reference depth from the surface (^{(b)})</td>
</tr>
<tr>
<td>* Dimensions of volumes :</td>
</tr>
<tr>
<td>► length (^{(c)})</td>
</tr>
<tr>
<td>► depth (^{(d)})</td>
</tr>
</tbody>
</table>

\(^{(a)}\) Levels for reporting endovascular brachytherapy

Although the different levels for reporting are not yet definitely established, the following criteria are recommended. Reporting at level 1 is based, in principle, on information derived from 2 radiographic projections. As a rule, reporting at level 2 should include all volumes, dimensions and doses reported at level 1, but for many of them, with a more accurate evaluation. In addition, information derived from CT, MRI and intravascular ultrasound sections should also be reported.

\(^{(b)}\) for non-centered catheters, the maximum and minimum values and mean values must be reported.

\(^{(c)}\) in particular, GTV, CTV, PTV, reference and Treated Volume, and relation to the active source length (see 6.3.1). In addition, for endovascular brachytherapy, lesion length, interventional length.

\(^{(d)}\) in the central plane and its variation along the lumen axis if significant.
8 Intracavitary Brachytherapy for Cervix Cancer: Definition of Concepts, Quantities, Doses and Volumes for Reporting

8.1 Introduction-The “historical systems”

Intracavitary brachytherapy for cervix carcinoma has been and is one of the most efficient radiotherapy techniques. This is due mainly to two factors. The anatomical conditions allow insertion of intrauterine and intravaginal sources in contact with the target volume. Secondly, because of the effects of the “inverse square law”, high doses are delivered to the target volume and the dose decreases rapidly with the distance to the source. This has two practical consequences: a benefit related to the protection of the organs at risk, but difficulty in treating lesions with extension (e.g., to the parametrium) with brachtherapy alone necessitating combination of brachtherapy with external beam therapy.

8.1.1 Milligram.hour

In the original Stockholm and Paris systems, the treatment was reported in terms of the amount of radium (in milligrams) and the duration of the application in hours (26,37,53,54,94,111). For example, in the Paris system, typically three intrauterine tubes (10 + 10 + 15 mg) and 2 vaginal tubes (15 + 15 mg) were used and the applications lasted for 6 days (Fig 6.21) (80).
Fig 6.21 (continued): sources is usually 16 mm, their linear activity being between 6 and 10 mg per cm, and their strength between 10 and 15 mg of radium. The total activity used is one of the lowest in use for such treatments and implies a typical duration of the application of 6 – 8 days. Typically, the ratio of the total activity of the vaginal sources to the total activity of the uterine sources should be 1 (with variations between 0.66 and 1.5). As far as the method of application is concerned, the historical Paris system does not imply any fixed distance between the vaginal sources, nor connection between vaginal and uterine sources (Pierquin [80]).

Fig 6.22: The Manchester system. Definition of points “A” and “B”. In the classical Manchester system, point A is defined as a point 2 cm lateral to the central canal of the uterus. Point B is defined as being in the transverse axis through points A, 5 cm from the midline. In clinical practice, dose calculations are often made from radiographs and point A is taken 2 cm up from the flange of the intrauterine source and 2 cm lateral from the central canal as indicated in the figure (Meredith, [64]). In a typical application, the loading of the intrauterine applicators is between 20 and 35 mg of radium and between 15 and 25 mg of radium for each vaginal ovoid. The resultant treatment time to get 8000 R at point A was 140 hours (from ICRU Report 38 (43)).

8.1.2 Dose at point A

The Manchester System introduced another approach (76,101). The dose was prescribed and reported at a selected reference point, “point A”, and a set of strict rules was imposed concerning the intrauterine/vaginal activity ratio and the size of the vaginal ovoids (Fig 6.22). Wide clinical experience has been accumulated with this system, and the clinical relevance of point A is recognized. Point A is still widely used worldwide (87). Reporting dose at point A is part of the reporting process recommended here.

8.1.3 The 60 Gy reference volume

In external beam therapy, because of the rather homogeneous dose in the central part of the PTV, selection of the “reference point for reporting” in the centre of the PTV seems obvious. This is not the case in intracavitary brachytherapy because of the steep dose gradient especially in the vicinity of the radioactive sources.

Therefore selection of a reference point for reporting in the vicinity of the source raises difficulties and another approach was recommended, in 1985, by the ICRU (43): instead of reporting the dose at a point, it was recommended that at an agreed dose level, the dimensions of the volume included in the corresponding isodose should be reported as the reference volume. The recommended dose level was 60 Gy. This “volume” approach which implies in principle that 3-D treatment planning is available, is recommended here as another part of the reporting process (27,87).

8.1.4 Dose rate and time-dose pattern

When radium only was available, due to its low specific activity, continuous low dose rate irradiation was used and few variations were possible (e.g., in fraction number). Modern equipment (see section 3, p. 163) makes it possible to use a broad range of time-dose patterns (e.g. HDR and PDR with different fractionation schedules, LDR with different dose rates). This raises a new type of difficulty when translating techniques, comparing results obtained with different time-dose patterns (see section 5, p. 168) and reporting volumes at stated dose levels such as the 60 Gy ICRU volume. This is one of the reasons why the 60 Gy volume was difficult to apply when using dose rates different from the conventional dose rate (0.5 Gy/hour) (29,30,32,68,87,108,109).
8.2 Dose distribution in brachytherapy (radiotherapy) for cervix cancer

Brachytherapy for cervix cancer is in fact a particular case of intraluminal brachytherapy. Due to the inverse square law, the dose decreases steeply as a function of the distance from the sources and this dose gradient is steepest close to the sources.

However, specifically for cervix treatment, combination of an intrauterine source and intravaginal sources results in (para)frontal “pear shape” isodose surfaces (volumes), used to extend dose distributions laterally and in (para)sagittal “banana shape” isodose surfaces (volumes), used to spare rectum and bladder in the AP direction (Fig 6.23). This “pear and banana shape” volume critically depends on the source arrangement.

Fig 6.23 Comparison of absorbed dose patterns of external and intracavitary therapy. Fig 23A shows the dose distribution for an irradiation of the pelvis with a 60Co teletherapy machine and four fields – the so called “box technique”. The border of the target area is indicated by the heavy dotted line (from ICRU Report 29, [42]). Fig 23B shows a typical dose distribution in an intracavitary application (from IAEA [40]), Fig 6.23C compares the resulting dose profile (from ICRU Report 38 [43]).
8.3 Reference points for reporting intracavitary brachytherapy

8.3.1 Reporting dose at point A

Definition of point A

Point A, as defined in this report, is specified relative to the applicator as visualised on orthogonal planar films. It is located in the oblique frontal plane (ICRU Report 38) containing the intrauterine source(s) and bisecting the vaginal sources. In that plane and from its intersection with the plane containing the vaginal sources, a point is taken, on the midline, cranially at a distance equal to the source-to vaginal mucosal distance (cranial contour of the vaginal sources) + 2 cm. The left and right A points are located in the oblique frontal plane, perpendicularly to the intrauterine source(s), at 2 cm laterally from the midline.

Fig 6.24 : Definition of point A for different applicators according to the definition as given in the text, A: ovoids/colpostats and intrauterine tube, B: ring and intrauterine tube, C: vaginal cylinder and intrauterine tube. In addition vaginal reference points are given at the level of the vaginal sources (modified from ABS recommendations).

Fig 6.24A: Manchester/Fletcher Ovoid Applicator

Fig 6.24B : Ring Applicator

Fig 6.24C : Cylindrical Applicator
**Rationale**

Point A and the related concepts were introduced in 1934-38 (76). Since then in many centres modifications have been introduced to the location of point A or to the concept of point A itself. The above definition of point A is recommended in this report taking into account recent developments in brachytherapy equipment and the diversity of methods of application. As can be seen from Fig 6.24 A-C, it permits an easy and unambiguous localisation of point A and can be used with different methods of application.

Although it is recognised that the steep dose gradient around the sources always makes the choice of any one point particularly difficult, the dose at point A is considered to be relevant for prescribing and reporting the intracavitary application in cervix treatment.

The doses at point(s) A, from the brachytherapy application must always be reported. The doses delivered to point(s) A by external beam therapy must also be reported. This recommendation is justified by the fact that point A has been used and is still used today for prescribing and reporting brachytherapy in a majority of centres world wide, providing a large amount of clinical information. Furthermore, many literature reports have shown that the dose at point A is related to outcome in terms of tumour control and side effects (29,83,87,108).

8.3.2 Reporting dose at reference points related to bony structures

Reporting dose at reference points related to well defined bony structures and lymph node areas is particularly useful when intracavitary brachytherapy is combined with external beam therapy, or followed by surgery.

8.3.3 Pelvic wall reference point

*Fig 6.25 : Determination of the right (RPW) and left (LPW) pelvic wall reference points (see text). (From Chassagne and Horiot [16]).*

The pelvic wall reference point, as proposed by Chassagne and Horiot (1977) (16), is intended to be representative of the absorbed dose at the distal part of the parametrium and at the obturator lymph nodes (Fig 6.25).

It can be visualised on AP and lateral radiographs and related to fixed bony structures. On a AP radiograph, the pelvic-wall reference point is located at the intersection of the following lines:
- A horizontal line tangential to the highest point of the acetabulum,
- A vertical line tangential to the inner aspect of the acetabulum.

On a lateral radiograph, the highest points of the right and left acetabulum, in the cranio-caudal direction, are joined and the lateral projection of the pelvic-wall reference point is located mid-way between these points.

The dose at the pelvic reference point should be reported. The pelvic-wall reference point is related to fixed bony structures, and not to the applicator as is point B.

### 8.3.4 Lymphatic trapezoid

![Fig 6.26: Determination of the lymphatic trapezoid. On the left is an anteroposterior view and on the right a lateral view (see text). (From Fletcher (25))](image)

Different points identified by means of the lymphatic trapezoid of Fletcher [25] are intended to be representative of the absorbed dose to the mid-external iliac-, low-common iliac- and low para-aortic lymph nodes.

The lymphatic trapezoid is obtained as follows (Fig 6.26):
- A line is drawn from the junction of S1-S2 to the top of the symphysis,
- Then a line is drawn from the middle of that line to the middle of the anterior aspect of L4,
- A trapezoid is constructed in a plane passing through the transverse line in the pelvic brim plane and the midpoint of the anterior aspect of the body of L4,
- A point 6 cm lateral to the midline at the inferior end of this figure is used to give an estimate of the dose rate to mid-external iliac lymph nodes (labelled R.EXT and L.EXT for right and left external respectively),
- At the top of the trapezoid, points 2 cm lateral to the midline at the level of L4 are used to estimate the dose to the low para-aortic areas (labelled R.PARA and L.PARA),
- The midpoint of a line connecting these 2 points is used to estimate the dose to the common iliac lymph nodes (labelled R.COM and L.COM).
8.4 Volumes for reporting and their dimensions

8.4.1 Treated Volume

8.4.1.1 Definition

The Treated Volume is the pear and banana shape volume that received (at least) the dose selected and specified by the radiation oncologist as being appropriate to achieve the purpose of the treatment, e.g., tumour eradication or palliation, within the limits of acceptable complications (Fig 6.27, 6.28) [43].

8.4.1.2 Recommendations for reporting

The 3 dimensions (Fig 6.27) of the Treated Volume should be reported separately as well as its actual volume. Reporting the product of the 3 orthogonal dimensions of the Treated Volume could be misleading and is not recommended.

The dose level selected to define the Treated Volume can be reported:

- as the prescribed dose, in absolute dose value (in Gy), and/or
- as a percentage of the dose delivered at reference points selected for prescribing and/or reporting.

Two additional volumes may be defined, related to the Treated Volume

8.4.1.3 High-dose volume

Recording and reporting the volume encompassed by the isodose corresponding to 150% (and 200%) of the dose defining the Treated Volume may be useful for interpretation of tumour effects, side effects and for purpose of comparison. However, this high-dose volume is probably less relevant than in interstitial therapy, since a large part of this volume lies within the applicator itself and the other part corresponds to radioresistant cervical and uterine tissue.

8.4.1.4 Irradiated volume

The irradiated volumes are the volumes, surrounding the Treated Volume, encompassed by a lower isodose to be specified, e.g., 90 – 50% of the dose defining the Treated Volume. Reporting irradiated volumes may be useful for interpretation of side effects outside the Treated Volume and for purpose of comparison.

8.4.2 Point A volume

8.4.2.1 Definition

The tissue volume (dimensions and actual volume) encompassed by the isodose level corresponding to the dose at point A is recommended for reporting in the present report: dimensions and actual volume (Fig 6.27, 6.28)

8.4.2.2 Recommendations for reporting

Dimensions should be reported as indicated in Fig 6.27.
The dose level at point A may - or may not - be equal to the dose level defining the Treated Volume, depending whether the radiation oncologist specifies that the dose at point A defines the Treated Volume (i.e., the dose necessary to achieve the goal of the treatment).

The dimensions of the point A volume describe the geometrical features of the pear and banana shape isodoses (long vs short, wide vs small, thick vs thin) depending on the source arrangement, for the same dose to point A and the same TRAK.

8.4.3 Reference volume

8.4.3.1 Definition

The reference volume is the volume encompassed by the reference isodose, selected and specified to compare treatments performed in different centres using different techniques. The dose selected to define the reference volume shall imply a consensus at an international level (or at least between the involved centres).

8.4.3.2 Rationale for the concept of reference volume

When comparing brachytherapy applications performed in different centres using different techniques, different volumes have to be compared: the Treated Volumes and the point A volumes (they have also to be correlated with the respective PTVs).

However, for a given application, Treated Volumes (or point A volumes) of different dimensions may be reported depending on the dose level selected to define these volumes. Inversely, applications reported as delivering the same (nominal) dose may actually be quite different if this dose corresponds to different volumes (24).

Therefore, for appropriate comparisons, a dose level must be chosen and agreed as “reference dose”. The volume encompassed by that dose is the “Reference Volume”. The selected reference dose may or may not be equal to the dose at point A, which may, in turn, be equal or not to the dose defining the Treated Volume.

8.4.3.3 Selection of the reference dose level

Firstly, as a sine qua non condition, selection of the reference dose level implies a consensus between centres: the goal for introducing the concept of the reference volume is indeed to allow centres to perform relevant comparisons.

Secondly, to be clinically relevant, the reference volume should be rather close to the Treated Volume and/or the „point A volume“.

In ICRU Report 38 (43), a reference dose level of 60 Gy is recommended. This dose is indeed appropriate for very early disease (e.g. stage IA) when brachytherapy alone is applied, or in stage I and proximal IIB, when brachytherapy is combined with radical surgery. In such situations, the dose defining the Treated Volume is close to 60 Gy (28).
Fig 6.27: Geometry for measurement of the dimensions of the pear-shape volume (Treated Volume, “point A” volume, reference volume) in a typical treatment of cervix carcinoma.

- Plane a is the “oblique frontal plane” that contains the intrauterine device. It is obtained by rotation of the frontal plane around a transverse axis.
- Plane b is the “oblique sagittal plane” that contains the intrauterine device. It is obtained by rotation of the sagittal plane around the AP axis. The height (dh) and the width (dw) of the pear-shape volume are measured in plane a as the maximal sizes parallel and perpendicular to the uterine applicator, respectively. The thickness (dt) of the pear-shape volume is measured in plane b as the maximal size perpendicular to the uterine applicator.

The dimensions dh, dw and dt refer to the brachytherapy application only (left part of the figure). When combination of brachytherapy and external beam therapy is taken into account (right part of the figure), these dimensions are symbolized by dH, dW and dT, respectively.

(modified from ICRU Report 38 (43)

In definitive treatment the total dose at point A and/or in the PTV2 (tumour extension at the time of brachytherapy) currently ranges between 75 and 90 Gy (and above). This includes limited disease (e.g. stage IB1, stage II B proximal) and the wide range of extensive disease (stage IB2 to II B/IVA). Therefore, one should consider selecting as reference volume, the volume encompassed by a higher dose level e.g. the 75 or 85 Gy isodose.

Selection of 60 Gy (definitive treatment for very early disease; combination treatment with surgery for limited disease) and 75/85 Gy (definitive treatment for limited and extensive disease) to define the reference volume does not imply that these doses are recommended as optimal therapeutic doses. It is only for purpose of comparison that the concept of reference volume was introduced in ICRU Report 38 and is recommended here again. (Fig 6.28).
Fig 6.28: Definitive cervix cancer brachytherapy (IB, IIB proximal, for details see 14.7-9). Reporting doses and volumes for five different clinical situations (tumour sizes) and treatment schedules. For cases (a), (b) and (c) brachytherapy is combined with external beam therapy. For cases (d) and (e), brachytherapy alone is applied (d) preop. BT (“IGR”); (e) BT alone (“Manchester”). The same brachy-therapy technique is assumed for all cases.

For cases (a), (b) and (c), the Treated Volume is defined by the 85 Gy isodose. For cases (d) and (e) the Treated Volume is defined by the 60 and 75 Gy isodoses, respectively.

For the five clinical cases, the GTVs are shown together with the 60-75-85-95 Gy isodose curves. On the lower part of the figure, the different isodoses are presented at a larger scale to illustrate the differences in the volume dimensions.
Fig 6.28 : continued.

<table>
<thead>
<tr>
<th></th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of the GTV</td>
<td>32 mm</td>
<td>38 mm</td>
<td>48 mm</td>
<td>26 mm</td>
<td>26 mm</td>
</tr>
<tr>
<td>85 Gy reference volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>width</td>
<td>58 mm</td>
<td>61 mm</td>
<td>67 mm</td>
<td>55 mm</td>
<td>58 mm</td>
</tr>
<tr>
<td>height</td>
<td>78 mm</td>
<td>82 mm</td>
<td>88 mm</td>
<td>80 mm</td>
<td>84 mm</td>
</tr>
<tr>
<td>volume (approx.)</td>
<td>80 cm³</td>
<td>106 cm³</td>
<td>148 cm³</td>
<td>59 cm³</td>
<td>87 cm³</td>
</tr>
<tr>
<td>60 Gy reference volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>width</td>
<td>68 mm</td>
<td>90 mm</td>
<td>100 mm</td>
<td>60 mm</td>
<td>66 mm</td>
</tr>
<tr>
<td>height</td>
<td>90 mm</td>
<td>110 mm</td>
<td>120 mm</td>
<td>88 mm</td>
<td>94 mm</td>
</tr>
<tr>
<td>Volume (approx.)</td>
<td>180 cm³</td>
<td>420 cm³</td>
<td>620 cm³</td>
<td>105 cm³</td>
<td>145 cm³</td>
</tr>
<tr>
<td>Total dose to point A</td>
<td>75 Gy</td>
<td>85 Gy</td>
<td>95 Gy</td>
<td>60 Gy</td>
<td>75 Gy</td>
</tr>
<tr>
<td>External beam dose to point A</td>
<td>25 Gy</td>
<td>45 Gy</td>
<td>45 Gy</td>
<td>0 Gy</td>
<td>0 Gy</td>
</tr>
</tbody>
</table>

In cases (a-c), the 85 Gy reference volume is equal to the Treated Volume. In case (b), the 85 Gy reference volume is also equal to the "point A" volume. In case (d), the 60 Gy reference volume is equal to the Treated Volume and to the "point A" volume. In case (e), the Treated Volume (75 Gy) is equal to the "point A" volume.

In addition, the reference volume is important when evaluating and comparing late side effects. Published data underline that the 60 Gy reference volume is relevant – in combination with ICRU reference points - for the prediction and reduction of late side effects (7).

8.4.3.4 Practical application of the reference volume concept

Brachytherapy alone

For comparing treatments with brachytherapy alone, physical doses have to be weighted to take into account possible differences in time-dose patterns as indicated in section 6.5. This radiobiological weighting influences the dimensions of the reference volumes. For example within the prospective Manchester trial on dose rate, a dose weighting factor of 15% was found: 75 Gy brachytherapy alone with radium (0.5 Gy/hour) could be replaced by 67.5 Gy with cesium-137 (1.4-1.8 Gy/hour) for the same Treated Volume with a comparable clinical result with regard to tumour control and side effects (38). A prospective randomised trial was performed at IGR comparing 0.4 and 0.8 Gy/hour: the increase in dose rate led to a significant increase in acute and late side effects (34).

Combination of brachytherapy and external beam therapy

The situation becomes more complicated when external beam therapy is combined with brachytherapy (12,22,33,59,107). Usually, external beam is used to treat a large PTV (PTV1: the whole pelvis) to 45-50 Gy. In the second phase of the treatment, brachytherapy is used to treat a smaller PTV which requires a higher dose (PTV2: usually the volume closely related to the GTV). To compare the brachytherapy applications the dose which has been delivered by external beam therapy must first be subtracted from the total dose. The weighting for differences in time-dose pattern must then be applied, as discussed above, before treatments can be appropriately compared.

For example, for a large tumour if 85 Gy seems to be appropriate to define the reference volume, and a dose of 45 Gy is delivered to the whole pelvis by external beam therapy, the dose level for definition of the reference volume for the brachytherapy application is: 85 Gy – 45 Gy = 40 Gy.

However, for a given dose, the biological effects produced by external beam and brachytherapy, may be different due to the differences in time-dose pattern and in dose–volume distribution.
The dose rate of the brachytherapy application may be different from the conventional low dose rate (0.5 Gy/hour): e.g. 1.5 Gy/hour (LDR), 20-30 Gy/hour (HDR). The dose level selected to define the reference volume is the dose which is considered to be “equivalent” to or “isoeffective” with the dose delivered at the conventional low dose rate, in the same clinical condition (Fig 6.28).

A biological weighting factor, $W_{\text{rate}}$, thus has to be applied to compensate/normalize for differences in dose rate. The difficult radiobiological problem raised by the selection of this weighting factor is discussed in Chapter 4. The value of $W_{\text{rate}}$ actually applied should always be based on widely accepted models and clearly reported. It should be kept in mind that the biological weighting factor $W_{\text{rate}}$ is valid only for a given tissue, effect and dose/dose rate.

Following the same example as above, if 85 Gy is considered appropriate to define the reference volume for conventional low dose rate, and if 45 Gy external beam therapy has been delivered, a dose of $85 - 45 = 40$ Gy defines the reference volume at LDR brachytherapy. For HDR brachytherapy, 4 fractions of 7 Gy are considered to correspond to 40 Gy LDR brachytherapy according to biological models and clinical experience (79,88). The reference volume is thus defined as the volume encompassed by the 4 x 7 Gy isodose (assuming, $\alpha/\beta = 10$ for the effects on the tumour, see chapter 4). The three orthogonal dimensions and the volume of that reference volume (7 Gy x 4) must be reported as recommended above, and can be compared with the dimensions of other brachytherapy applications performed with HDR, MDR, or LDR (88). An analogue procedure must be followed when using the 60 Gy reference volume.

NB : Additional recommendations for reporting the 3 dimensions of the volumes

(1) As an additional recommendation, the width ($d_{\text{inh}}$) and the thickness ($t_{\text{inh}}$) of the volumes measured in the planes passing through Point A may also be reported. Indeed these dimensions are closely related to the GTV/PTV2.

(2) The right and left dimensions of the width and the anterior and posterior dimensions of the thickness of the volumes should be reported separately if they differ significantly with regard to the intrauterine source (e.g., if different loadings of vaginal sources are used).

(3) The 3 orthogonal dimensions of the volumes should be reported individually and not their product. Firstly, for cervix carcinoma, because of the „pear shape”, the actual computed volumes are much smaller (about 50%) compared with the product of their 3 dimensions. Secondly, the lateral and AP-PA dimensions are clinically meaningful for tumour control with regard to parametrial extension and complications, respectively.

8.4.4 Volume approach based on 3-D imaging and computer assisted 3-D dose calculation

Development of 3-D image based treatment planning in brachytherapy has significantly improved the 3 D assessment of dose-volume relations. Dose distribution can now be evaluated in different volumes such as the GTV, CTV and PTV (24,27,29,89,95,97,104,105). Dose-volume histograms can be derived and analysed but the methods for deriving the relevant information still need to be defined and no agreement has been reached so far (compare Fig 5.15,14.14,16.7,17.10).

In order to link the information gained so far from extensive clinical experience before these new tools were available, correlations of coverage of GTV and PTV with doses at point A and with reference volumes, such as 60, 75, and 85 Gy volumes should be analysed (24).
8.5 Organs At Risk (OAR): Reference points and volumes

8.5.1 Definition

In brachytherapy for uterine carcinoma, the most relevant organs at risk are the rectum, the sigmoid, the bladder, the bowel and the vagina (section 2.6).

8.5.2 ICRU bladder and rectum reference points

At the time of publication of ICRU Report 38 (43), an estimation of the dose to “organs at risk” could only be derived from standard orthogonal radiographs of the application. Therefore, reference points were defined in relation to the sources as seen on radiographs (16).

8.5.2.1 Bladder reference point

It is related to a Foley balloon in the trigone of the bladder. The balloon is filled with 7 cm$^3$ of radio-opaque fluid. The catheter is pulled downwards to bring the balloon against the urethra (Fig 6.29).

On the lateral radiograph, the bladder reference point is obtained on an AP line drawn through the centre of the balloon. The reference point is taken on this line at the posterior surface of the balloon.

On the AP radiograph, the reference point is taken at the centre of the balloon.

Fig 6.29 : Determination of the reference points for bladder and rectum as proposed by Chassagne and Horiot [16].
8.5.2.2 Rectum reference point

The reference point for the rectal dose is related to the applicator and located 5 mm behind the posterior vagina wall on an AP line drawn from the middle of the vaginal sources (Fig 6.29).

On the lateral radiograph, an anterior-posterior line is drawn from the lower end of the intrauterine source (or from the middle of the intravaginal sources). The point is located on this line, 5 mm behind the posterior vaginal wall (not in the contrast filling tube). The posterior vaginal wall is visualised, depending upon the technique, by means of an intravaginal mould or by opacification of the vaginal cavity with radio-opaque gauze used for packing.

On the frontal radiograph, this reference point is taken at the intersection of (the lower end of) the intrauterine source through the plane of the vaginal sources.

8.5.3 Clinical significance of the bladder and rectum reference points

The clinical significance of the bladder and rectum reference points has been questioned and is still a matter for debate (7,28,39,51,57,67,97,99,100).

A significant number of observations support a correlation between rectal complications and the dose to the rectum reference point (19,77,93,104). In contrast, the bladder reference point was found to be reproducible, but does not correlate well with bladder complications.

All investigators found that the actual maximum dose to the bladder was, in most cases, significantly higher than the dose at the ICRU reference points, usually located more cranially. Indeed, some centres calculate the dose 1.5 - 2 cm cranial (Point ALG) relative to the ICRU Reference Point (8,27).

However, because of variation in individual anatomical conditions, extent of disease, applicator design and technique, it has not been possible so far to agree on new reference points to replace the points recommended in ICRU Report 38 (43).

Different vaginal reference points are used in different traditions, e.g. at 5 mm lateral from the surface of the ovoids at the level of the vaginal sources (see Fig 6.24C) or at the vaginal surface (25). No international agreement has been reached on a definitive vaginal reference point.

8.5.4 Volume approach to evaluate doses in Organs At Risk

The development of 3-D image based treatment planning has significantly changed the situation. Dose distribution can now be evaluated in different volumes such as the GTV, CTV, PTV, Treated Volume and Organs at Risk, such as bladder, rectum, sigmoid, bowel (24,27,29,89,95,97,104). Dose-volume histograms can be derived and analysed but there are not yet any generally agreed methods (see Chapter 14).

In the present situation, following values are recommended for reporting doses to the Organs at Risk:

1°) The maximum bladder and rectum doses. The maximum dose to consider is the dose received in a volume of at least 2 and 5 cm³;

2°) The volume of the Organ At Risk that receives a dose close to or higher than the dose considered to be significant in relation to tolerance. Because of lack of definitive data, volumes corresponding to dose levels of 60-90 Gy should be considered. The volumes should be reported in cm³ (absolute values) and as a percentage of the organ volume.
The methods used to determine the volumes and the doses should always be reported. If in vivo measurements were performed, the technique and results should also be reported.

### 8.6 Quantities, reference points and volumes recommended for reporting intracavitary therapy for cervix carcinoma: Summary

Following data are recommended for reporting intracavitary therapy for cervix carcinoma.

- **8.6.1 Description as complete as possible of the clinical conditions (see section 2, p. 158)** (a)
- **8.6.2 Complete description of the technique (see section 3, p. 163)** (a)
- **8.6.3 Complete description of the time-dose pattern (see section 5, p. 168)** (a)
- **8.6.4 Treatment prescription (see section 1.1, p. 155)** (a)
- **8.6.5 Total Reference Air Kerma (TRAK) (see section 4, p. 165)** (b)
- **8.6.6 Dose at reference points: Point A and reference points related to bony structures (see sections 8.3.1-4)** (c)
- **6.7 Volumes for reporting and their dimensions: Treated Volume, “point A volume”, reference volume (see sections 8.4.1-3)** (d)
- **6.8 Dose to Organs at Risk: bladder, rectum (see section 8.5, p. 206)** (e)(f)

**NB:** Reporting at level 2 (3) shall always include all data that are recommended at level 1

(a) The clinical conditions, treatment technique, time-dose pattern, treatment prescription should be described as completely as possible when reporting at level 1, completely at level 2.

(b) The TRAK should be, and can be reported at level 1.

(c) The dose at Point(s) A should be reported at level 1 (see definition in section 8.3.1). When a fixed, fully rigid applicator is used, determination of absorbed dose to point A is straightforward and can usually be derived from pre-calculated sets of tables/isodose charts, as point A is defined in relation to the sources/applicator. The same is true also when semi-rigid or semi-fixed applicators are used for which only a limited number of source geometries are possible.

For applicators where the positions of the sources, relative to each other are not fixed, calculation of dose to point A is possible based on reconstruction from orthogonal or quasi orthogonal radiographs.

Doses at other anatomical reference points can also be evaluated and reported at level 1 based on the evaluation of the orthogonal radiographs: pelvic wall reference point(s) and lymphatic trapezoid (see section 8.3.3 and 8.3.4). However, the procedures take time and may be difficult to establish when only level 1 reporting is possible. Doses for all anatomical reference points mentioned above should be reported at level 2.

(d) Reporting the dimensions of the Treated Volume, the Point A Volume and the Reference Volumes (e.g. 60, 75, 85 Gy volumes) is typically part of reporting at level 2. However, at level 1 it is possible to report the 3 dimensions based on standard dose distributions, e.g. from an atlas or a computer “library”.
When reporting at level 2/3, a series of CT and/or MRI sections are available as well as a 3-D dose distribution and DVHs can be derived. The dose distribution for the GTV and the PTV can then be derived. Dose volume analysis should be done for doses used in traditional reporting, e.g. 60, 75, 85 Gy. The dose distribution based on a point A prescription can also be analysed with regard to coverage of GTV and PTV.

(e) The doses to the bladder and rectum ICRU reference points should be reported when reporting at level 1 (section 8.5.2-3). They can be evaluated from orthogonal radiographs, as defined in ICRU 38 (43). However, this evaluation takes time and is not always possible due to the local conditions.

When reporting at level 2, a series of CT and/or MRI sections are available as well as a 3-D dose distribution. DVHs can then be derived. The maximum bladder and rectal dose in a certain volume (2 and 5 cm³) should be reported as indicated in section 8.5.4. In addition, at level 2, the volume of the organ at risk receiving a dose close to or higher than the dose considered to be significant in relation to tolerance should also be reported (e.g. 60/70/80 Gy).

(f) If in vivo measurements were performed, the method and the results should be reported.
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