Editors' pick

A multi-criteria optimisation approach for HDR prostate brachytherapy:

II. Benchmark against clinical plans

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What was your motivation for initiating this study?

Computerised treatment-planning systems are used to formulate clinical prescriptions into mathematical optimisation problems, and to create treatment plans that fit these prescriptions to the treatment facilities that are available.

However, most available algorithms are not inherently patient-specific and usually the treatment plans must be manually altered to draw up clinically acceptable plans for each patient. As a result, the planning procedure can be time-consuming and the result is planner-dependent [1-3].

The main motivation for this study was to improve the efficiency of planning in high-dose-rate (HDR) prostate brachytherapy. We developed a multi-criteria optimisation (MCO) algorithm from an existing commercial algorithm (inverse planning simulated annealing [4]), and compared the planning times and the quality of the plans produced through use of the MCO algorithm with the same factors when clinical plans were produced in the normal way.

What were the main challenges during the work?

Manual re-planning is a major obstacle to the improvement of planning efficiency in the traditional planning process. Several challenges had to be overcome to remove this obstacle. The first was to understand the different automated planning approaches that were described in the literature and choose the one that was best suited to this study. We chose the proposed MCO approach because (1) it mimicked the manual planning process, (2) it generated automatically a high-quality plan dataset around a population-based planning template, and (3) it enabled the selection of plans from the plan dataset that were acceptable according to the standards of the Radiation Therapy Oncology Group (RTOG).

After the MCO algorithm had been implemented, the main challenge was to improve the speed at which the algorithm worked to make it useful in a clinical setting.

When the dosimetric results of MCO plans and clinical plans were compared, the challenge was to find comprehensive criteria that took account of both the tumour coverage and the sparing of organs at risk.

What were the most important findings of your study?

The computing efficiency of an MCO algorithm can be improved by (1) narrowing the whole solution space to the one that is clinically relevant through use of dosimetric regression models, and (2) using computing techniques that involve parallel working of the computer processing unit.

As a result, compared with the traditional planning method that is used in HDR prostate brachytherapy, plans were obtained that showed improved acceptance according to RTOG and RTOG+ standards (the target V100 threshold was increased to 95% from 90%) and planning time was reduced.

What are the implications of this research?

Given the results of this study and a companion study [5], we decided to conduct follow-up studies [6-7]. As a result, we successfully implemented a novel, real-time MCO algorithm that was based on a graphics processing unit [6] and that was fast enough to generate thousands of Pareto-optimal plans in seconds. We also proposed a user-friendly navigation tool [7] in HDR prostate brachytherapy.

We hope these findings can cause more attention to be paid to the investigation of MCO algorithms as the next generation of inverse planning approaches.

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References:

1. K. Moore et al. Experience-based quality control of clinical intensity-modulated radiotherapy planning. International Journal of Radiation Oncology*Biology*Physics, 81(2):545 - 551, 2011.
2. B.E. Nelms et al. Variation in external beam treatment plan quality: An inter-institutional study of planners and planning systems. Practical Radiation Oncology, 2(4):296 – 305, 2012.
3. B. Wu et al. Patient geometry-driven information retrieval for IMRT treatment plan quality control. Medical Physics, 36(12):5497–5505, 2009.
4. E. Lessard and J. Pouliot. Inverse planning anatomy-based dose optimization for HDR- brachytherapy of the prostate using fast simulated annealing algorithm and dedicated objective function. Medical Physics, 28(5):773–779, 2001.
5. S. Cui et al. A multi-criteria optimization approach for HDR prostate brachytherapy: I. Pareto surface approximation. Physics in Medicine & Biology, 63(20): 205004, 2018.
6. C. Bélanger et al. A GPU-based multi-criteria optimization algorithm for HDR brachytherapy. Physics in Medicine & Biology, 64(10): 105005, 2019.
7. C. Bélanger et al. Evaluating the impact of real-time multicriteria optimizers integrated with interactive plan navigation tools for HDR brachytherapy. Brachytherapy, 19(5):607–617, 2020.