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Strategizing Static Angle Modulated Ports (STAMPs) Configuration in RapidArc Dynamic (RAD) Planning for Lung Radiation Therapy

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Introduction and Purpose

RapidArc Dynamic (RAD) is a novel delivery technique available on Varian TrueBeam machine. It combines VMAT's rotation delivery nature with IMRT's static multi-segment delivery. Such combination in theory presents better opportunities and flexibility to improve plan quality depending on site specific need. However, the elevated complexity of delivery relies on careful selection of all tunable parameters, including static angle–modulated ports (STAMPs), collimator angle, static/arc dominance etc. In this study, we strategized optimal STAMPs selection for lung RAD planning.

Methods

A STAMP efficiency index (SEI) was defined for each target voxel as a function of voxel location and candidate beam direction.

$$SEI(x,\alpha) = \frac{\sum_{OAR_i} w_{OAR_i} \times d_{OAR_i}(x,\alpha) + w_{NT} \times d_{NT}(x,\alpha) + w_{Target} \times d_{Target}(x,\alpha)}{d_{NT}(x,\alpha) + \lambda}$$

where the weighting factors w represent the relative contribution of dose deposited in different anatomical structures to the SEI. OAR_i denotes the i th OAR included in the calculation, and NT represents normal tissue excluding the OAR and target along the beam path. The parameter λ is a regularization constant introduced to ensure numerical stability and prevent divergence of the index when the beam–target intersection length approaches zero. For deposited dose estimation, attenuation of the primary beam and lung tissue heterogeneity were modeled using a pencil beam algorithm. Scattered dose was neglected to maintain computational efficiency. An additional constraint based on a spring-coupled mass model was introduced to quantify STAMP angular dispersion. By summing the voxel-level SEI and the dispersion term, a total efficiency index (TEI) was obtained for each multi-STAMP configuration.

Methods *Cont.*

Eight lung cancer patients treated with volumetric modulated arc therapy (VMAT, 7-case) or intensity modulated radiation therapy (IMRT, 1-case) were included under IRB approval. RAD plans were generated using a single full arc integrated with seven STAMPs corresponding to the optimized configurations for 2Gy/30Fx. Plan quality was evaluated against clinically approved plans at key dosimetric endpoints.

Results

Figure 1 STAMP efficiency index (SEI) for non-coplanar beam angles visualized using a Mollweide projection for an example case. Warmer colors indicate increased OAR dose ratios, corresponding to less favorable beam orientations, whereas cooler regions represent superior STAMP beam angles.

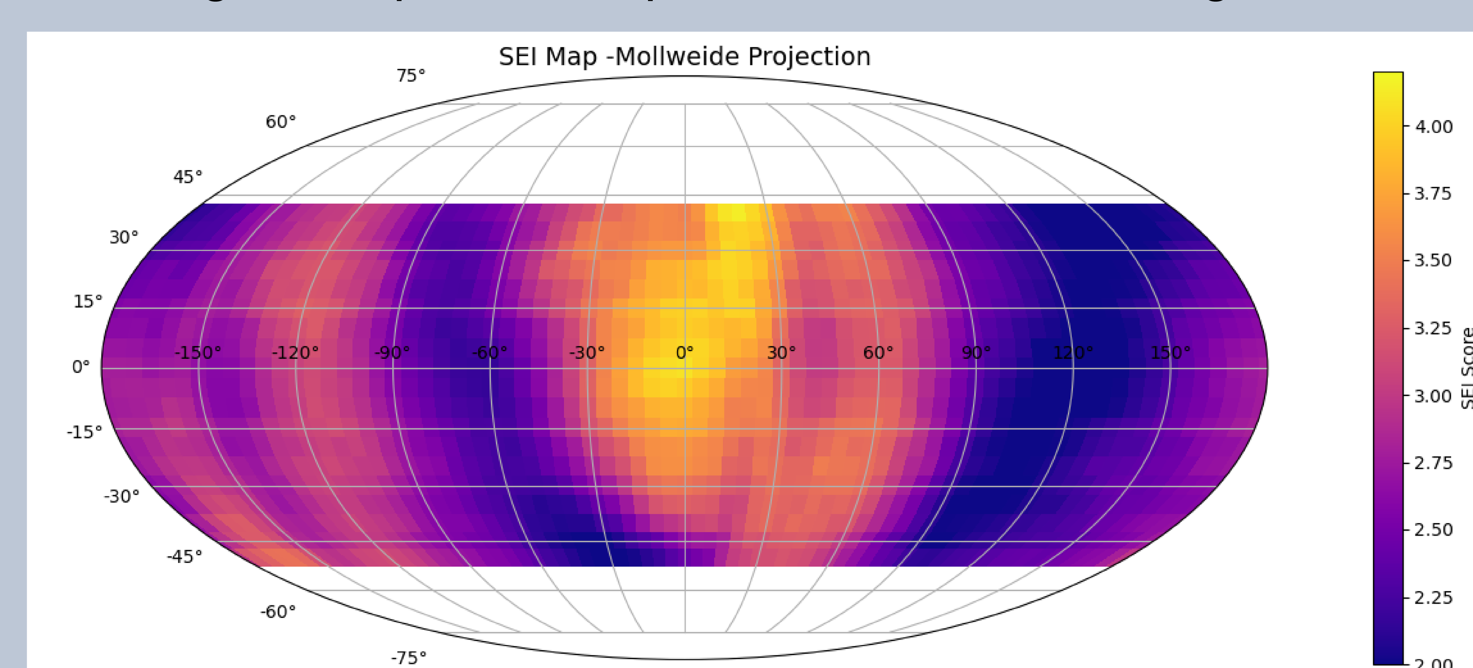
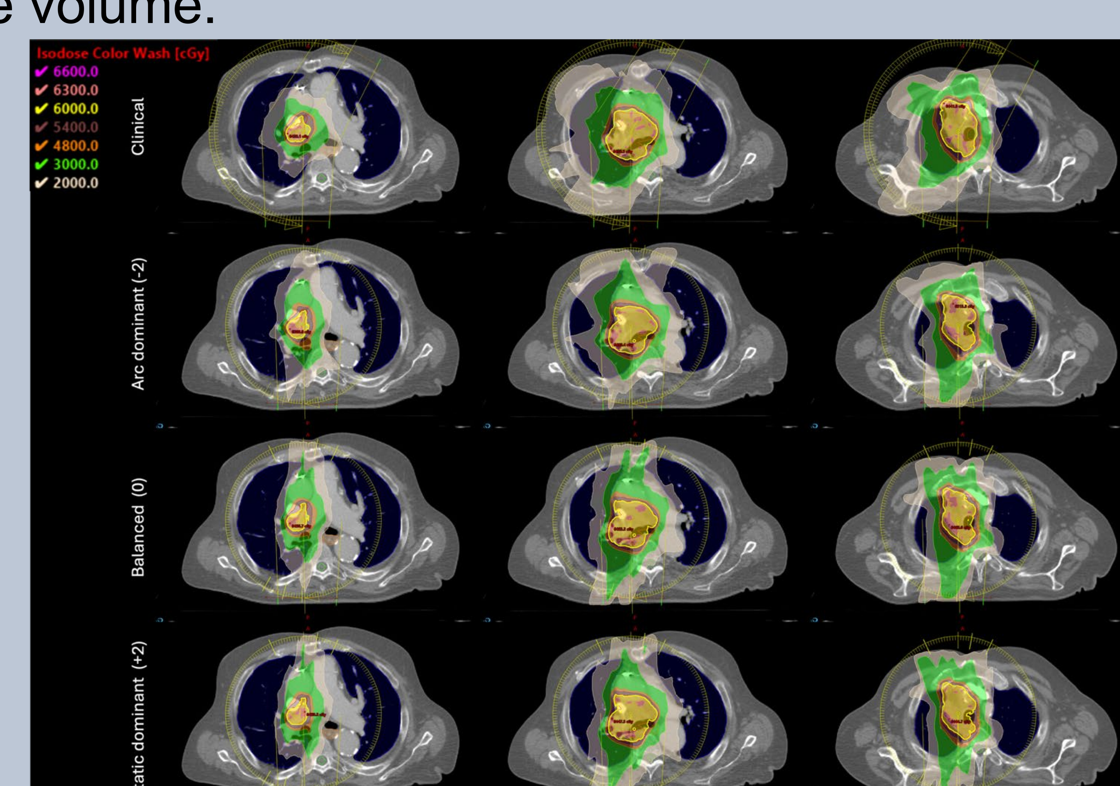


Figure 2 Comparison of key dosimetric endpoints across eight patients for six planning strategies. Lung V20, heart mean dose, spinal cord maximum dose, and esophagus mean dose are shown as a function of patient index. Each colored line represents a different planning technique, including the clinical baseline and five alternative dominance configurations. Lung V20 (%): the percentage of lung volume receiving at least 20 Gy ; Dmean (Gy): the average dose within the volume.



Results *Cont.*

RAD plans with optimized STAMP configurations demonstrated improved target conformity compared with clinical plans (conformity index: 1.02 vs. 1.06). In addition, RAD plans achieved comparable or improved OAR sparing, including reduced lung V20% (18.4% vs. 20.0%) and lower maximum spinal cord dose (30.3 Gy vs. 32.9 Gy).

An example case is shown in Figure 2, RAD plans demonstrate substantially improved lung sparing, with visibly reduced low and intermediate-dose spread (V20) within the bilateral lungs. In addition, improved esophageal sparing is observed, with lower isodose penetration into the esophagus contour compared with the clinical plan.

Conclusion

An automated STAMP configuration framework for RAD lung planning is proposed. This approach streamlines the RAD planning workflow and demonstrates dosimetric improvement compared with conventional IMRT/VMAT plans.

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