Impact of Motion Management and Lung Density on Dose Calculation Algorithm Accuracy in Lung SBRT

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2026 AAPM Annual Meeting – Vancouver, BC

Background and Purpose

- Lung SBRT is highly sensitive to dose calculation accuracy in low-density lung tissue.
- Respiratory motion management techniques (DIBH and 4DCT) alter lung density and may affect algorithm performance.
- Previous investigations have shown that Anisotropic Analytical Algorithm (AAA) can overestimate dose in heterogeneous lung media.[1,2,3]
- Evaluate the impact of lung density on dose calculation accuracy in lung SBRT.
- Compare AAA and Acuros XB (AXB) dose calculations using independent secondary calculation methods.
- Assess whether AXB reoptimization improves agreement with independent dose calculations.

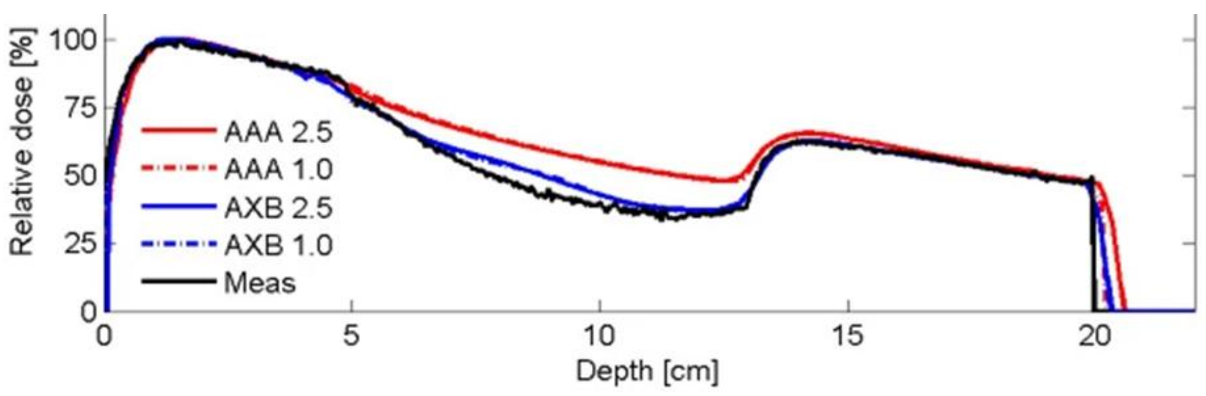

Figure 1: Example heterogeneous lung phantom depth-dose comparison from Kroon et al. demonstrating improved agreement between measured dose and Acuros XB (AXB) compared with AAA in low-density lung-equivalent material.[1]

Methods

- Retrospective analysis of 21 lung SBRT patients:
  - 11 DIBH and 10 4DCT
- Clinical plans optimized and calculated in Eclipse v16.1 using AAA
- AAA plans copied and recalculated with AXB using identical beams and MUs
- Plans reoptimized using AXB
- All plans exported via DICOM to Mobius3D (CCC) and RadMonteCarlo (MC)
- Comparison metrics:
  - PTV and GTV V100%, D90%, and gamma analysis (2%/2 mm, 10% threshold)

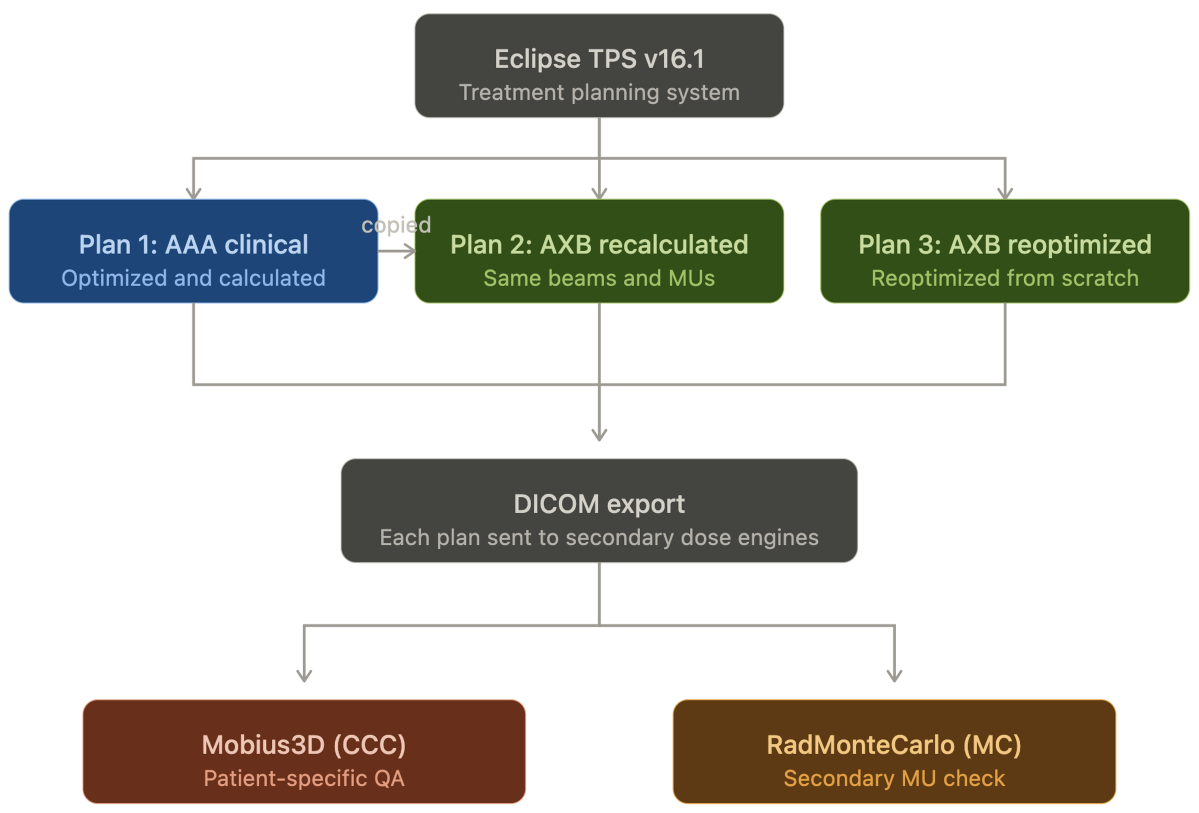

Figure 2: Study workflow and dose calculation engines utilized.

Results

- Lower lung density, particularly in DIBH patients, was associated with increased AAA dose overestimation and reduced agreement with independent dose calculation methods.

		HU			Volume (cc)	
Motion Management	n	Lung	PTV	GTV	PTV	GTV
DIBH	11	-846	-643	-183	10.2	2.0
4DCT	10	-753	-536	-181	16.7	3.8
Combined	21	-802	-592	-182	13.3	2.9

Table 1: Patient and target characteristics. DIBH patients exhibited substantially lower mean lung density than 4DCT patients (-846 HU vs. -753 HU), while target densities were similar between cohorts.

	PTV		GTV	
Plan	Mobius D90%	RadMonteCarlo Gamma Pass Rate	Mobius D90%	RadMonteCarlo Gamma Pass Rate
AAA	-6.4%	88.9%	-1.1%	97.7%
AXB Recalculated	-1.5%	99.2%	-0.9%	100.0%
AXB Reoptimized	-1.6%	99.0%	-0.6%	99.9%

Table 2: Summary of comparisons with independent dose calculations. AAA demonstrated the largest disagreement (PTV D90% = -6.4%, gamma pass rate = 88.9%), whereas AXB recalculated and AXB reoptimized plans showed excellent agreement (PTV D90% ≈ -1.5%, gamma pass rates ≥99%). GTV agreement remained high across all algorithms.

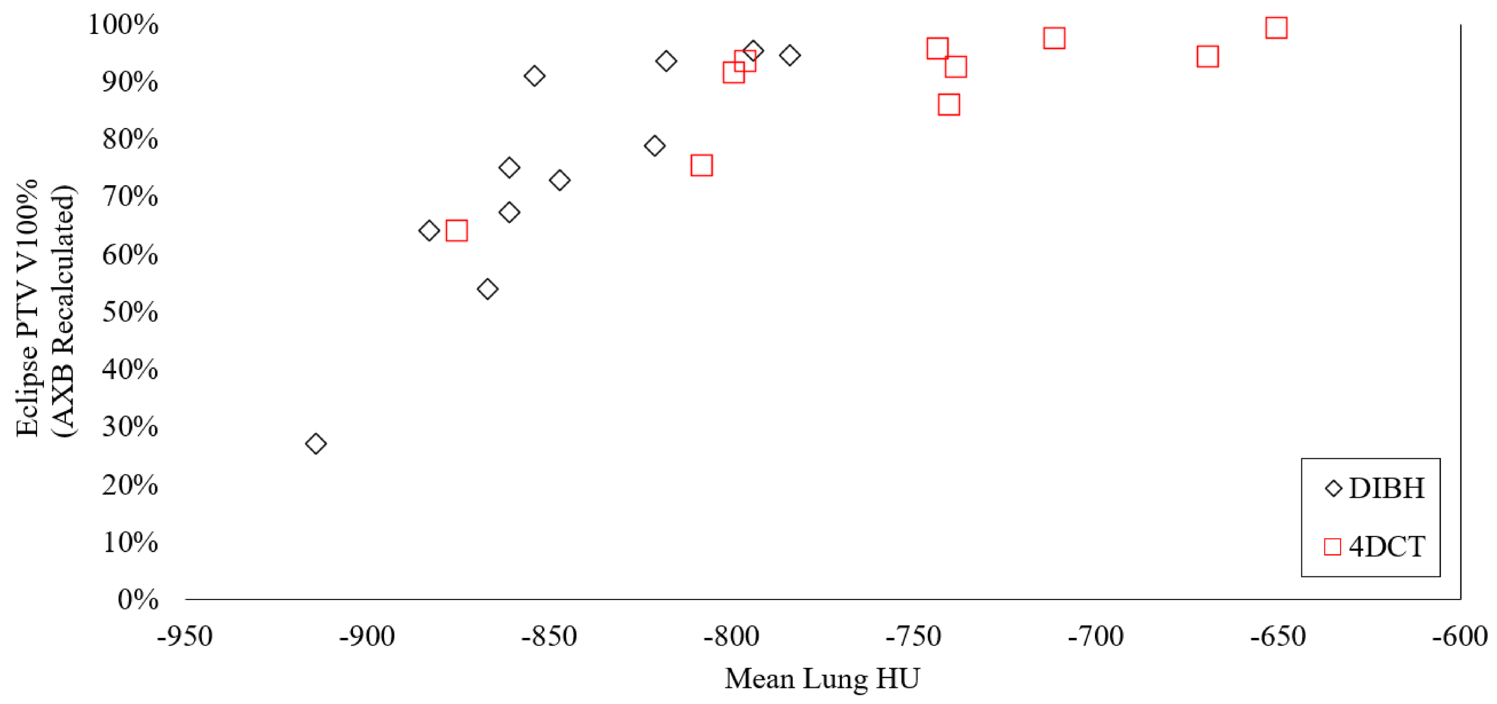

Figure 3: PTV V100% of AAA plans recalculated with AXB as a function of mean lung HU. Lower lung density was associated with larger reductions in target coverage, with the greatest effect observed in DIBH patients.

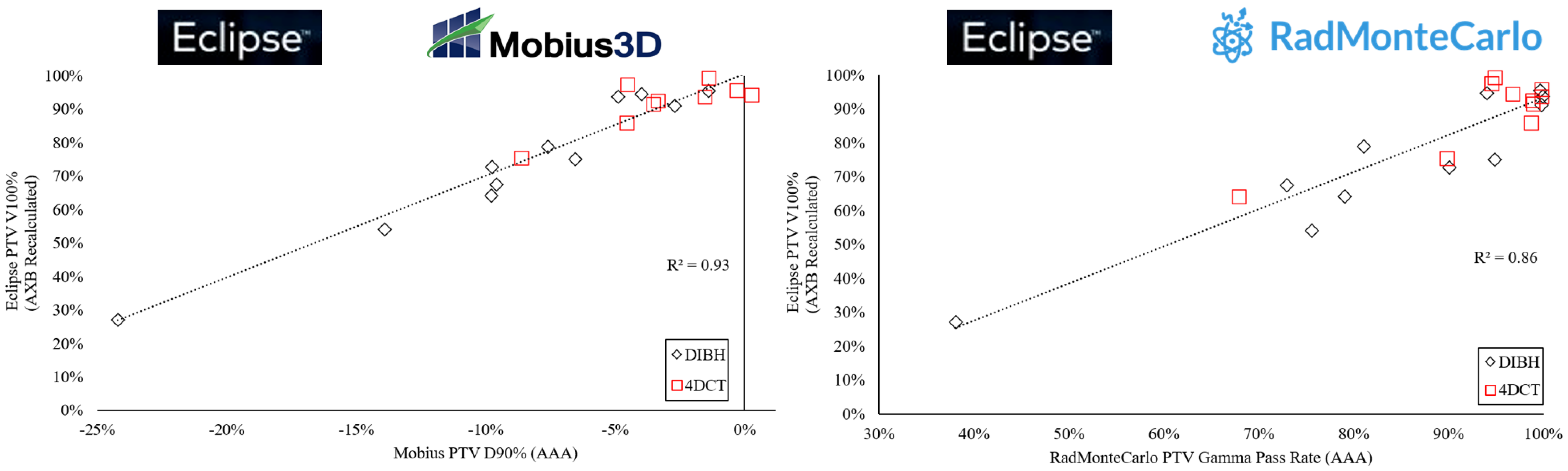

Figure 4: (left) Strong correlation between AXB-calculated PTV V100% and Mobius3D (CCC) PTV D90% ($R^2 = 0.93$), indicating that reduced target coverage identified by AXB was independently confirmed by CCC calculations. (right) Strong correlation between AXB-calculated PTV V100% and RadMonteCarlo gamma pass rate ($R^2 = 0.86$). Plans with lower AXB target coverage exhibited poorer agreement with independent Monte Carlo calculations.

Conclusions

- Lung density significantly impacts dose calculation accuracy in lung SBRT.
- AAA systematically overestimated target dose, with the largest discrepancies observed in low-density DIBH lungs.
- Recalculation with AXB revealed substantial reductions in PTV coverage, indicating potential underdosing of the target.
- GTV coverage was comparatively stable, with GTV D90% differences remaining <1.2% across all calculation methods.
- AXB demonstrated superior agreement with independent CCC and Monte Carlo calculations for both DIBH and 4DCT patients.
- Advanced algorithms such as AXB or Monte Carlo should be considered for lung SBRT, particularly when treating patients with highly inflated, low-density lungs.

References

1. Kroon, P. S., Hol, S., & Essers, M. (2013). Dosimetric accuracy and clinical quality of Acuros XB and AAA dose calculation algorithm for stereotactic and conventional lung volumetric modulated arc therapy plans. Radiation Oncology, 8, 149. https://doi.org/10.1186/1748-717X-8-149
2. Lobb, E., & Plypoo, A. (2022). Limits for the therapeutic application of the analytical anisotropic algorithm in the context of ablative lung radiotherapy near the minima of lung density and tumor size. Journal of Applied Clinical Medical Physics, 23(7), e13634. https://doi.org/10.1002/acm2.13634
3. Yaparpalvi, R., Mynampati, D., Kuo, H., Garg, M., Tome, W., & Kalnicki, S. (2016). Influence of Acuros XB and AAA dose calculation algorithms on plan quality metrics and normal lung doses in lung SBRT. Medical Physics, 43(6). https://doi.org/10.1118/1.4956785