# Mitigation Strategies for Proton Lung Planning in the Presence of Pleural Effusion: A Case Study

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## Abstract

Pleural effusions (PE) are present in ~15% of lung cancer patients at the time of diagnosis and go on to develop in up to 50% of patients during the course of the disease.[1] This presents a unique challenge for proton therapy treatment planning because proton beams have a "physical finite range" for which the dosimetrist must account.[2] Any path length change through the patient anatomy will affect the beam range and may "deteriorate the dose distribution," which frequently requires an adaptive plan.[2]

Adaptive proton therapy plans must be created offline; therefore, a plan robust to path length changes can provide more consistent target dose and prevent treatment breaks.[2] Standard mitigation strategies include choosing beam angles that avoid or minimize traversing any potentially inconsistent anatomy, as well as careful and frequent monitoring with rescans (RECTs). However, in some cases a pleural effusion may be impossible to avoid with beam geometry alone. An additional strategy made practical by recent improvements in the calculation speed of treatment planning systems (TPS) is "pseudomultiple-CT robust optimization"[3] in which duplicated CTs are co-optimized simultaneously with different density overrides. This method has previously been shown to improve plan robustness and decrease hot spots in the vicinity of inconsistent density such as bowel air.[3]

In this case study, the authors used a combination of these strategies in order to improve the dose consistency of a proton therapy treatment plan for a lung patient with an unavoidable pleural effusion. The case study includes the dose comparison between the nominal plan and weekly rescan dose evaluations, as well as the volumetric changes observed in the pleural effusion over the course of treatment. The nominal plan remained robust to the significant change in pleural effusion volume, with ITV coverage V95% > 95% on all weekly rescans.

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## References

(1) Scagliotti GV. Symptoms, signs and staging of lung cancer. *Eur Respir Mon*. 2001;17:86-119.

(2) Albertini F, Matter M, Nenoff L, Zhang Y, Lomax A. Online daily adaptive proton therapy. *Br J Radiol*. 2020;93(1107):20190594. doi:10.1259/bjr.20190594

(3) Zhu M, Kaiser A, Mishra MV, et al. Multiple Computed Tomography Robust Optimization to Account for Random Anatomic Density Variations During Intensity Modulated Proton Therapy. *Adv Radiat Oncol*. 2019;5(5):1022-1031. Published 2019 Dec 26. doi:10.1016/j.adro.2019.12.003

## Methods

A patient presented with adenocarcinoma of the left upper lung and a 473 cc pleural effusion in the posterior left lung. The patient was simulated with a 4D CT that was phase-binned into 10 scans. Proton treatment was planned to 60 GyRBE in 30 fx on the 4D Average CT (TPCT) using Raystation 11A TPS. The patient began treatment 14 days after simulation.

1. Beam angles were chosen to avoid as much pleural effusion as possible, as well as other potential sources of range error such as breast tissue, skin folds and the table edge.
2. Beam weights were adjusted to minimize and diffuse the dose from beams that ranged through the pleural effusion. The PTV was targeted with 3 beams of unequal SFO weighting: an RAO weighted 50% which fully avoided the pleural effusion, and 2 posterior obliques each weighted 25% and both of which partially traversed the pleural effusion.
3. The pleural effusion was contoured into independent structures on the Average TPCT and two of the 4D phases. The Average scan was left unforced (to nominal PE density of ~1.02 g/cm$^3$), one phase was forced to the built-in value of "Lung" (mass density of 0.26 g/cm$^3$) to simulate full PE resolution, and the second phase was forced to the built-in value of "Cork" (with an intermediate mass density value of 0.60 g/cm$^3$) to simulate partial PE resolution. The 3 CT's were co-optimized simultaneously using a robust MFO ITV objective with range uncertainty of 3.5% and positional uncertainty of 5 mm.
4. The pleural effusion was monitored with weekly 4D rescans on fractions 3, 8, 13, 18 and 23.

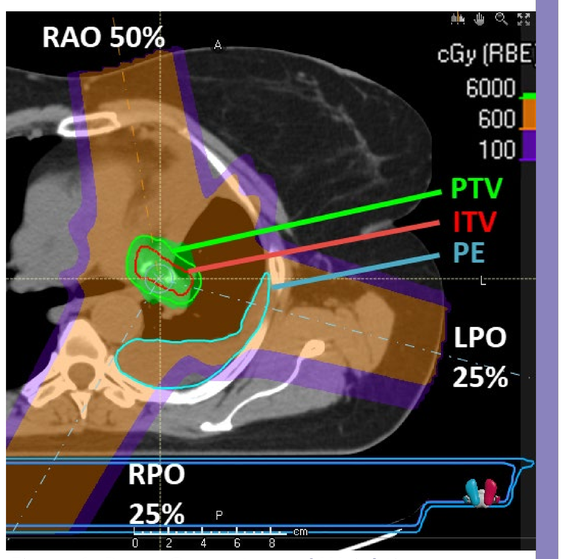


Figure 1: Beam Geometry and Weighting

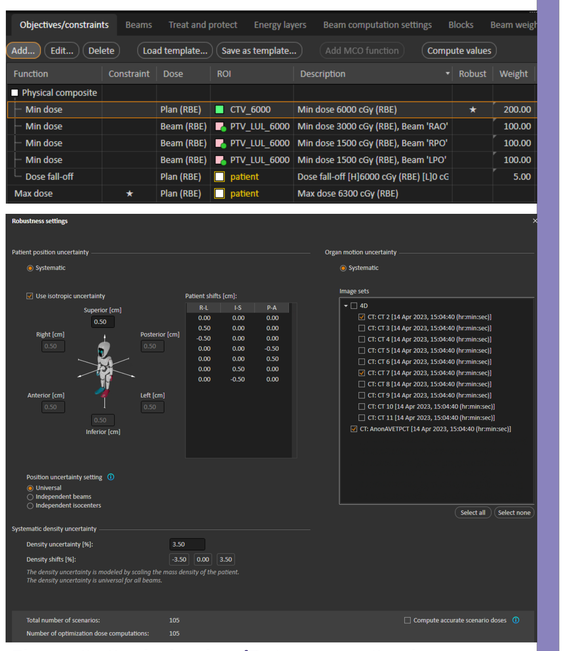


Figure 2: Optimization/Robustness Settings

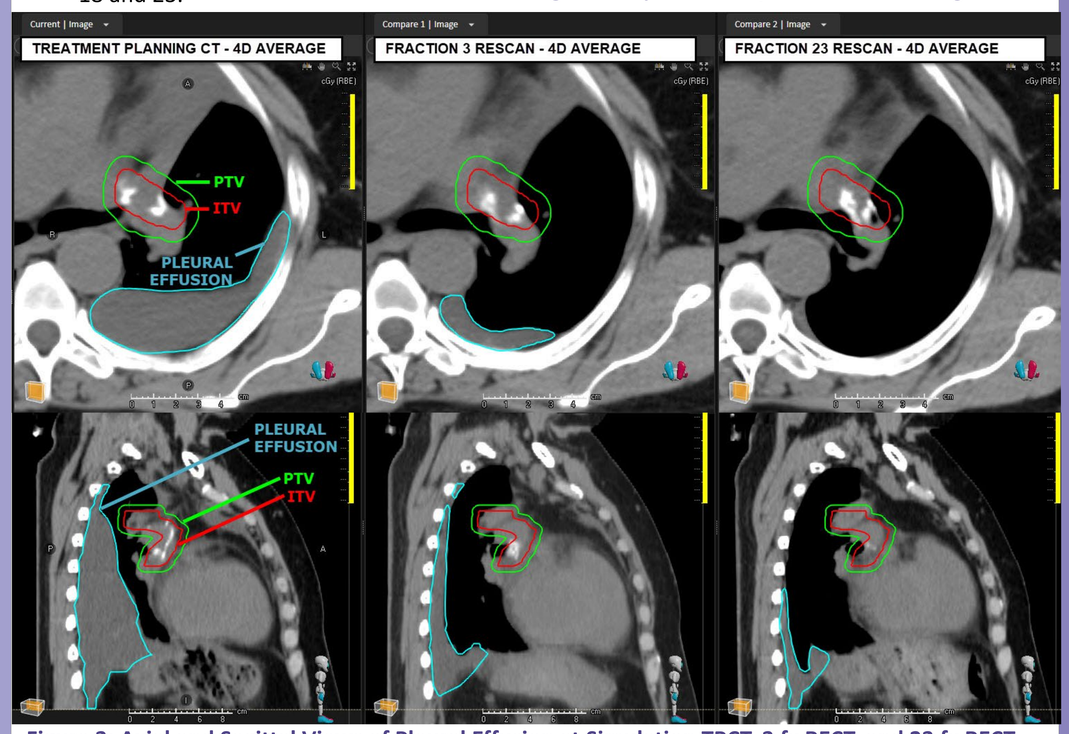


Figure 3: Axial and Sagittal Views of Pleural Effusion at Simulation TPCT, 3 fx RECT, and 23 fx RECT

## Results

The pleural effusion volume significantly decreased during the span of rescans, varying between 473 cc - 72 cc, including near-complete resolution at the level of the ITV by fraction 18 (day 38 since TPCT). This caused a dramatic path length change for both posterior obliques, yet V95% ITV coverage remained above 95% on each rescan throughout treatment with no adaptive plans required.

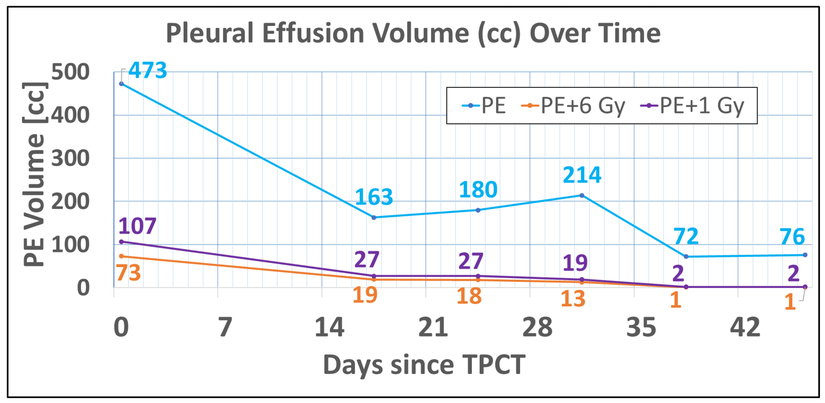


Figure 4: Volume of PE Total + Intersecting 6 GyRBE (10%) IDL and 1 GyRBE IDL

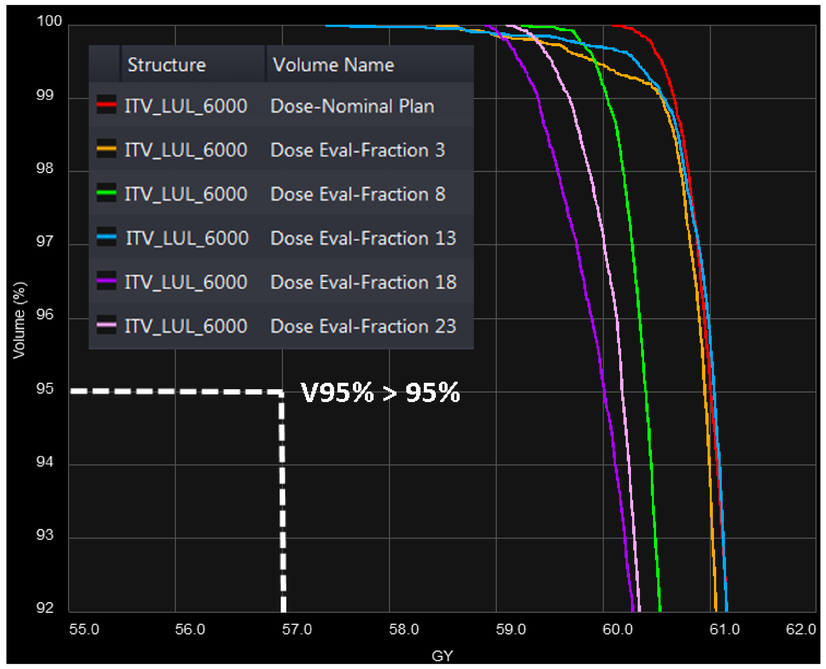


Figure 5: DVH of ITV Calculated on Nominal Plan and 5 Rescans

## Discussion

Use of "pseudomultiple-CT robust optimization" to simulate an *increasing* pleural effusion is not recommended, as the size and position of an increase is unpredictable compared to a *decreasing* pleural effusion which is most likely to shrink within its original boundary. However, in the case of a rescan showing an increased pleural effusion, this method can also be used during adaptive planning to co-optimize on previous CT's and hedge against future decreases.

Furthermore, this technique necessarily provides extra dose coverage to the target compared to a nominally-robust plan, which may potentially result in higher OAR dose as well.[3] Carefully evaluate if a sensitive or near-tolerance OAR is adjacent to the target, especially in the distal or proximal beam direction.

## Conclusion

Co-optimizing on multiple DICOM-registered CTs to simulate path length changes through potentially unstable patient anatomy can successfully contribute to maintaining robust and consistent dose coverage throughout proton therapy treatments. In turn, this may reduce the need for treatment breaks associated with offline adaptive planning.

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