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Effectiveness of Rectal Spacers in Reducing Normal Tissue Complication Probability (NTCP) in Prostate Cancer Radiotherapy

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ABSTRACT

Purpose: To evaluate the effectiveness of SpaceOAR in sparing the rectum by calculating the normal tissue complication probability (NTCP) from radiotherapy treatment plans for prostate cancer patients treated with and without a spacer.

Methods: Dose-Volume Histograms (DVHs) of 224 previous prostate cancer treatment plans were anonymized, exported, and analyzed using a Python script to calculate bladder and rectum NTCP values using a linear quadratic model. Three dose fractionation schemes were analyzed: 40 Gy in 5 fractions (SBRT), 70 Gy in 28 fractions (IMRT), and 81 Gy in 45 fractions (IMRT). For each fractionation scheme, NTCPS with and without a spacer were compared using a t-test to assess statistical significance. Additional t-tests were performed between each pair of fractionation schemes to determine whether observed differences were dose-dependent or attributable solely to the presence of a spacer.

Results: SpaceOAR reduced rectal NTCPs across all investigated dose fractionation schemes. Calculated p-values demonstrated a statistically significant difference in rectal NTCP for the 40 Gy, 70 Gy, and 81 Gy plans (Spacer mean=1.83%, 2.10%, 3.37%; No spacer mean= 6.01%, 5.98%, 9.46%; p=0.0031, 0.0005, 0.0015; α=0.05). No statistically significant difference was seen in bladder NTCP values with all averages being ~0% (p=0.523, 0.659, and 0.313). When comparing the values across differing dose levels with a spacer in place, no significant correlation was found (p=0.578 for 40 vs. 70 Gy, p = 0.191 for 40 vs. 81 Gy, and p = 0.280 for 70 vs. 81 Gy).

Conclusion: The collected data suggests implementation of SpaceOAR results in a significant reduction in rectal NTCP. This effect remains consistent across varying dose fractionation schemes analyzed and across a large patient pool (N = 224). These findings indicate that SpaceOAR is a valuable tool for reducing normal tissue complications in the rectum for prostate radiotherapy.

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PURPOSE

The purpose of this project was to evaluate the effectiveness of SpaceOAR in sparing the rectum by calculating the normal tissue complication probability (NTCP) from radiotherapy treatment plans for prostate cancer patients treated with and without a spacer, then performing a statistical evaluation to assess any differences.

METHODS AND MATERIALS

- Dose-Volume Histograms (DVHs) of 224 previous prostate cancer treatment plans were anonymized, exported, and analyzed using a Python script to calculate bladder and rectum NTCP values using a linear quadratic model.
- Three dose fractionation schemes were analyzed:
  - 40 Gy in 5 fractions (SBRT)
  - 70 Gy in 28 fractions (IMRT)
  - 81 Gy in 45 fractions (IMRT)
- For each fractionation scheme, bladder and rectum NTCPs with and without a spacer were compared using a t-test to assess statistical significance.
- Additional t-tests were performed between each pair of fractionation schemes to determine whether observed differences were dose-dependent or attributable solely to the presence of a spacer.

DISCUSSION

- The large sample size (224 total plans evaluated) can give high confidence that spacer implementation is reducing NTCP in the rectum on average.
- Both models used yielded statistically significant reductions in rectum NTCP (Table 2).
  - Model LQPoissonK (reported in abstract) predicted for more complications including necrosis, stenosis, and fistula formation.
  - From the data, spacers appear to reduce NTCP by about 50%-66% (Table 1).
  - Notably, for the SBRT cases, NTCP is a valuable metric compared to v70 since maximum dose does not exceed 40 Gy.
- Calculated NTCPs can support other metrics often used to assess rectal toxicity like rectal v70 and clinical quality of life (QoL) evaluations.
- Figure 1 demonstrates a case where a spacer patient has lower maximum dose compared to a patient with no spacer. The spacer patient has a maximum dose of about 37 Gy which confers with lower NTCP. The patient with no spacer has a maximum dose of 42 Gy which confers with higher NTCP.

RESULTS

- SpaceOAR reduced rectal NTCPs across all investigated dose fractionation schemes.
- Calculated p-values demonstrated a statistically significant difference in rectal NTCP:
  - 40 Gy (Spacer mean=1.83%, No spacer mean= 6.01%)
  - 70 Gy (Spacer mean=2.10%, No spacer mean=5.98%)
  - 81Gy plans (Spacer mean=3.37%, No spacer mean=9.46%)
- No statistically significant difference was seen in bladder NTCP values with all averages being ~0% .
- When comparing the values across differing dose levels with a spacer in place, no significant correlation was found.

CONCLUSIONS

- The data suggests that SpaceOAR use results in a significant reduction in rectal NTCP.
- This effect remains consistent across varying dose fractionation schemes analyzed and across a large patient pool (N = 224).
- These findings indicate that SpaceOAR is a valuable tool for reducing normal tissue complications in the rectum for prostate radiotherapy.
- Further study may involve evaluation of Tumor Control Probability (TCP).

Figure 1: Isodose distributions for a no spacer patient (1a) and a spacer patient (2a); DVH with rectum in blue for no spacer (1b) and spacer (2b). Rectum and PTV DVH are given by the dark blue and turquoise lines respectively.

Rectum NTCP				
Treatment Plan Type	Mean Spacer (LQPoissonK)	Mean Spacer (LQPoissonS)	Mean No Spacer (LQPoissonK)	Mean No Spacer (LQPoissonS)
40 Gy SBRT 5 fx	1.83% (SD=2.87%)	3.84% (SD=3.47%)	6.01% (SD=5.27%)	8.47% (SD=3.75%)
70 Gy IMRT 28 fx	2.1% (SD=2.89%)	3.48% (SD=2.61%)	5.98% (SD=5.01%)	6.8% (SD=3.71%)
81 Gy IMRT 45 fx	3.37% (SD=3.35%)	3.62% (SD=2.64%)	9.46% (SD=4.89%)	7.6% (SD=2.81%)

Table 1: Mean NTCP and standard deviation values in rectum.

Spacer vs. No Spacer T-Test (α=0.05)		
Treatment Plan Type	P-value (LQPoissonK)	P-value (LQPoissonS)
40 Gy SBRT 5 fx	0.003128923	4.2235E-05
70 Gy IMRT 28 fx	0.000517856	0.000113032
81 Gy IMRT 45 fx	0.001519049	0.00200456

Table 2: P-values of Spacer vs. No spacer groups in each fractionation scheme

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