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Radiobiological Influence of Mixed Photon Energies for Prostate Cancer through Tumour Control Probability and Normal Tissue Complication Probability

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INTRODUCTION

Currently, Volumetric Modulated Arc Therapy (VMAT) is performed mostly with a single energy photon beam. A few studies demonstrated benefits of using mixed energy photon beams for VMAT [1-2] and IMRT [3] compared to conventional single energy VMAT. However, all previous studies on mixed energy VMAT considered only physical dose distribution and the dose volume histogram for the evaluations. Additional radio-biological evaluation tools, namely tumor control probability (TCP) and normal tissue complication probability (NTCP) can provide an estimate of radiobiological efficacy of each method, which, in turn, can be useful for evaluating the biological impact of each technique on various tissues. ICRU 83 also acknowledges that the use of concepts such as TCP, NTCP or EUD might be added to level 2 reporting in the future.

AIM

The purpose of this work was to determine the radiobiological efficacy of mixed photon energy beams vs. single photon energy through tumor control probability (TCP) and normal tissue complication probability (NTCP).

METHOD

For 15 prostate cancer cases treated with a dose of 79.2Gy in 44 fractions, three VMAT plans (6MV, 15MV, and 6&15MV) were generated using the same optimization parameters and priority weighting.

The single energy plans involved 6MV partial-arcs and a 15MV partial-arcs, while the mixed energy plan involved a hybrid of 6MV partial arcs in anterior-posterior direction and 15MV partial-arcs from the lateral directions.

The Lymann Kutcher Burman parameters, representing Grade≥2 rectal bleeding, were chosen from literature: m=0.14; n=0.24; D_{50}=75.7. For urinary urgency, the LKB parameters included m=0.5; n=1.0; D_{50}=64.2.

The TCP parameters were a=-10, TCD_{50}=28.34 and γ_{50}=1. A paired two-sided student's t-test was used, with P<0.05 as statistically significant.

RESULTS

- For prostate disease control, the average TCP of mixed energy plan was comparable to 6MV (98.8%&98.7%; P=0.45) and 15MV (98.8%&98.7%; P=0.17).
- Both mixed and single energy plans generated comparable NTCP for the femoral heads.
- In comparison to mixed energy, 6MV and 15MV resulted in a higher average EUD to rectum (48.56Gy&51.78Gy; P=0.001 and 48.56Gy&52Gy; P=0.001), and mixed energy produced lower NTCP (0.8%&1.9%; P=0.001 and 0.8%&1.8%; P=0.002) respectively.
- The EUD to bladder was higher in 6MV (17.44Gy; P=0.0003) and 15MV (17.41Gy; P=0.0002) plans compared to the mixed energies and the mixed energy technique reduced NTCP by 1% relative to 6MV (7.86% P=0.0014) and 15MV (7.84%; P=0.0017).
- Figure 1 shows the equivalent uniform dose (EUD) and Normal Tissue Control Probability (NTCP) comparison between 6 MV, 15 MV and both 6 & 15 MV mixed beams for rectum and bladder for 15 prostate cancer cases.
- The mix energy technique demonstrates a reduced EUD and NTCP for rectum for 13 out of 15 prostate cases compared to 6MV alone and 15MV alone VMAT plans.
- Using both 6 & 15 MV beams reduced EUDs and NTCP for all 15 patients compared to either 6MV or 15MV VMAT plans.
- Both techniques were able to maintain the average TCP and EUD for prostate.

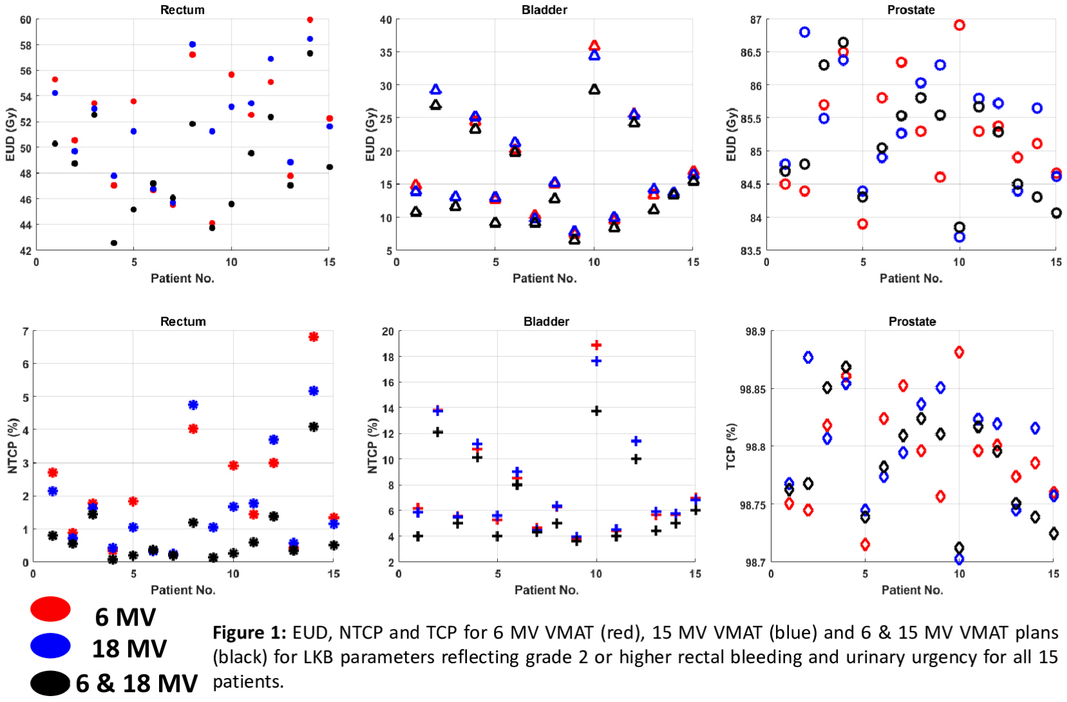

Figure 1: EUD, NTCP and TCP for 6 MV VMAT (red), 15 MV VMAT (blue) and 6 & 15 MV VMAT plans (black) for LKB parameters reflecting grade 2 or higher rectal bleeding and urinary urgency for all 15 patients.

CONCLUSIONS

- Using both 6 & 15 MV resulted in significantly lower NTCP and EUD for bladder and rectum without compromising TCP and EUD for prostate compared to using either of the photon energies alone.

CONTACT INFORMATION

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