

Dosimetric evaluation of Acuros XB and AAA on lung volumetric modulated radiation therapy plan for stereotactic body radiation therapy technique

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Abstract

The purpose of this study was to compare the tissue heterogeneity correction of Acuros XB (AXB) and the analytical anisotropic algorithm (AAA) calculation in lung volumetric modulated radiation therapy (VMAT) plan for stereotactic body radiation therapy (SBRT) technique at different calculation grid size. The Gafchromic EBT2 films were used for percentage depth dose measurement with 6 MV photon beam of Varian Clinac iX at single field of 3x3, 5x5 and 10x10 cm² field sizes for validated the basic principle. The central axis depth dose was compared for dose calculation by AXB and AAA algorithm version 11.0.31. Nine cases of lung SBRT technique with 54 Gy in 2 partial arcs of VMAT plan were optimized and calculated by AAA 2.5 mm grid size. The same plan was subsequently recalculated with different algorithms and calculation grid size while maintaining monitor units: AAA 1.25 mm, AXB 2.5 mm and AXB 1.25 mm, respectively. PTV volume of $D_{95\%}$, CI and $R_{50\%}$, lung at $D_{1000\text{ cc}}$ and $V_{20\text{ Gy}}$ and chest wall at $D_{10\text{ cc}}$ were evaluated. The percentage depth dose of standard field showed re-buildup region beyond inhomogeneity interface. No dose differences between grid sizes at the same algorithm were observed. The percentage deviations of percent dose of AXB were lesser than AAA when compared with Gafchromic EBT2 film measurement at 10 cm depth. The $D_{95\%}$ and CI of PTV volume were significantly different between algorithm and calculation grid size but the doses in lung and chest wall were not significantly different. The Gafchromic EBT 2 film measurements confirmed that the AXB was more accurate dose calculation in heterogeneity media than AAA which correlate with other studies. The recalculated plans by AXB demonstrated lower dose in PTV volume because most of PTV volume composed of the lung tissue. However, the dose measurement in clinical cases should be performed in phantom in the future. The AXB is recommended for tissue heterogeneity correction, especially for small lesions embedded in tissue heterogeneity.

Keyword: Tissue heterogeneity correction, Acuros XB, AAA, Lung SBRT

INTRODUCTION

Nowadays, the Volumetric Modulated Arc Therapy (VMAT) is one technique which widely uses in radiotherapy treatment than Intensity Modulated Radiation Therapy (IMRT) in many regions, especially for small lung tumor due to it can decrease the treatment time, reduce the uncertainty caused by breathing and gives higher dose conformity to the tumor. It leads to reduce the high dose to normal tissue.

The stereotactic body radiotherapy (SBRT) has been applied for treatment of small tumor in lung region. It gives the higher dose per fraction to tumor but lesser number of fractions than conventional treatment. Then, the dose at normal structures (lung, chest wall, spinal cord, heart) is carefully determined. However, the dose accuracy in lung with small tumor is quite difficult to estimate due to the electronic disequilibrium. Many treatment planning systems try to develop the algorithm for tissue heterogeneity correction. The Acuros XB (AXB) is one algorithm of Eclipse treatment planning system that has introduced to correct dose in tissue heterogeneity. It uses the Linear Boltzman transport equation for heterogeneity correction in patient dose calculation. There are studies^[1,2] show the dose calculation with AXB more accurate than the Analytical Anisotropic Algorithm (AAA) (previous heterogeneity correction algorithm) and accurate alternative to Monte Carlo.

This study aims to compare the dose accuracy between AAA and AXB algorithms by using Gafchromic EBT2 film to measure dose in phantom. The percentage depth doses (PDD) were compared with different field size and calculation grid size. Subsequently, the lung VMAT plans in SBRT technique were compared between both algorithms and different calculation grid sizes.

MATERIALS AND METHODS

A. Dose evaluation of single field in heterogeneity phantom

The 3D image of 7.5 cm Styrofoam, representing low density, ($\rho = 0.03 \text{ g/cm}^3$) sandwiched between 5 cm solid water phantom, representing water, ($\rho = 1.02 \text{ g/cm}^3$) was scanned with 4-sliced CT scanner (LightSpeed RT GE Medical system, Waukesha, WI, USA). The CT images were transferred to Eclipse treatment planning system (Varian Medical System, Palo Alto, CF, USA) for dose calculation with AXB and AAA algorithm version 11.0.31 at 3x3, 5x5 and 10x10 cm² field sizes and different calculation grid sizes, 1.25 and 2.5 mm, respectively. All dose calculations utilized 6 MV photon beam of Varian Clinac iX (Varian Medical System, Palo Alto, CF, USA) at a source-to-surface distance of 100 cm and 200 monitor unit. The Gafchromic EBT2 films were used for dose measurement. Figure 1 shows the phantom and Gafchromic EBT2 films setup for dose calculation and measurement. The central axis depth dose comparisons

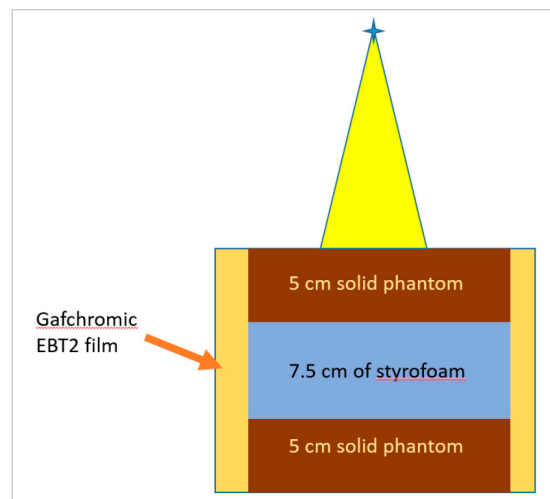


Figure 1 The phantom and Gafchromic EBT2 films setup for dose calculation and measurement for 3x3 cm², 5x5 cm² and 10x10 cm² field size at 100 cm SSD

were determined. The percentage deviations of percent dose from Gafchromic EBT2 film to AAA and AXB at 2.5 mm calculation grid size of 10 cm depth were calculated.

B. Clinical application in lung tumor

Nine cases of peripheral lung SBRT plan were selected to replan with 54 Gy (18 Gy/Fx) in VMAT technique with 2 partial arcs. The average PTV volume was 58.18 cc. The AAA 2.5 mm grid size was used for dose optimization and calculation. This study used the criteria for PTV and organs at risk optimization per protocol RTOG 0813 [3]. Figure 2 shows the parameter setup in the Eclipse treatment planning system for dose optimization. The 95% of PTV volume was covered by the prescription dose. The same plan was subsequently recalculated with different algorithms and calculation grid size while maintaining the same monitor units: AAA 1.25 mm, AXB 2.5 mm and AXB 1.25 mm, respectively. The isodose distribution and DVH parameters were evaluated in term of [3]:

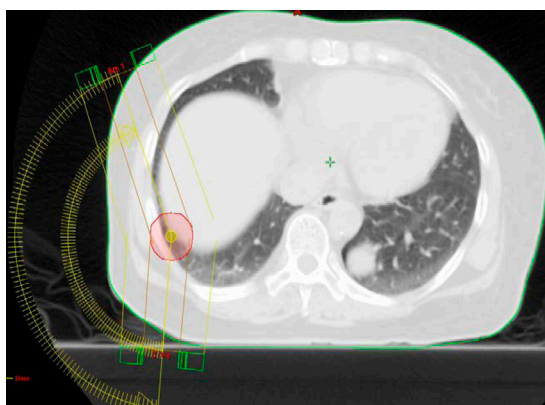


Figure 2. The axial view of sample case for lung VMAT plan with 2 partial arcs in SBRT technique. The parameter setting was 6 MV of photon beam at gantry 340°-185° (CCW and CW) for 6x4 cm² field size

- $D_{95\%}$: the dose to 95% of PTV volume as displayed on dose volume histograms (DVH)
- Conformity Index (CI) : the volume enclosed by the prescription isodose divided by the target volume
- $R_{50\%}$: the ratio of the volume of 50% of prescription dose isodose to the volume of the PTV
- lung at $D_{1000\text{ cc}}$ and $V_{20\text{ Gy}}$ and chest wall at $D_{10\text{ cc}}$

The paired t-test with significant level $p < 0.05$ was used for the test of statistical differences of VMAT plans between AAA-AXB at 2.5 mm for different algorithm and AXB 1.25 mm- AXB 2.5 mm for different calculation grid size.

RESULTS

A. Dose evaluation of single field in heterogeneity phantom

Figure 3 shows the PDD of dose calculation and measurement in each field size. In low density region, the AXB calculations show lesser different to Gafchromic EBT2 film measurement than AAA calculations for all field size. It means that, the AXB is more accurate for dose heterogeneity correction than AAA, which is confirmed by Bush et al. [4]. Table 1 shows the percentage deviation of percent dose from Gafchromic EBT2 film measurement to AAA and AXB at 10 cm depth for 2.5 mm calculation grid size. Small field shows larger percentage deviations of percent dose due to the changes in secondary electron fluence or may be a partial loss of electronic equilibrium; it effects to decrease in absorbed dose. The rebuild up region beyond heterogeneity interface is the same in both algorithms, overestimate than Gafchromic EBT2 film measurement. However, the AAA shows more overestimate than AXB which correspond to the study of Yusuke et al. [5]. The maximum percentage deviations of percent dose for rebuild up region are 17.38 and

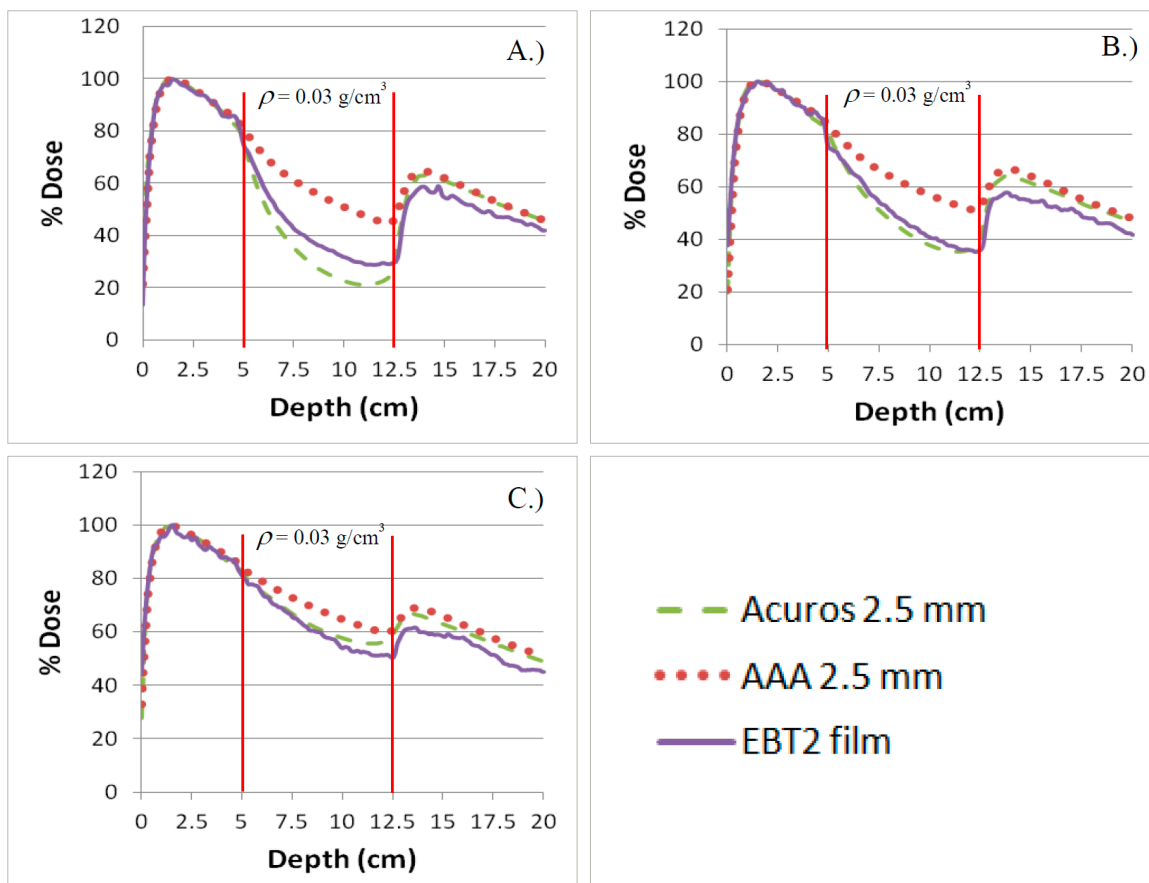


Figure 3 The PDD in heterogeneity phantom between AXB, AAA calculation and measurement at 2.5 mm calculation grid size
(A.) 3x3 cm² field size (B.) 5x5 cm² field size (C.) 10x10 cm² field size

13.04, overestimate than Gafchromic EBT2 film measurement, for AAA and AXB respectively. Figure 4 shows the PDD of dose calculation between different calculation grid size for AXB algorithm at 3x3 cm² field size. No dose differences between calculation grid sizes at the same algorithm are observed for single field which similar to the study of Kroon et al.^[6] studied.

B. Clinical application in lung tumor

Table 2 shows the summary of doses at PTV volume of D_{95%}, CI and R_{50%}, lung at D_{1000cc} and V_{20 Gy} and chest wall at D10cc for nine lung VMAT plans using SBRT technique. The result showed mainly dose differences at PTV volume but the dose in organs at risk were comparable between algorithm (AAA and AXB) and calculation grid size (2.5 and 1.25 mm). Figure 5 shows the isodose distribution and DVH of

Table 1 The percentage deviation of percent dose from Gafchromic EBT2 film to AAA and AXB at 10 cm depth for 2.5 mm calculation grid size

FS (cm ²)	% Dose at 10 cm depth 2.5 mm calculation grid size			% Deviations of %Dose	
	AAA	AXB	EBT 2 Film	AAA- EBT2 Film	AXB- EBT2 Film
3x3	50.87	22.55	31.94	59.27	-29.40
5x5	56.77	37.80	40.67	39.59	-7.06
10x10	64.82	57.84	53.88	20.30	7.35

Table 2 The doses at PTV volume of D_{95%}, CI and R_{50%}, Lung at D_{1000 cc} and V_{20 Gy} and chest wall at D_{10 cc} for nine lung VMAT plans in SBRT technique

Volume	Dose Limit	AAA Grid size (mean ± SD)		Acuros Grid size (mean ± SD)	
		1.25 mm	2.5 mm	1.25 mm	2.5 mm
PTV					
- D _{95%}	54 Gy	(55.33 ± 0.92) Gy	(55.05 ± 0.84) Gy	(52.55 ± 5.90) Gy	(52.01 ± 5.49) Gy
- CI	< 1.2	1.03 ± 0.06	1.02 ± 0.05	0.92 ± 0.21	0.91 ± 0.19
- R _{50%}	< 4.5	3.01 ± 0.48	3.00 ± 0.48	2.88 ± 0.47	2.88 ± 0.46
Lung					
- D _{1000cc}	< 11.5%	(1.70 ± 1.43) Gy	(1.69 ± 1.42) Gy	(1.70 ± 1.52) Gy	(1.68 ± 1.54) Gy
- V _{20 Gy}	10%	(5.55 ± 3.93) %	(5.52 ± 3.91) %	(5.51 ± 3.96) %	(5.52 ± 3.97) %
Chest wall					
- D _{10cc}	< 30 Gy	(38.81 ± 16.26) Gy	(36.87 ± 13.05) Gy	(38.25 ± 16.06) Gy	(38.14 ± 15.99) Gy

PTV volume for the example case. The AAA shows more target coverage to PTV than AXB due to the overestimate on boundaries of the heterogeneous tissue as Yusuke et al.^[5] discussion.

The summary of relative differences between algorithm and calculation grid size were analyzed by using isodose distribution and dose volume histograms. We focused on AAA 2.5 mm-AXB 2.5 mm for different algorithm and AXB 2.5 mm - AXB 1.25 mm for different calculation grid size because the AXB 1.25 mm was used in clinical setting that the heterogeneity needs to

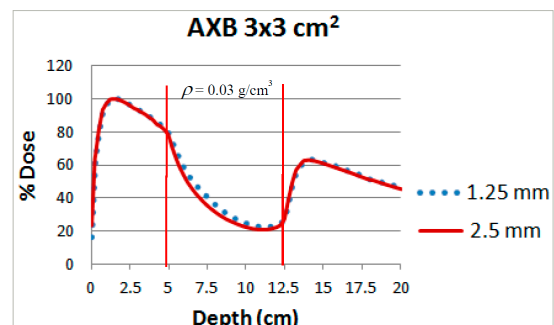


Figure 4. The PDD of dose calculation between 1.25 mm and 2.5 mm calculation grid size for AXB algorithm at 3x3 cm² field size.

Table 3 Relative differences between algorithm (AAA and AXB) and calculation grid size

	Relative differences $\left(\frac{AXB\ 2.5 - AAA2.5}{AAA\ 2.5}\right) \times 100\%$ Average $\pm$ SDV (min-max)	p-value	Relative differences $\left(\frac{AXB\ 1.25 - AXB2.5}{AXB\ 2.5}\right) \times 100\%$ Average $\pm$ SDV (min-max)	p-value
PTV				
- D _{95%}	-5.43% $\pm$ 10.54% (-35.18% to -0.37%)	< 0.05*	0.96% $\pm$ 0.99% (-1.50% to 1.88%)	< 0.05*
- CI	-10.70% $\pm$ 19.84% (-66.37% to -1.00%)	< 0.05*	1.44% $\pm$ 2.92% (-5.26% to 6.25%)	< 0.05*
- R _{50%}	-3.80% $\pm$ 6.93% (-23.19% to 0.51%)	< 0.05*	-0.10% $\pm$ 0.44% (-0.67% to 0.68%)	0.64
Lung				
-D _{1000 cc}	-8.09% $\pm$ 13.68% (-27.78% to -1.39%)	0.96	2.01% $\pm$ 5.33% (-0.59% to 17.00%)	0.35
- V _{20 Gy}	-1.08% $\pm$ 5.67% (-17.04% to 1.80%)	0.18	-0.16% $\pm$ 0.59% (-1.62% to 0.42%)	0.77
Chest wall				
- D _{10 cc}	2.01% $\pm$ 11.55% (-2.24% to 34.85%)	0.50	0.30% $\pm$ 0.49% (-0.19% to 0.97)	0.12

*Significant relative difference tested by two-tailed student t-test

be corrected for small lesion. Table 3 shows the relative differences between algorithm and calculation grid size for lung VMAT plan of SBRT technique. There were significantly differences between algorithms at the 2.5 mm calculation grid size for PTV volume but no significantly differences in organs at risk consideration. The AXB 1.25 mm had significantly higher D_{95%} and CI of PTV volume than AXB 2.5 mm. There was no significantly differences in dose of lung and chest wall for both algorithm and calculation grid size

DISCUSSION

From the basic principle that applied to the clinical data, we showed that the AAA calculation overestimated dose in low density tissue. However, this effect reduced when the field of treatment was larger. These results were confirmed by two studied [4,5]. In addition, the location of tumor may effect to the dose differences

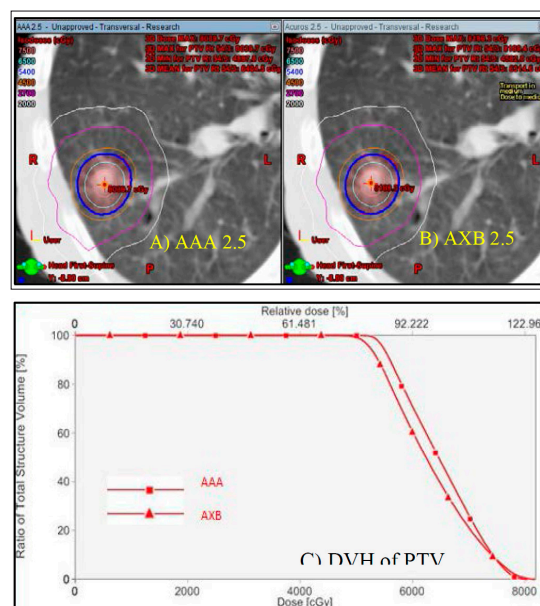


Figure 5. The isodose distribution and DVH of PTV volume for the example case

between algorithm and calculation and grid size as stated by Fogliata et al.^[7]. The recalculated plan by AXB showed lower dose in PTV volume because most of PTV volume composed of the lung tissue that AXB was more accurate. No dose difference in organs at risk was observed between algorithm and calculation grid size due to PTV volume was too small. It is simple to achieve the optimization criteria.

CONCLUSION

AXB is recommended for tissue heterogeneity correction, especially for small lesion embedded in tissue heterogeneity.

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