

Comparison of AAA and Acuros XB Dose Calculation Algorithms for SRS

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INTRODUCTION

Single isocenter multiple target (SIMT) stereotactic radiosurgery (SRS) provides an effective treatment of brain metastases. The goal of SRS, including SIMT SRS, is to deliver a highly conformal dose distribution to targets while minimizing the dose to the critical structures such as the brain, brain stem, chiasm, optical nerve, and lenses. Moreover, the delivered dose to the target and the surrounding tissue affect SRS outcomes. The accuracy of dose calculation is a critical challenge in the SIMT SRS application.

Two dose calculation algorithms, analytical anisotropic algorithm (AAA) and Acuros XB, have been implemented in a commercial treatment planning system (TPS). The AAA was originally developed to meet the clinical expectations, short computation time and high dose calculation accuracy. The AAA is a kernel-based convolution model algorithm. Acuros XB is a deterministic algorithm and applies a deterministic solution of the linear Boltzmann transport equation (LBTE).

AIM

Since Acuros XB has been introduced for years, relatively few studies have investigated its performance in SRS treatments. Most of them focused on SBRT lung cases. The purposes of this project are to compare SIMT SRS dose distribution obtained by Acuros XB dose calculation algorithm and commonly used AAA with clinical brain metastases cases, which represent heterogeneities and usually use small fields, to investigate the effects of size, distance to isocenter, and heterogeneity, heterogeneity as well as to access dosimetric accuracy.

METHOD

Treatment planning system used in this project was Eclipse (Varian Medical Systems, Palo Alto, CA). The dose calculation algorithms were Acuros XB (V15.6) and AAA (V13.6) with heterogeneity correction. The calculation grid size was 1 mm. Acuros XB used dose-to-medium and dose-to-water dose reporting modes to calculate doses.

- Forty clinical cases with 189 targets were used to evaluate the dose distribution differences.
- All plans were generated using the Eclipse treatment planning system (TPS) V13.6 and calculated using Analytical Anisotropic Algorithm (AAA).
- Each patient plan consisted of two to 14 targets and treated using volumetric modulated arc therapy (VMAT).
- These plans were recalculated for the purpose of this project using Acuros XB using the same geometry, voxel resolution, and monitor units.
- Parameters used for plan comparison included planning tumor volume (PTV) coverage to 99%, 95%, and 1%, PTV minimum dose, PTV mean dose, PTV maximum dose, conformity index (CI), heterogeneity index (HI), and whole brain V_{3Gy} , V_{6Gy} , and V_{12Gy} .
- The dosimetric accuracy was evaluated based on the gamma pass rate with threshold criteria 3%/1mm on SRS MapCHECK.
- The significance of the difference for each metric between AAA and Acuros XB plans was analysed by the paired t-test. P value less than 0.05 is defined as statistical significance.

RESULTS

Table 1 Comparison between AAA and Acuros XB for PTVs. For d_m and AAA, the maximum difference of PTV minimum dose was -7.91%. The maximum difference of $D_{99\%}$ was -6.13%.

	Relative difference (AXB_ D_m -AAA)/AAA*100% Mean \pm Std (min-max)	P value	Relative difference (AXB_ D_m -AAA)/AAA*100% Mean \pm Std (min-max)	P value
PTV				
D 1%	0.80 ± 1.54 (-3.91, 4.43)	<0.0001	2.72 ± 2.03 (-7.49, 9.31)	<0.0001
$D_{95\%}$	0.24 ± 1.75 (-5.69, 3.24)	0.00756	2.28 ± 1.16 (-0.26, 5.68)	<0.0001
$D_{99\%}$	-0.03 ± 1.95 (-6.13, 3.79)	0.34578	2.11 ± 1.22 (-1.36, 5.21)	<0.0001
Min	-0.23 ± 2.41 (-7.91, 5.29)	0.7705	1.91 ± 1.99 (-2.98, 7.17)	<0.0001
Max	0.62 ± 1.74 (-4.52, 4.54)	0.0003	2.74 ± 2.17 (-2.57, 10.75)	<0.0001
Mean	0.74 ± 1.38 (-3.45, 3.41)	<0.0001	2.58 ± 1.33 (-1.29, 7.63)	<0.0001

Table 2 Comparison between AAA and Acuros XB for plan quality. It shows the statistical significance difference between algorithms for CI (p=0.007), HI (p<0.0001) and, coverage (p=0.0140). The maximum differences for CI and coverage are -26.87% and -28%, respectively.

	Relative difference (AXB_ D_m -AAA)/AAA*100% Mean \pm Std (min-max)	P value	Relative difference (AXB_ D_m -AAA)/AAA*100% Mean \pm Std (min-max)	P value
CI	-0.72 ± 9.96 (-26.87, 16.71)	0.007	16.61 ± 8.77 (3.63, 41.06)	<0.0001
HI	0.62 ± 1.73 (-4.52, 4.54)	<0.0001	2.74 ± 2.17 (-2.56, 10.75)	<0.0001
Coverage	-0.67 ± 3.29 (-28.36, 13.40)	0.0140	0.43 ± 1.10 (-0.30, 11.37)	<0.0001

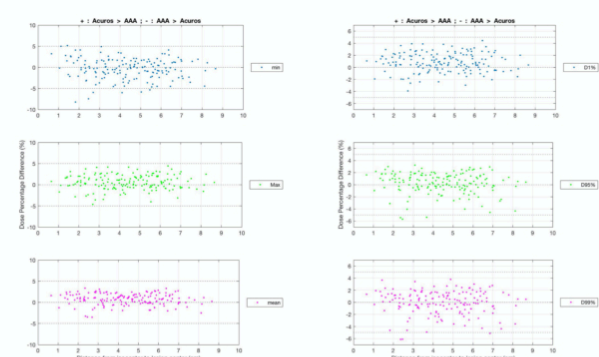


Figure 1 (Left) The scatter plot of dose percentage difference (AXB (D_m), AAA) and distance from isocenter to lesion center for PTV dose. (Right) The scatter plot of dose percentage difference (AXB (D_m), AAA) and distance from isocenter to lesion center for dose to 1%, 95%, and 99% of the PTV.

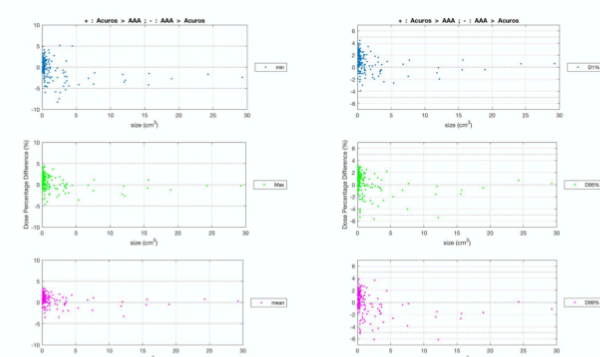


Figure 2 (Left) The scatter plot of dose percentage difference (AXB (D_m), AAA) and size for PTV dose. (Right) The scatter plot of dose percentage difference (AXB (D_m), AAA) and size for dose to 1%, 95%, and 99% of the PTV.

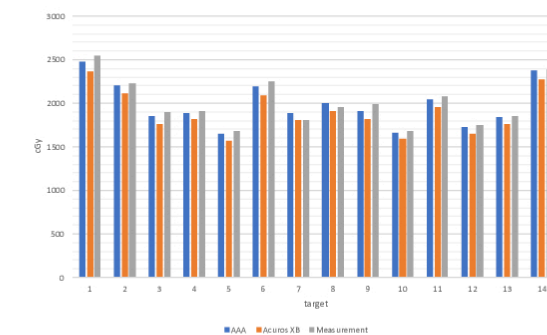


Figure 4 Calculated dose from AAA and Acuros XB and measurement by using SRS MapCHECK.

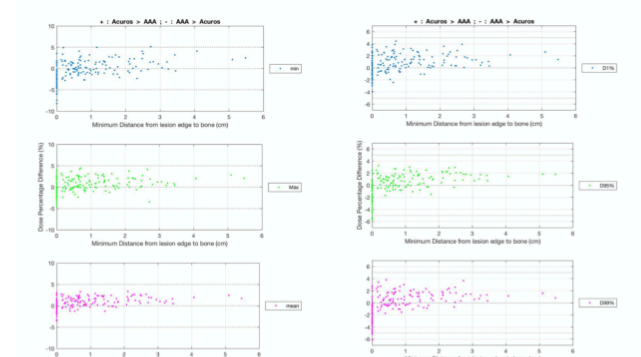


Figure 3 (Left) The scatter plot of dose percentage difference (AXB (D_m), AAA) and minimum distance from lesion edge to bone for PTV dose. (Right) The scatter plot of dose percentage difference (AXB (D_m), AAA) and minimum distance from lesion edge to bone for dose to 1%, 95%, and 99% of the PTV.

Table 4 Gamma passing rates comparing measurement and calculated dose. It shows that the AAA is close to the measurements and better compared to the Acuros XB.

	Gamma Pass Rate(%)		
	Mean	Std	Range
AAA	99.9	0.17	99.4, 100
AXB	97.9	2.11	93.6, 100

CONCLUSIONS

- The results of clinical data showed a significant difference for mean dose, maximum dose, $D_{1\%}$, CI and HI of PTV.
- Sizable dose differences were found in AAA and Acuros XB (D_m), particularly in the PTV minimum dose and PTV coverage.
- Differences between AAA and Acuros XB (D_m) were generally less than differences between AAA and Acuros XB (D_w).
- Heterogeneity and tumor size introduced uncertainty for dose calculation.
- However, the dose difference showed no dependence on the distance from isocenter to lesions.
- The results of the measurement study showed a better agreement with the calculation of AAA than Acuros XB.

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ACKNOWLEDGEMENTS

Thank you very much to my research advisor, Dr. Zhiheng Wang, for your guidance and support in this project. Many thanks to Dr. Justus Adamson for your patience and your answers to my many questions.

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