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Dosimetric Evaluation of Robust Intensity Modulated Proton Therapy versus PTV-based Volumetric Arc Radiation Therapy in Peripheral Lung SBRT: Target Coverage and Normal Tissue Sparing Comparison

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Abstract
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Abstract

Objectives:

To investigate the dosimetric differences between Intensity Modulated Proton Therapy (IMPT) and photon Volumetric Arc Radiation Therapy (VMAT) in Stereotactic Body Radiotherapy (SBRT) treatment planning for patients with peripherally located lung lesions, including both primitive and metastases.

Methods:

Twenty patients with peripherally located and > 3cm lung lesions who underwent 4D-CT scanning as part of their clinical treatment were retrospectively evaluated. The IMPT and VMAT plans were independently created for each patient by two medical physicists in two different departments. The original SBRT fractionation regimen, comprising 4 x 12 Gy[RBE] (n=4), 5 x 10 Gy[RBE] (n=11) and 8 x 7.5 Gy[RBE] (n=5), was maintained across all patients. Gated plans were generated on the end-exhale phase for IMPT technique and on the end-inhale phase for VMAT technique. In both scenarios, three contiguous phases were used to create an internal target volume (ITV). IMPT plans were optimized on the clinical target volume (CTV) using robust planning into the treatment planning system. A collimated active spot-scanning proton beam gantry armed with a 4mm ITV-to-collimator edge margin was used as delivering system, and treatments were planned with 2 up to 4 coplanar beams. VMAT treatments were planned with Monte Carlo algorithm on a planning target volume (PTV) created by adding a 3mm isotropic expansion to the ITV, and 2 coplanar arcs with 6-FFF photon beams were used. The comparative analysis encompassed target coverage, the conformity index (CI), the gradient index (GI), and the chest wall, ribs, and lungs – ITV dose parameters. The statistical significance of observed differences was assessed by performing the Wilcoxon-Mann-Whitney test (alpha=0.05).

Results:

Both techniques successfully achieved all dosimetric objectives, with the exception of the ribs constraint, which was exceeded in 2 IMPT plans and 13 VMAT plans. All the IMPT doses to the chest wall, ribs, and lungs were significantly lower than those by VMAT plans. On average, the organs at risk (alpha/beta=3) biological effective dose (BED3) was reduced by 15.3 Gy for chest wall D70cc (P< 0.001), 36.2 Gy for chest wall D2cc (P=0.020), and 43.5 Gy for ribs D2cc (P< 0.001). The mean lungs – ITV volume receiving 53.5 Gy (BED3 equivalent of V20 Gy) passed from 3.0% to 1.3% (P< 0.001). The target coverage was kept above 95% in both IMPT and VMAT plans, but ITV D99% and CTV D99% were higher in VMAT plans (ITV: 95.2% vs 98.3%; CTV: 95.4% vs 98.8%; P< 0.001). A 3mm/3.5% robust evaluation revealed that in the worst scenario CTV coverage did not drop below 93.6% for IMPT and 98.4% for VMAT. No statistically significant differences were observed in terms of CI and GI when comparing the IMPT and VMAT treatment plans. The mean ± SD values were 0.670 ± 0.117 and 11.154 ± 6.740 for protons, and 0.639 ± 0.088 and 11.940 ± 6.170 for photons, respectively.

Conclusion(s):

The PTV-based VMAT optimization resulted in greater plan robustness compared to IMPT robust

optimization. Anyway, IMPT plans maintained a clinically acceptable CTV coverage, while providing a significant reduction in the dose to the organs at risk when compared with VMAT plans. These findings suggest the potential for a decrease in late toxicities in challenging lung patients undergoing SBRT. A Normal Tissue Complication Probability (NTCP) analysis is ongoing to assess the clinical implications of these dosimetric differences.