Dosimetric benefits of Robust GTV-based optimization compared with PTV-based treatment planning for photon lung SBRT

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Résumé

Introduction: In lung stereotactic body radiotherapy (SBRT), respiratory motion-related uncertainties are commonly managed by creating an internal target volume (ITV), while set-up and intra-fraction uncertainties are accounted for by adding margins to create the planning target volume (PTV). Conventionally, the PTV is used for dose prescription and plan optimization. However, in lung SBRT, PTV dose may not accurately reflect the dose delivered to the gross tumor volume (GTV) (Lacornerie et al., 2014), and local control correlates more strongly with GTV dose metrics (Morcet-Delattre et al., 2025). Robust GTV-based optimization may address these limitations by explicitly accounting for set-up and motion uncertainties during the plan generation, enabling direct GTV dose prescription. This study aimed to compare robust and PTV-based approaches for photon lung SBRT in terms of agreement between planned and delivered GTV dose, dose to healthy tissue, and plan efficiency.
Material and Methods: Ten patients treated for lung SBRT on a VersaHD linac (Elekta) with a VMAT technique were included in this retrospective study. For each patient, a PTV-based plan (ITV + 4 mm) and a robust GTV-based plan were generated using RayStation v2024b (RaySearch Lab) treatment planning system. For robust optimization, a set-up uncertainty of 4 mm was considered for all patients and GTV respiratory motion was extracted from each patient's planning 4DCT scan. Delivered GTV dose was estimated by applying actual patient shifts during treatment delivery (derived from registrations of treatment CBCT with the planned CT) and by recalculating dose for each fraction across all 4DCT phases. Effective GTV D98% and D50% were extracted from dose–volume histograms (DVH) and averaged over all phases and treatment fractions. Dose to healthy tissue was evaluated by analyzing isodose volumes and lungs DVH. Plan efficiency was analyzed based on number of monitor units (MU) and equivalent square field size of beam's control points.

Results: Compared to delivered dose, planned GTV D98% was overestimated in both planning strategies, with a mean (min-max) difference of +7% (–2%, +19%) and +9% (–2%, +25%) for PTV-based and robust plans, respectively. In contrast, delivered GTV D50% was consistent with planned GTV D50%, with a mean difference of -1% (–6%, +4%) and 0% (–2%, +2%), for PTV-based and robust plans, respectively. Robust planning systematically reduced low and intermediate isodose volumes, resulting in a 14% mean reduction of integral dose, and systematically decreased lung doses with a mean reduction of –61 cc (–19,

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–130 cc) and –39 cc (–1, –111 cc), for the V5Gy and the V10Gy, respectively. Compared to PTV-based plans, robust plans had comparable number of MU with a mean difference of +1% (–5%, +7%), and had similar field sizes with a mean difference of +4% (–5%, +11%). *Conclusion:* Robust GTV-based optimization achieved target dose coverage comparable to PTV-based planning under setup and respiratory uncertainties, while reducing dose to healthy tissues and maintaining plan efficiency. The observed agreement between planned and delivered GTV D50% supports its relevance as a robust metric for dose prescription in lung SBRT. These results question the suitability of PTV-based prescription and support the use of robust GTV-based dose prescription as a more consistent and clinically meaningful approach.

Mots-Clés: Stereotactic body radiation therapy, dose planning, tumor motion, robust optimization, lung SBRT