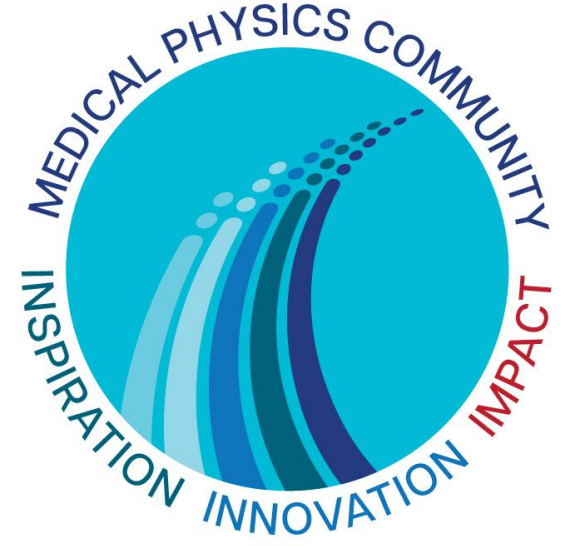




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Energy Layer Spacing Effects on Target Coverage and Homogeneity in Dynamic ARC PBS Proton Lung Plans

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Objective

DynamicARC is a pencil beam scanning (PBS) proton therapy technique that enhances delivery efficiency and plan quality. This study evaluated how energy layer spacing (ELS) shapes target coverage, dose homogeneity, and organ-at-risk (OAR) sparing in lung DynamicARC planning.

Methods

- Four anonymized lung cancer patients were replanned to 50 Gy(RBE) in 5 fractions using a single partial arc for IBA ProteusOne in RayStation (research version;2023B).
- ELS was varied from 0.10–0.40 cm (0.05 cm increments) while all other parameters were held constant.
- Robust optimization incorporated setup (± 5 mm) and range ($\pm 3.5\%$) uncertainties.
- Metrics included CTV_D99%, CTV_D95%, CTV_Dmax, CTV_D1%, CTV_D95wcs, homogeneity index (HI), and OAR doses.

Methods

- CTV D99% showed minimal variation across ELS values (mean ≈ 49.48 Gy(RBE)), reaching its lowest at 0.10 cm and its highest at 0.35 cm. CTV D95% was met at every ELS except 0.15 cm, which fell marginally short (49.96 Gy(RBE)).

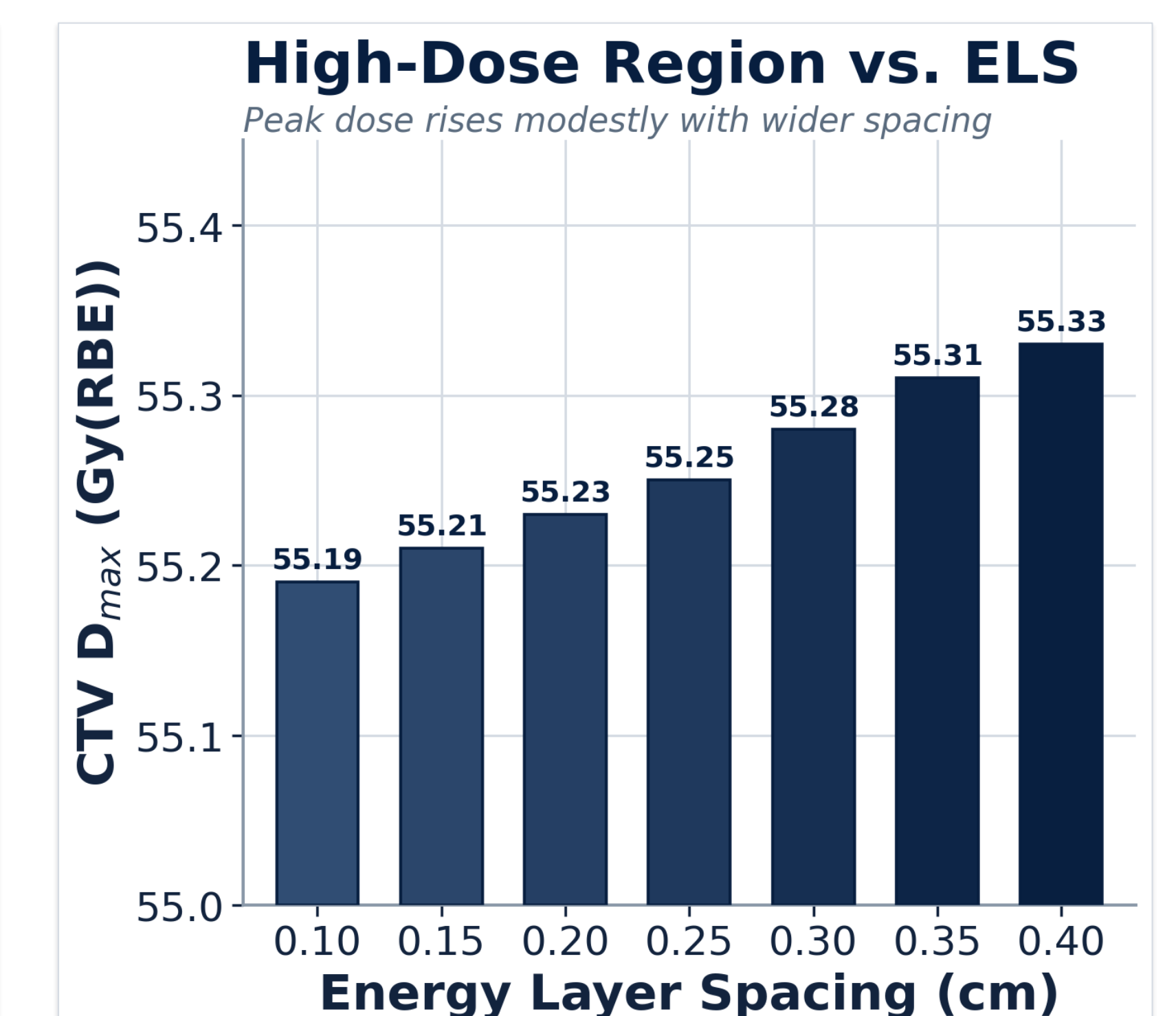
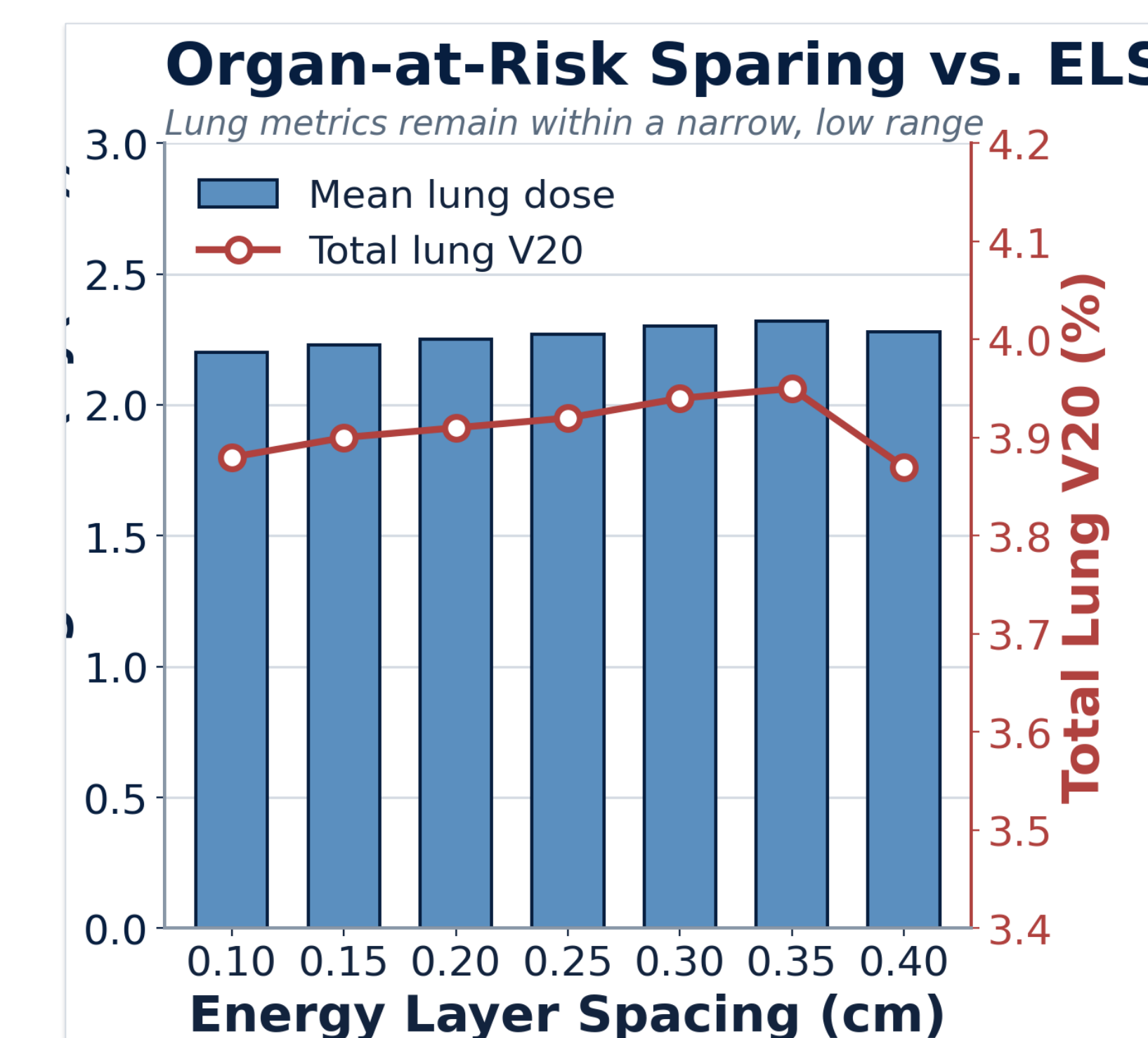
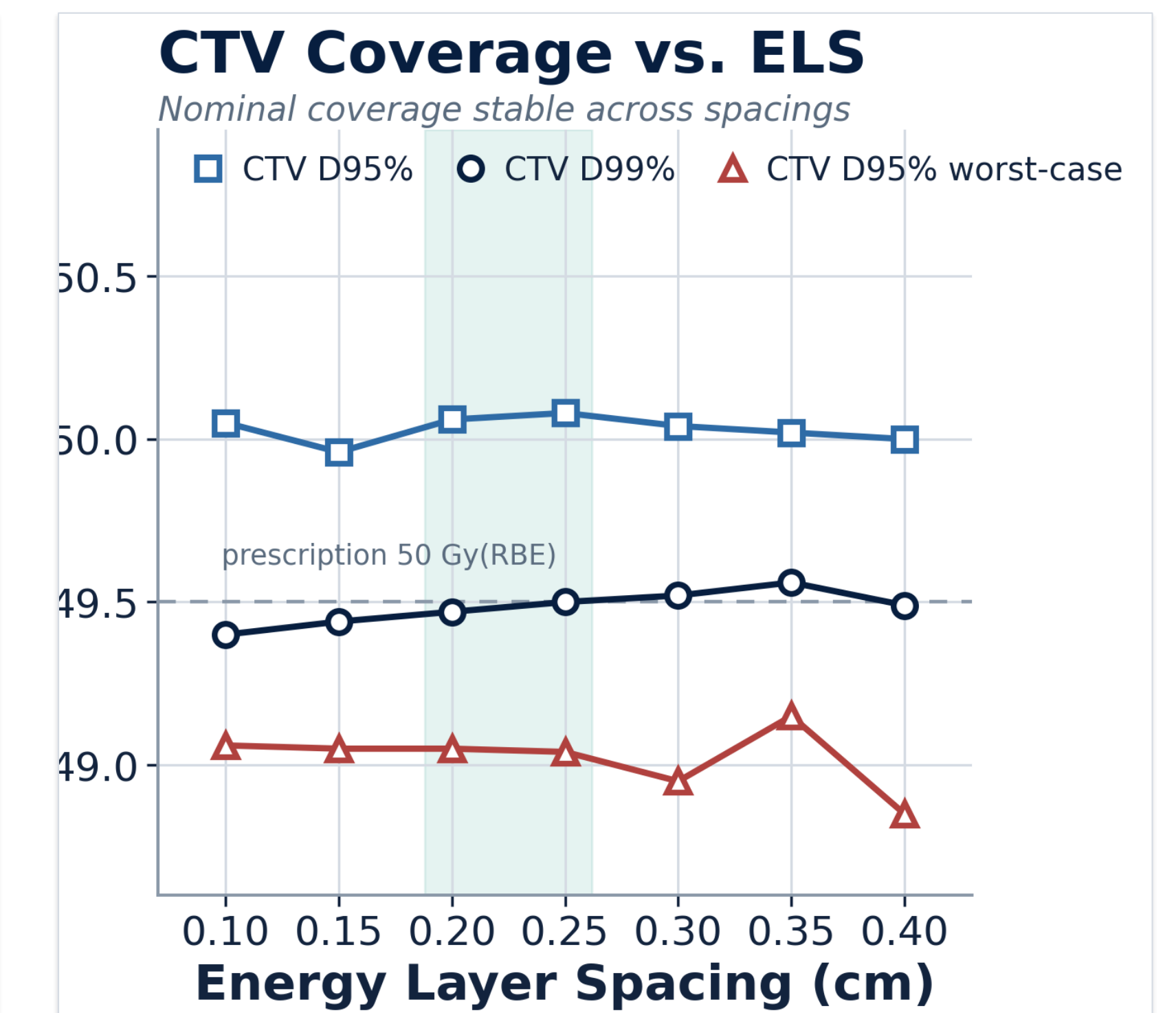
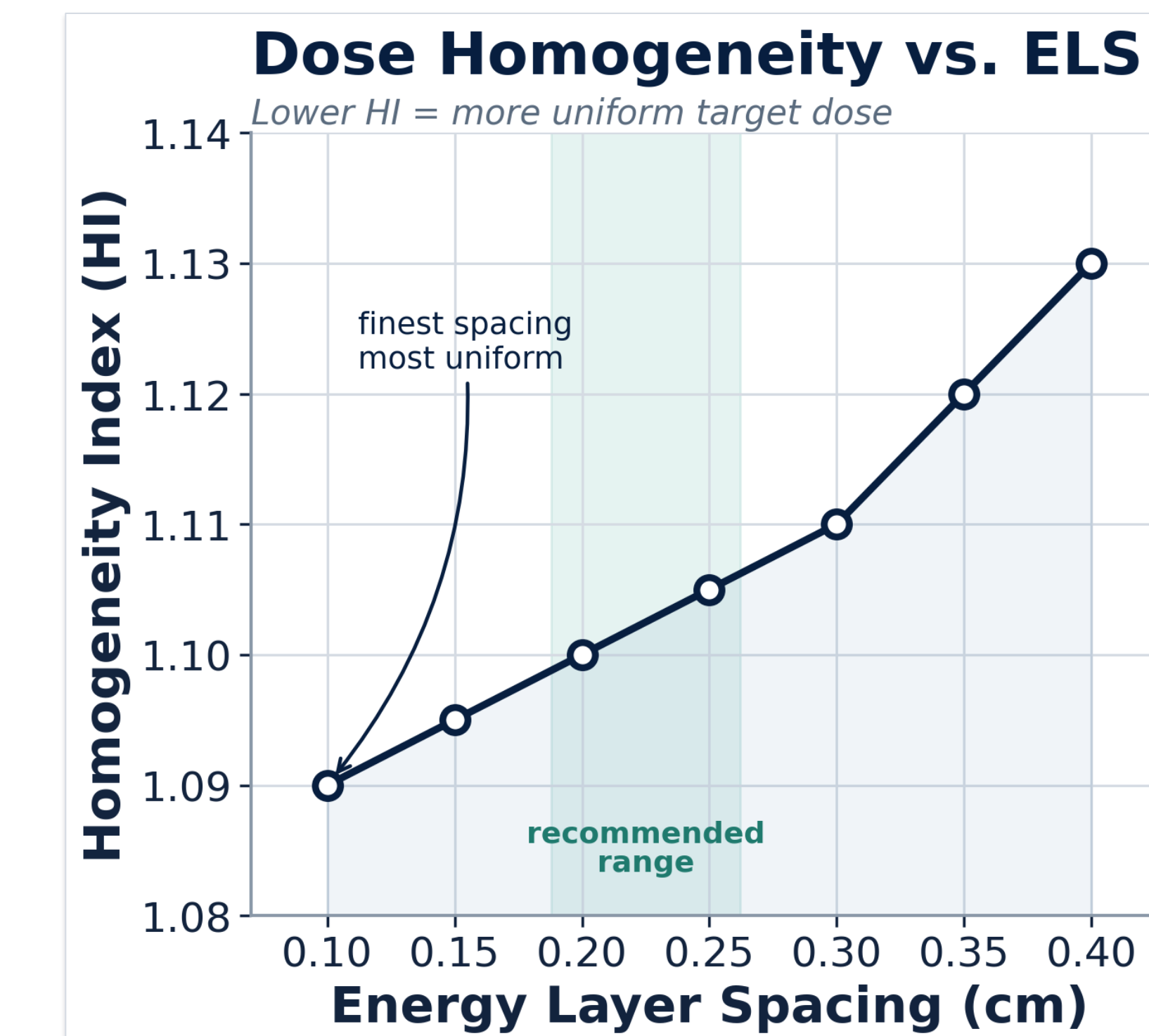
Results

- High-dose regions grew with wider spacing; CTV_Dmax ranged from 55.19 to 55.33 Gy(RBE). Worst-case coverage (CTV_D95wcs) remained stable at smaller spacings (≈ 49.05 Gy(RBE)), with greater fluctuation observed at $ELS \geq 0.30$ cm.
- HI indicated improved dose uniformity at smaller ELS, with patient HI values of approximately 1.09–1.10 at fine spacing, increasing to 1.12–1.13 at 0.40 cm.
- For OARs, total lung V20 remained low across all plans (3.87–3.95%). Mean lung dose ranged from 2.20 to 2.32 Gy(RBE), with the highest value at ELS 0.35 cm. Spinal cord and esophagus constraints were satisfied for all ELS values, although larger spacings produced greater inter-plan variability.

Conclusions

- Energy layer spacing primarily influenced dose homogeneity and high-dose regions, while nominal target coverage and OAR constraints remained largely unaffected.
- An ELS of 0.20–0.25 cm delivered the most consistent balance of dose uniformity and robust coverage, and is recommended for lung DynamicARC planning.
- A planned follow-up study will assess respiratory-motion interplay across ELS values using 4DCT-based simulations and/or motion phantoms.

Results



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