Preliminary Study for Clinical Feasibility of SBPT vs SBRT for Thoracic and Liver Disease Sites

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Introduction

SBRT is an established modality for the treatment of localized lung and liver tumors; however, it presents significant challenges in minimizing radiation exposure to surrounding organs at risk. Proton therapy employs the Bragg Peak to deliver precise dose with no exit radiation, reducing toxicity to normal tissues. This is particularly beneficial for the lungs and liver, which are susceptible to radiation-induced damage such as radiation pneumonitis and radiation-induced liver disease (RILD).

This study evaluates whether stereotactic body proton therapy (SBPT) can improve dose distribution and reduce OAR exposure compared to photon-based SBRT in thoracic and liver tumors, while maintaining effective tumor coverage.

Methods

The study cohort consisted of 14 patients previously treated with photon therapy: six thoracic cases originally treated between 2012 and 2014, and eight liver cases treated between 2019 and 2025. Clinically acceptable trial plans were created in RayStation: three beam arrangements for each liver case (two, three, and four beams, using non-contrast breath-hold images and three plans per thoracic case (one VMAT SBRT, two proton plans).

All plans were evaluated on the same CT datasets with identical contouring. Dose distributions, dose-volume histograms (DVHs), and robustness under setup uncertainties (2 mm for liver, 5 mm for thoracic) were compared. Clinical goals for target coverage and organ-at-risk (OAR) sparing were applied based on UT MD Anderson guidelines

Results

Thoracic Results

All plans met GTV coverage goals, while only two SBPT plans achieved PTV coverage under 5 mm robustness. Multi-beam Proton Therapy significantly reduced dose to all evaluated organs at risk compared to Volumetric Modulated Arc Therapy. Average reductions included 91.76% for spinal cord maximum dose, 67.05% for esophagus maximum dose, and 86.83% for mean heart dose. Lung V20 constraints were met in all cases, with most proton plans demonstrating decreased lung dose. Differences between 3- and 4-beam configurations were minimal, with no consistent dosimetric advantage observed.

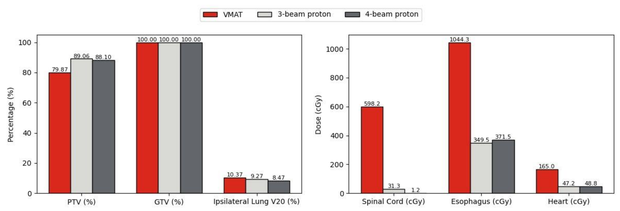

Figure 1. Proton SBPT (3- and 4-beam) achieved full tumor coverage while dramatically reducing doses to the spinal cord, esophagus, heart, and lung compared to VMAT, demonstrating superior organ sparing without compromising tumor control.

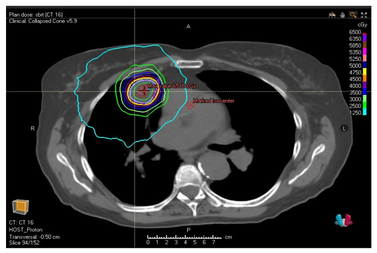

Figure 2. Dose distribution for patient 4 SBRT plan

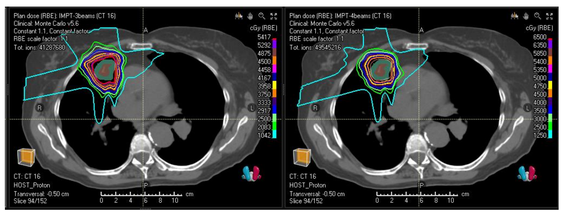

Figure 3. Dose distribution for patient 4 SBPT 3-beam and 4-beam plan.

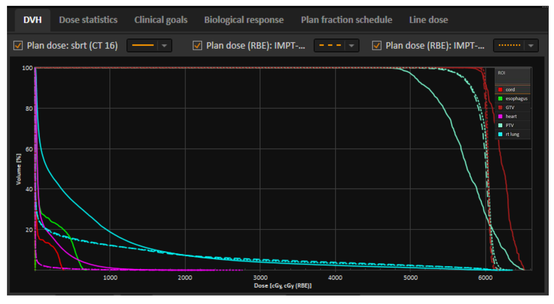

Figure 4. DVH clinical goal for thoracic patient 4.

Liver Results

All plans achieved clinically acceptable PTV and GTV coverage under 2 mm robustness, with multi-beam Proton Therapy demonstrating slightly improved target coverage compared to Intensity-Modulated Radiation Therapy. Proton plans reduced mean Liver-GTV dose (566 cGy vs. 811 cGy) and high-dose liver volume (V700: 232 cc vs. 344 cc). Chest wall dose was also lower, particularly with 3- and 4-beam configurations (2054 cGy vs. 2556 cGy). While all proton plans improved organ sparing, 3- and 4-beam arrangements provided the most consistent reductions across patients

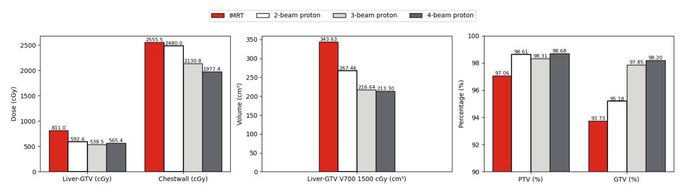

Figure 5. Multi-beam Proton Therapy (3- and 4-beam) reduced liver and chest wall dose and lowered high-dose liver volume compared to Intensity-Modulated Radiation Therapy, while maintaining or improving PTV and GTV coverage, demonstrating enhanced organ sparing without compromising target coverage.

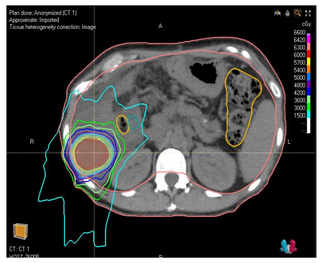

Figure 6. Dose distribution IMRT patient 7.

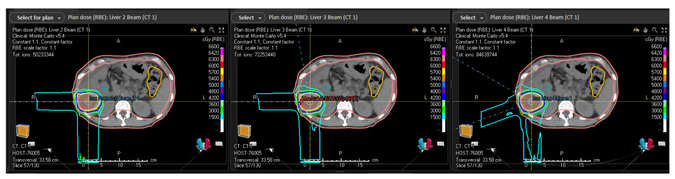

Figure 7. Dose distribution patient 7 SBPT plan. 2-beam, 3-beam and 4-beam dose plan.

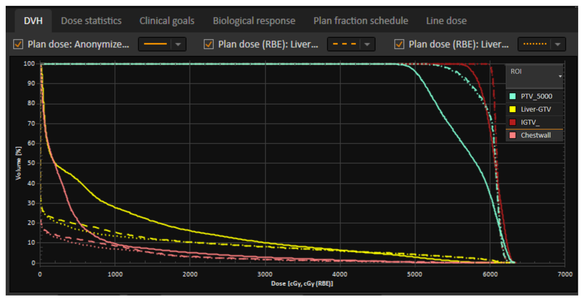

Figure 8. DVH clinical goal for liver patient 7.

Discussion

In this comprehensive study, proton plans were able to achieve relatively higher tumor control while reducing toxicity to normal tissue in comparison to the photon SBRT plans. However, with proton therapy the range uncertainty makes treatment plans sensitive to set up errors. In comparison, IMRT/VMAT plans allow for modulation flexibility with the tradeoff of higher toxicity to normal tissues with entrance and exit dose. In this study, the limitations included the sample size, robust analyzes parameters, and the lack of motion interplay. These findings support further research for the LET optimization of these or similar plans. Evaluating range uncertainties of the trial plans created for this study may also be beneficial to clinical developments. Similar research may also be carried through to other body sites. This study sought to discover if measurable improvements could be made to dose distributions of lung and liver tumors.

References

1) Chang JY et al. Consensus statement on proton therapy in early-stage and locally advanced non-small cell lung cancer. Int J Radiat Oncol Biol Phys. 2016
2) Register SP et al. Proton stereotactic body radiation therapy for centrally and superiorly located stage I non-small-cell lung cancer. Int J Radiat Oncol Biol Phys. 2011
3) Li H et al. Challenges and opportunities in stereotactic body proton radiotherapy of liver malignancies. J Radiosurg SBRT. 2023
4) Arscott WT et al. Stereotactic body proton therapy for liver tumors: Dosimetric advantages and clinical implications. Phys Imaging Radiat Oncol. 2018
5) Nantavithya C et al. Phase 2 study of SBRT and proton therapy for high-risk early-stage non-small cell lung cancer. Int J Radiat Oncol Biol Phys. 2018
6) Marks LB et al. Radiation dose-volume effects in the lung. Int J Radiat Oncol Biol Phys. 2010