Robustness recipe for minimax robust optimisation in IMPT for oropharyngeal cancer patients

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DOI
10.1016/S0167-8140(16)31804-7

Publication date
2016

Document Version
Final published version

Published in
Radiotherapy & Oncology

Table I. Estimated Relative Risks, model parameters and input distributions

	Bladder	Rectum	CI
RR (VMAT/C-ion)	1.31 (0.65, 2.18)	0.58 (0.41, 0.80)	95%
RR (VMAT/IMPT)	1.73 (1.07, 2.39)	1.11 (0.79, 1.45)	95%
α (Gy^{-1})	0.25 (σ=0.075)	0.25 (σ=0.075)	Gaussian
B (Gy^{-2})	0.033 (σ=0.0055)	0.046 (σ=0.0077)	Gaussian
RBE_{min} (C-ion)	1.25 (1.2, 1.3)	1.25 (1.2, 1.3)	triangle
RBE_{max} (C-ion)	6 (5, 7)	6 (5, 7)	triangle
RBE_{min} (proton)	1.03 (1.01, 1.05)	1.03 (1.01, 1.05)	triangle
RBE_{max} (proton)	1.25 (1.2, 1.3)	1.25 (1.2, 1.3)	triangle

Conclusion: Based on the modest variations in RR across the large spread in parameter values, the treatment modalities are not expected to have very different SC risk profiles with respect to these organs. The α value had the strongest influence on the RR and may change the RR in favour of one technique instead of another (particle vs photons).

OC-0554

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Purpose or Objective: Treatment plans for intensity-modulated proton therapy (IMPT) can be robustly optimized by performing 'minimax' worst-case optimization, in which a limited number of error scenarios is included in the optimization. However, it is currently unknown which error scenarios should be included for given population-based distributions of setup errors and range errors. The aim of this study is to derive a 'robustness recipe' describing the setup robustness (SR; in mm) and range robustness (RR; in %) settings (i.e. the absolute error values of the included scenarios) that should be applied in minimax robust IMPT optimization to ensure adequate CTV coverage in oropharyngeal cancer patients, for given Gaussian distributions of systematic and random setup errors and range errors (characterized by standard deviations Σ, σ and ρ, respectively).

Material and Methods: In this study contoured CT scans of 6 unilateral and 6 bilateral oropharyngeal cancer patients were used. Robustness recipes were obtained by: 1) generating treatment plans with varying robustness settings SR and RR, 2) performing comprehensive robustness analyses for these plans using different combinations of systematic and random setup errors and range errors (i.e. different values of Σ, σ and ρ), and 3) determining the maximum errors for which certain SR and RR settings still resulted in adequate CTV coverage. IMPT plans were considered adequately robust if at least 98% CTV coverage (V95%≥ 98%) was achieved in 98% of the simulated fractionated treatments. Robustness analyses were performed using Polynomial Chaos methods, which allow for fast and accurate simulation of the expected dose in fractionated IMPT treatments for given error distributions. Separate recipes were derived for the unilateral and bilateral cases using one patient from each group. The robustness recipes were validated using all 12 patients, in which 2 plans were generated for each patient corresponding to Σ = σ = 1.5 mm and ρ = 0% and 2%.

Results: The robustness recipes are depicted in Figure 1. We found that 1) systematic setup errors require larger SR than random setup errors, 2) bilateral cases are intrinsically more robust than unilateral cases, 3) the required RR only depends on ρ, and 4) the required SR can be fitted by second order polynomials in Σ and σ. The formulas for the robustness recipes are: $SR = -0.15\Sigma^2 + 0.27\sigma^2 + 1.85\Sigma - 0.06\sigma + 1.22$ and RR = 3% for ρ = 1% and 2% for unilateral cases, and $SR = -0.07\Sigma^2 + 0.19\sigma^2 + 1.34\Sigma - 0.07\sigma + 1.17$ and RR = 3% and 4% for ρ = 1% and 2%, respectively, for bilateral cases. The recipe validation resulted in 22 plans being adequately robust, while for the remaining two plans CTV coverage was adequate in 97.8% and 97.9% of the simulated fractionated treatments.

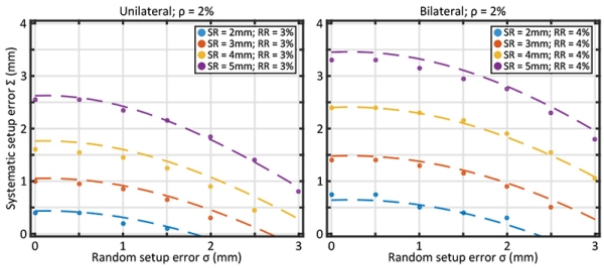

Figure 1. Combinations of systematic (Σ) and random (σ) setup errors that give adequate CTV coverage (V95% ≥ 98%) for 98% of the simulated fractionated treatments for a range error (ρ) of 2% for a unilateral and bilateral patient. In each plot different SR and RR settings are shown. The solid round markers show the obtained data, the dashed lines are a quadratic fit.

Conclusion: Robustness recipes were derived that can be used in minimax robust optimization of IMPT treatment plans to ensure adequate CTV coverage for oropharyngeal cancer patients.

Proffered Papers: RTT 6: Advanced radiation techniques in prostate cancer

OC-0555

Organ at risk dose parameters increased by daily anatomic changes in prostate cancer SBRT

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Purpose or Objective: Stereotactic body radiotherapy (SBRT) is increasingly used to treat low and intermediate stage prostate cancer (PC). In our institution, SBRT is delivered in 4-5 fractions of high dose using the CyberKnife system with marker-based tracking. Tracking accurately aligns the treatment beams to the prostate just prior and during the treatment fraction. However, surrounding organs at risks (OARs) may move relative to the prostate, causing the OAR dose to deviate from what was planned. The aim of this work is to quantify the daily dose to OARs in SBRT for PC, and compare it to the planned dose.

Material and Methods: For 9 patients, four to five repeat CT scans were acquired prior to each daily SBRT fraction and were analyzed. The bladder, rectum, anus, and urethra were contoured in the planning and repeat CTs. The urethra was divided in three parts: the cranial and the caudal part of the urethra prostatica (UP) and the membranous urethra (MU, 2 cm caudal to the prostate). The repeat CTs were aligned to the planning CT based on the four implanted markers. Subsequently, the planned dose distribution was projected on the aligned repeat CTs. For each patient, dose-volume parameters of the OARs were recorded, averaged over the 4-5 repeat CTs and compared to planning.

Results: The greatest deviation between the delivered and planned dose was seen for the MU. The planned mean dose of 24.0 Gy was exceeded in the repeat CTs by on average 59±17% (1 SD) and the D5% was increased by 7±3%, from 38.7 to 41.6 Gy (Fig. 1a). For the mean dose of the caudal and cranial UP the deviation from planning was limited: 1±1% and 5±5% respectively. The planned mean and V1cc (dose allowed to 1cc of the organ) rectum dose, 10.9 and 32.8 Gy respectively, was on average 5±5% and 12±11% higher in the repeat CTs (Fig. 1b). The mean dose of the anus increased as well, with 15±24% from 8.7 to 9.8 Gy. The planned V1cc bladder dose (40.2 Gy) was reproducible in the repeat CTs