The Impact of Low-Density Media on Dose Calcuations for Lung Stereotactic Body Radiation Therapy

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Introduction

- Stereotactic body radiation therapy (SBRT) is the standard of care to treat early-stage, inoperable non-small cell lung cancer.[1]
- SBRT delivers ablative doses of radiation to the target over a few fractions.[2]
- The target in lung SBRT typically includes a tissue-equivalent tumour surrounded by low-density air and healthy lung tissue, and occasionally healthy bone as well.
- Histrocially, lung SBRT treatments have been planned using the Analytical Anisotropic Algorithm (AAA), and the current dosimetric planning guidelines are based on these calculations.
- AcurosXB (AXB) more accurately predicts dose to media compared to AAA, particularly in very low-densities which can exist in lung SBRT planning target volumes.

Goal: Characterize the relationship between AXB calculated-dose and target density in the context of lung SBRT treatment planning.

Methods

Five lung SBRT patients previously treated with a prescription of 48 Gy in four fractions and dose calculated with AXB were identified.

1. Determine the correlation between target density and planned dose.
   a) Each patient's planning target volume (PTV) voxels were identified using the average intensity projection of their four-dimensional computed tomography (CT) scan.
   b) The planned dose and Hounsfield-unit (HU) of each PTV voxel was extracted.
   c) Spearman's rank and Pearson's correlation coefficients were used to quantify the correlation between PTV voxel planned dose and HU.
2. Determine the relationship between target density and mean lung dose.
   a) Each patient's CT was copied four times.
   b) Voxels within the PTV with an HU < -200 (PTV_{LD}) were modified to -600 HU, -800 HU, -900 HU, and -975 HU.
   c) New 6X, 6FFF, and 10FFF treatment plans (48 Gy/4 fractions) were created on each modified scan using both AAA and AXB for dose calculations.
      i. V100% = 95%, D_{max} < 130%
   d) The mean dose to the ipsilateral lung excluding the PTV was recorded.

Results

Table 1. Correlation results between PTV voxel HU and planned dose.

Patient	Spearman's Rank Correlation Coefficient	p-value	Pearson's Correlation Coefficient	p-value
All	0.19	<0.001	0.17	<0.001
A	0.32	<0.001	0.16	<0.001
B	0.21	<0.001	0.06	<0.001
C	0.39	<0.001	0.28	<0.001
D	0.40	<0.001	0.35	<0.001
E	0.03	0.005	0.09	<0.001

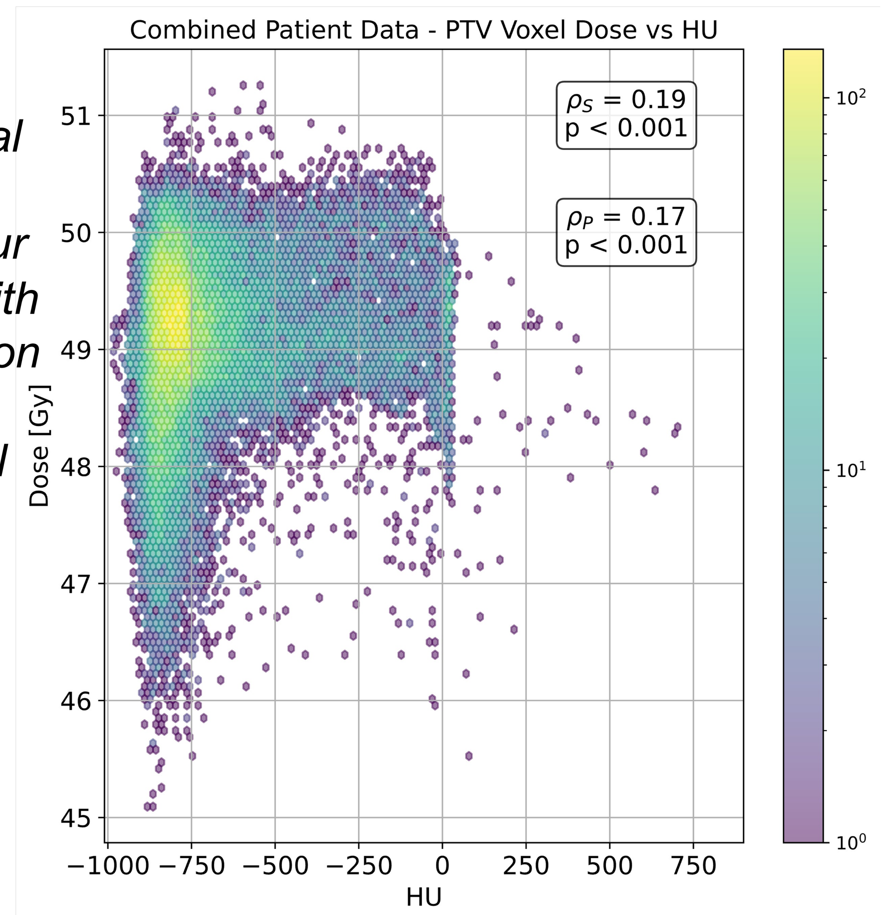

***Figure 1.** Combined PTV voxel dose and HU data for five clinical lung SBRT treatment plans with dose prescription of 48 Gy in four fractions and dose calculated with AXB. Spearman's rank correlation coefficient (ρ_S) and Pearson's correlation coefficient (ρ_P) for all patients combined are 0.19 (p <0.001) and 0.17 (p <0.001), respectively.*

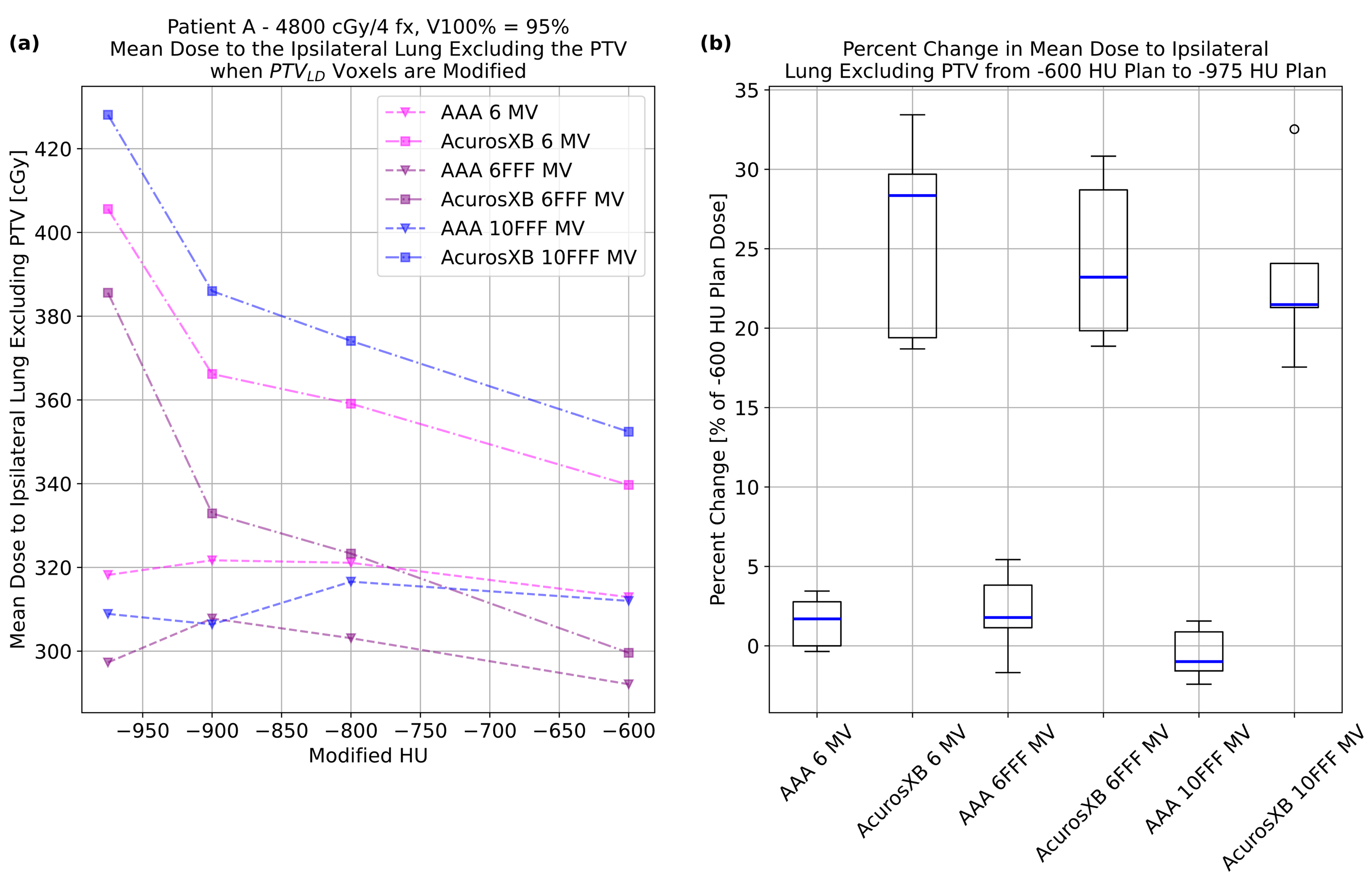

***Figure 2.** (a) Mean dose to the ipsilateral lung excluding the PTV calculated by both AAA (triangles) and AXB (squares) as the density of the PTV_{LD} was modified. Calculations for 6X (magenta), 6FFF (purple), and 10FFF (blue) beams are shown. (b) Percent change in the mean dose to the ipsilateral lung excluding the PTV $\left(\frac{D_{-975\,HU}-D_{-600\,HU}}{D_{-600\,HU}}\times 100\%\right)$ for doses delivered with 6X, 6FFF, and 10FFF photon beams and dose calculated with AAA and AXB.*

Discussion

- There is a statistically significant, non-linear, positive correlation between PTV voxel HU and planned dose, despite these clinical lung SBRT plans being optimized to deliver a uniform dose to PTV.
- This suggests additional fluence is required to deliver equivalent doses to low-density media compared to those of higher density.
- As the density of the PTV_{LD} decreases, AXB predicts that the mean dose to the ipsilateral lung excluding the PTV will increase (>20%), while AAA predicts very little change (< ±2%).
- This suggests that additional fluence is required to achieve the prescribed dose to low-density PTVs when plans are calculated with AXB as opposed to AAA.

Conclusion

- When calculating dose with AXB in the context of lung SBRT treatment planning, the density of the target will influence the fluence required to achieve the prescribed dose.
- The additional fluence required to achieve the prescribed dose to the low-density PTV and meet AAA-based dosimetric planning objectives may not be necessary.
- New AXB-based dosimetric planning guidelines should be developed for lung SBRT treatment planning.

We characterized the relationship between dose calculated by AXB and target density in the context of lung SBRT. Future work will investigate treatment planning modifications to improve the dosimetry associated with lung SBRT when using AXB.

References

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2. M. Guckenberger, Dose and Fractionation in Stereotactic Body Radiation Therapy for Stage I Non-Small Cell Lung Cancer: Lessons Learned and Where Do We Go Next?, International Journal of Radiation Oncology*Biology*Physics 93, 765–768 (2015).

Ethics Approval

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More Info

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