Fast automated multi-criteria planning for HDR brachytherapy explored for prostate cancer

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Introduction
We developed an automated multi-criteria treatment planning workflow for high dose rate (HDR) brachytherapy, compatible with our clinical treatment planning system (TPS). The aim is to establish planner-independent, enhanced plan quality and short optimisation times, allowing daily online plan generation.

Workflow
- Export CT + contours + dwell positions from Oncentra Brachy TPS
- Export dwell times to Oncentra TPS
- Forward dose computation, obtain DVHs and evaluate plan
- Do for 22 patients

Background and protocol
The test cohort consisted of 22 planning CTs with catheter reconstructions and delineations for low-intermediate risk prostate cancer patients who were previously treated with 4 × 9.5 Gy HDR brachytherapy. Data of 5 patients was used to configure the autoplanning system, Erasmus-iCycle².

The fixed configuration was then used to also automatically generate treatment plans for the other 17 patients. Automatically generated plans were compared to the corresponding clinical plans. All evaluations were performed in the clinical TPS. Clinically applied hard constraints were used for automated planning: Diel, < 80% of the prescribed dose (PD) for rectum and bladder, and D95% < 120% of PD for the urethra. The objectives in order of priority were to 1) prostate V100% = 95%, 2) minimise urethra D3%, 3) improve conformity.

The dwell times for the autoplans are then exported to Oncentra, and the dose is recomputed for evaluation. For comparison, both the clinical and automated plans were rescaled to exactly match 95% coverage, unless one of the other constraints were met first.

Convex problem solving
The automated planning configuration was embedded in our non-linear convex optimisation framework², which has the advantage of fast convergence to a globally optimal solution. Hereto, the dose-volume constraints (Diel, < 80%) on the rectum and bladder were reformulated to a convex approximation, using the LTCP³ cost-function with parameters 30.6 Gy and cell sensitivity of -0.6.

For the objectives, the urethra D3% was optimised by stepwise reducing the urethra maximum dose, followed by maximising the prostate coverage. When the coverage reached 95%, the urethra maximum and prostate coverage are kept as a constraint, followed by a minimisation of the dose at 7 mm distance of the prostate to improve conformity.

Result: Urethra D3% dose reduction

Results
Automated plan optimisation took on average 9.8 seconds (range: 2.7 – 21.6 seconds), including computation of the dose kernels. Computations were performed on an Intel Core i7-7700.

The autoplans of 21/22 patients showed 95% tumour coverage within the imposed hard constraints. Coverage of patient 4 was lower than desired (94.8%), though slightly higher than in the clinical plan (94.5%), both due to the urethra constraint. For 21/22 patients the autoplan showed a reduction in the most important OAR objective, urethra D3% (see figure above). The absolute mean and maximum reductions were 1.8 Gy and 4.1 Gy, respectively.

References