RESEARCH ARTICLE

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Dosimetric Comparison between Acuros XB (AXB) and Anisotropic Analytical Algorithm (AAA) in Volumetric Modulated Arc Therapy

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Abstract

Aim: Dose calculation accuracy between Anisotropic Analytical Algorithm (AAA) and Acuros XB (AXB) for various megavoltage (MV) photon beams for both flattening filter (FF) and flattening filter free (FFF) beams and to validate the accuracy of these dose calculations using inhomogeneous phantom in volumetric modulated arc therapy (VMAT). **Material and methods:** A Cheese Phantom having 20 holes that can be filled with all virtual water plugs or set of density calibration plugs was used for VMAT planning using two different algorithms using either single or double arc. Further phantom was used irradiate plan in linear accelerator and the point doses measured using a 0.053 cc A1SL ionization chamber along electrometer . Different plans, cylindrical shape, C-shaped and donut targets were planned 6MV, 10MV, 6FFF MV and 10FFF MV beam energy. **Result:** The minimum average mean dose difference was 1.2% for PTV structures between AAA and AXB (p=0.02). Apart from these structures, the following density plugs have a more than 2% difference in maximum dose with statistical significance. (i) Solid water (MD=6.1%, p=0.016), (ii) Bone 200 (2.3%, p=0.029), (iii) CB_30% (MD=2.4%, p=0.050) and (iv) Cortical bone (MD=4.3%, p=0.018). In 6MV FFF and 10 MV FFF plans, the difference between AAA and AXB was not statistically significant (Fig 3). The Conformity index for the AAA less than that of AXB, in all energies and for all the PTVs. The CI was better in AXB than AAA, but the CI was not having much variation due to changes in beam energies, particularly for Cylinder shaped PTV. **Conclusion:** All combinations of beam energy AAA showed higher values in the maximum dose than the Acuros XB, except for the lung insert. Nonetheless, AAA showed a higher mean dose than the Acuros XB. Differences between these two algorithms for most of the beam energies are minimal.

Keywords: Acuros- AAA- algorithm- dose calculation -78

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Introduction

The modern radiotherapy treatments such as volumetric modulated arc therapy (VMAT) require a high accuracy dose calculation (Otto, 2008). The accuracy of the dose calculations in radiation treatment planning systems (RTPS) using different algorithms depends on how correctly calculates the radiation transport in the heterogeneous medium. Many studies compared the accuracy of dose calculation of convolution/Superposition algorithm with the Pencil beam (PB) algorithm (Knöös et al., 2006). One such commercially available convolution/ superposition algorithm is the Analytical Anisotropic Algorithm (AAA) implemented in (Eclipse Version 15.1) External beam treatment planning systems supplied by Varian Medical Systems, Palo Alto, CA, USA (Fogliata et al., 2006). The AAA algorithm accounts using photon scatter kernel in different directions for the tissue heterogeneity anisotropically in three dimensional volumes. The final dose distribution is the resultant of the superposition of photon and electron convolutions. The AAA could improve the dose calculation accuracy over PB in inhomogeneous region. The accuracy of the AAA is not adequate for complex shaped inhomogeneous region dose calculations which need a gold standard Monte-Carlo (MC) dose calculation algorithm (Yan et al., 2017).

To improve the accuracy of dose calculations in heterogeneous region, the MC dose calculation was introduced in radiotherapy. There are various MC codes are available such as EGSnrc, BEAMnrc and DOSEXYZnrc for radiotherapy dose calculations which requires the phase space model for the individual linear accelerators (Rogers et al., 2005). But the Monte Carlo simulations are very much time-consuming which limits the efficiency of treatment planning.

Alternative to MC is to deterministically solve the

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linear Boltzmann transport equation. Several studies were published by many authors based on dose calculations in Acuros XB (AXB) algorithm for implementing in the external beam planning system and the AXB provides fast and accurate dose calculations alternative to MC-based calculations, particularly when heterogeneous tissues are involved, resulting in new strategy (Fogliata et al, 2011; Tsuruta et al., 2014). In the previous study stated that AXB dose calculation accuracy is comparable to MC, but AAA produces errors in heterogeneous regions and in the air cavity regions, the AXB overestimates the dose (Onizuka et al., 2016). Tsuruta et al., 2014 studied the comparison between AXB, MC and AAA for Stereotactic Body radiotherapy (SBRT) in lung cases. In that study, they stated that AXB provided good agreement of within 3% with XVMC than AAA of 4.1% and the calculation time of AXB was faster than MC and concluded that, AXB has a balance for the dosimetric accuracy and calculation time of 221.6 ± 53.1 s (range, 124-358 s), 66.1 ± 16.0 s (range, 42-94 s), and 6.7 ± 1.1 s (range, 5-9 s) for XVMC, AXB, and AAA, respectively. Ojala et al., 2014 studied the comparison of AAA, PBC and AXB. This work suggests AAA or the AXB should be used in lung SBRT for the target volume lesser than 20-25 cc. A Cakir et al., 2019 evaluated and compared the AXB and AAA for nasal cavity, paranasal sinus and breast cases in terms of integral dose and stated that AXB could provide the more accuracy where the high tissue heterogeneity appears and in breast radiotherapy AXB provides a significantly dosimetric improvements and AAA may cause the serious differences in the integral doses on critical organs.

The aim of this study is to evaluate the dose calculation accuracy between AAA and AXB for various megavoltage (MV) photon beams for both flattening filter (FF) and flattening filter free (FFF) beams and to validate the accuracy of these dose calculations using inhomogeneous phantom in volumetric modulated arc therapy (VMAT) for various inhomogeneous inserts. In this study, we created various targets and ring structures to analyse the planning efficiency using Homogeneity Index (HI) and Conformity Index (CI) in the plans calculated by these two algorithms. The novelty in this study was the validation of algorithms with complex targets and critical structures in an inhomogeneous medium which earlier authors were not performed.

Materials and Methods

Phantom Design and CT Simulation

A Tomotherapy Cheese phantom (Gammex RMI, Middleton, WI, USA) with the density of water equivalent was used in this study. It contains a various chamber and film inserts which provides a point dose spatial dose measurements for different positions. This phantom contains different density plugs like Lung 450, Adipose, Breast, Solid Water, Brain, Liver, Inner Bone, Bone 200, CB-30%, CB-50%, Cortical Bone, Lung-300 (Fig 1). This phantom can be used for electron density calibration for dose calculation. The inhomogeneous phantom was aligned with flat couch tabletop and three fiducials were placed at identical positions (right, left and anterior) with the help of lateral and sagittal lasers. The phantom was scanned in dedicated CT scanner (Light speed, GE Healthcare, Milwaukee, WI). The scan was performed in helical mode with head & neck protocol (80mAs, 120 kVp) with a slice thickness of 2.5 mm. These scanned images were exported from the CT console to RTPS with the modality of digital image communication in medicine (DICOM). The phantom images were imported in RTPS (Eclipse Version 15.1, Varian Medical Systems, Palo Alto, USA).

Target, Normal Structure Delineation, and Dose planning

The complex targets and critical structures were created based on American Association of Physicists in Medicine (AAPM) Intensity-modulated Radiotherapy (IMRT) practical guide (Ezzell et al., 2003) and the shapes which were mentioned by V Kaliyaperumal et al., 2017 (Ezzell, 2009). In this study, there were three different complex-shaped targets with ring structures were drawn on inhomogeneous phantom namely a. C shaped target (PTVC) b. cylindrical target (PTVcy) and c. Torus shaped target (PTVT) along with ring structures. A ring structure of 0.5 cm margin and 0.5 cm thickness is drawn for each PTV for reducing the spillage of the dose around the PTVs. The arc geometric tool was used to create the VMAT plan such a way that single arc was used in the for PTVC, PTVCy and double arcs were used in the VMAT Plan for the PTVT due to its complex shape.

The Varian True beam STx (Varian Medical Systems, Palo Alto, USA) linear accelerator has the beam energies of 6 MV, 6FFF, 10 MV and 10 FFF in our centre and these energies were used for the calculation of VMAT plans for both AAA and AXB Algorithms. The optimization was done using Photon Optimizer and calculation was performed with AAA algorithm with the prescription dose of 2 Gy to target and reducing the dose to surrounding structures. The normal tissue objective (NTO) was used to reduce the dose in the critical structure with the penalty of 100. The final dose calculation was performed with the calculation grid size of 2.5mm. Similarly, the plan was re-calculated using the AXB algorithm with the same arcs, MU, dose prescription, grid size. There are two modes are available for dose calculation in AXB algorithm 1. Dose to water and 2. Dose to medium. In this study, all the dose calculations were performed using dose to medium option along with heterogeneity correction was on.

Plan Evaluation

The plan evaluation was performed based on target coverage which was dose received by 95 % of target volume (D95%), Homogeneity index (HI) and conformity index (CI). The HI is defined in International commission on Radiation Units and Measurements (ICRU) report No. 83 (2010) using the following Eqn, (1)

$$Homogeneity\ Index\ (HI) in\ \% = \frac{(D2\% - D98\%)}{D50\%}\ x\ 100 \qquad (1)$$

Where, D2%- dose received by the 2% target volume; D98%- dose received by the 98% target volume; D50%- dose received by the 50% target volume.

The HI denotes the homogenous dose distribution on

the plan. If the HU value is less, then the plan is stated that more homogenous and vice versa. The Ideal value of HI is 0.

The CI is broadly splitted into two 1. Radiation therapy oncology group (RTOG) CI (Shaw et al, 1993) and Paddick CI (Paddick, J 2000). The RTOG CI is defined using the equation (2):

$$Conformity\ Index(RTOG\ CI) = \frac{prescrption\ isodose\ volume}{Target\ volume} \quad (2)$$

The ideal value of RTOG CI is 1. Normally, the plan which has the RTOG CI value between 1 and 2 is accepted for treatment and if it is exceeding the value of 2 then the plan is not accepted. The discrepancy in the RTOG CI is the dose spillage which is going outside the target volume cannot be taken into consideration. Due to the above limitation, the CI was proposed by Paddick et al (2000) and stated that the CI (Equation 3) represents an attempt to measure objectively how well the dose distribution of radiation follows the shape of the target.

$$Conformity\ Index(Paddick\ CI) = \frac{TV\ PIV\ X\ TV\ PIV}{TV\ X\ PIV} \quad (3)$$

Where TV_{PIV} is the volume of the target covered by the prescription isodose. PIV is the Prescription isodose volume in the total body. TV,volume of the target.

The ideal value of Paddick CI was 1. Normally a conformal plan will have the Paddick CI value more than 0.85.

Delivery Verification

The plans were selected based on the plan evaluation process. These selected plans were executed in linear accelerator with planned condition, i.e., the same inhomogeneous phantom with density plugs which were used in CT simulation. Initially the fiducials were aligned with in-room laser and the isocenter co-ordinates were transferred as per planning. The pre verification imaging was done and it was co-registered with reference images to verify the phantom position. The cylindrical chamber with the volume of 0.053 cc (A1SL Extradin, Standard Imaging, Middleton, WI, USA), along with the inhomogeneous phantom was used to measure the point doses within target regions as well as normal tissue regions for the corresponding energies.

Statistical Analysis

The dosimetric comparison between AAA and AXB for various density plugs were evaluated using the descriptive statistics and two tailed students t-test. The above test (students t-test) was used to compare the HI and CI for AAA and AXB. The significance level was set as 0.05 which means the p-value which was less than 0.05 could provide the mean difference between two samples were statistically significant. The statistical analysis was done using IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, N.Y., USA).

Results

For 6MV, the maximum difference in the maximum dose between AAA and AXB was found in the 15_SS density plug (23.3%) and it was statistically significant (p=0.035). The average mean dose difference also was found in the same density plug (15_SS, MD=24.4%, p=0.014%). The minimum difference for the average maximum dose was found in the breast density plug but it has statistically insignificant (MD=0.3%, P=0.663). The minimum average dose difference in mean dose was observed in the PTV structure which has a 1.2% difference between AAA and AXB (p=0.02). Apart from these structures, the following density plugs have a more than 2% difference in maximum dose with statistical significance. (i) Solid water (MD=6.1%, p=0.016), (ii) Bone 200 (2.3%, p=0.029), (iii) CB_30% (MD=2.4%, p=0.050) and (iv) Cortical bone (MD=4.3%, p=0.018). The average mean dose difference which have more than 2% was found in the following structures in 6MV (i) Breast (MD=2.3%, p=0.050), (ii) Solid water (MD=8.2 %, MD=0.01), Brain (MD=3.9%, p=0.001), (iii) Inner-

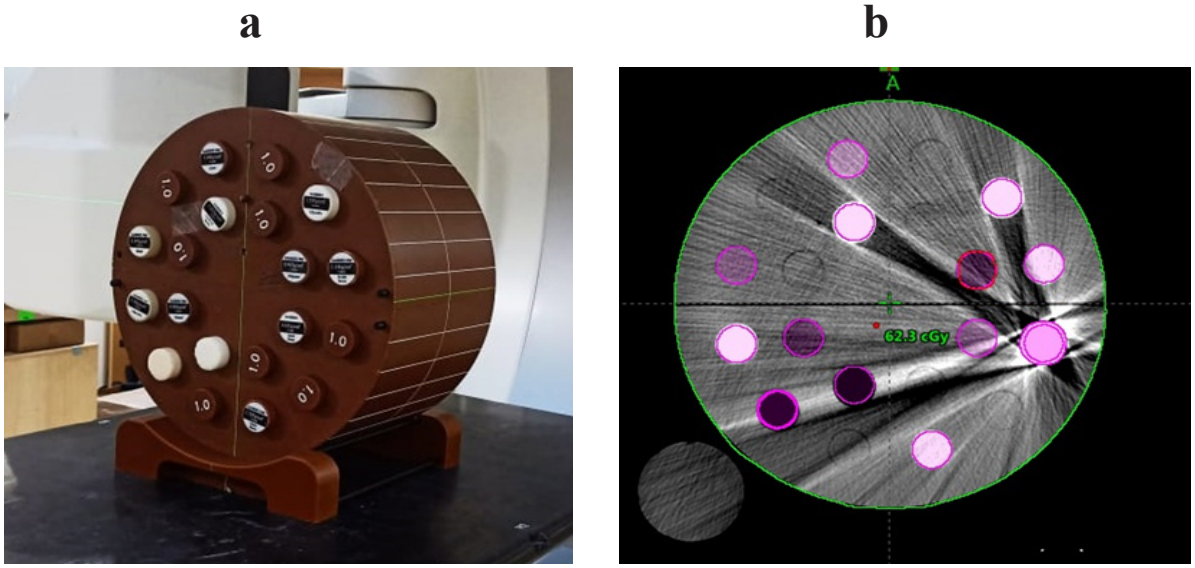

Figure 1. a, Cheese Phantom with density plugs; b, CT Scan Image of Cheese Phantom with density Plugs

Table 1. The Maximum and Mean Dose Difference between AAA and Acuros XB algorithm-based Plans for 6MV with Various Density Plugs

Inhomogeneous Structures	Max Dose (cGy)				Mean Dose (cGy)			
	AAA	Acuros XB	Mean Diff (%)	P value	AAA	Acuros XB	Mean Diff (%)	P value
LUNG-450	71.1	72.1	-1.4	0.172	26.1	25.4	2.6	0.063
ADIPOSE	169.2	166.7	1.5	0.158	63.7	62	2.6	0.093
BREAST	152.5	152	0.3	0.663	53.9	52.6	2.3	0.051
SOLID WATER	155.5	146	6.1	**0.016**	55.9	51.4	8.2	**0.010**
BRAIN	96.8	94.9	1.9	0.113	34.6	33.2	3.9	**0.001**
LIVER	84.4	82.6	2.1	0.131	29.1	28.2	3	0.340
INNER-BONE	64.1	63	1.8	**0.006**	23.3	22.5	3.2	**0.050**
BONE200	86.4	84.4	2.3	**0.029**	32.6	31.5	3.2	**0.028**
CB-30%	87.1	85	2.4	**0.050**	32.6	31.3	3.9	**0.043**
CB-50%	82.9	70.7	14.8	0.364	31.5	30.2	4.3	**0.034**
CORTICAL BONE	171.7	164.4	4.3	**0.018**	62.1	58.4	5.9	0.069
LUNG-300	130	131.7	-1.3	0.402	53.9	52.8	1.9	0.202
15_SS	94.1	72.2	23.3	**0.035**	33.7	25.5	24.4	**0.014**
PTV	209.7	208.8	0.4	0.253	200.5	198.2	1.2	**0.020**

AAA, Anisotropic Analytical algorithm; SS, Stainless Steel

Bone (MD=3.2%, p=0.050), (iv) Bone 200% (MD=3.2%, p=0.028) and (v) CB-30% (MD=3.9%, p=0.043 (Table 1). In 6MV FFF, the average maximum difference between AAA and AXB was observed in 15_SS density plug (MD=20.9%, p=0.041) and in maximum difference in mean dose was also found in the same plug (MD=23.1%, p=0.027). The Solid water density plugs were more than 2% mean difference (MD=5.3%, p=0.039) variation between AAA and AXB algorithm. All other density plugs have less than 2% maximum dose difference or the difference was statistically insignificant. While analyzing the mean dose difference, the following density plugs were observed more than 2% difference with statistically significant between AAA and AXB. (i) Breast (MD=3.3%, p=0.049) (ii) Brain (MD=4.2%, p=0.021), (iii) Inner-Bone (MD=3.9%, p=0.05) (iv) Bone200 (MD=3.4%, p=0.034) (v) CB-50% (MD=3.3%, p=0.042) (Table 2).

In 10MV, the maximum difference in the average maximum dose and mean dose was observed in 15_SS and it has a difference of 15.1% (p=0.003) and 17.2% (p=0.008) respectively when comparing AAA and AXB. The average maximum difference which has more than 3% was observed in the following plugs. (i) Solid water (MD=6.3%, p=0.037), (ii) CB-30% (MD= 3.2%, p=0.026). In mean dose, the following plugs were more than 3% dose difference between AAA and ACUROS XB algorithms. (i) Solid water (MD=8.0%, p=0.041) (ii) Brain (MD=3.3%, p=0.014) (iii) CB-30% (MD=4.4%, p=0.02

Table 2. The Maximum and Mean Dose Difference between AAA and ACUROS Algorithm-based Plans for 6MV FFF with Various Density Plugs

Inhomogeneous Structures	Max Dose (cGy)				Mean Dose (cGy)			
	AAA	Acuros XB	Mean Diff (%)	P value	AAA	Acuros XB	Mean Diff (%)	P value
LUNG-450	76.1	77	-1.2	0.082	27.6	26.6	3.6	0.058
ADIPOSE	168.7	166.8	1.1	0.081	62.7	61	2.8	0.069
BREAST	140.5	140.8	-0.2	0.803	50.7	49	3.3	**0.049**
SOLID WATER	150.3	142.3	5.3	**0.039**	51.8	47.6	8.1	0.087
BRAIN	92.3	91	1.4	**0.050**	32.8	31.4	4.2	**0.021**
LIVER	90.5	88.6	2.1	0.139	30.5	29.3	3.9	0.076
INNER-BONE	69.1	67.9	1.8	**0.001**	23.4	22.5	3.9	**0.050**
BONE200	90.8	88.9	2.1	**0.060**	32.3	31.2	3.4	**0.034**
CB-30%	83.2	81.5	2.0	**0.008**	29.9	28.8	3.8	0.077
CB-50%	89.2	88.3	1.0	0.076	31.3	30.2	3.3	**0.042**
CORTICAL BONE	172.6	166.7	3.4	0.101	61.6	58.5	5.1	0.068
LUNG-300	134.3	134.6	-0.2	0.764	52.9	52	1.6	0.100
15_SS	86.1	68.2	20.9	**0.041**	29.8	22.9	23.1	**0.027**
PTV	209.2	210.1	-0.4	0.264	199.9	197.7	1.1	**0.005**

AAA, Anisotropic Analytical algorithm; FFF, Flattening filter free; SS, Stainless Steel

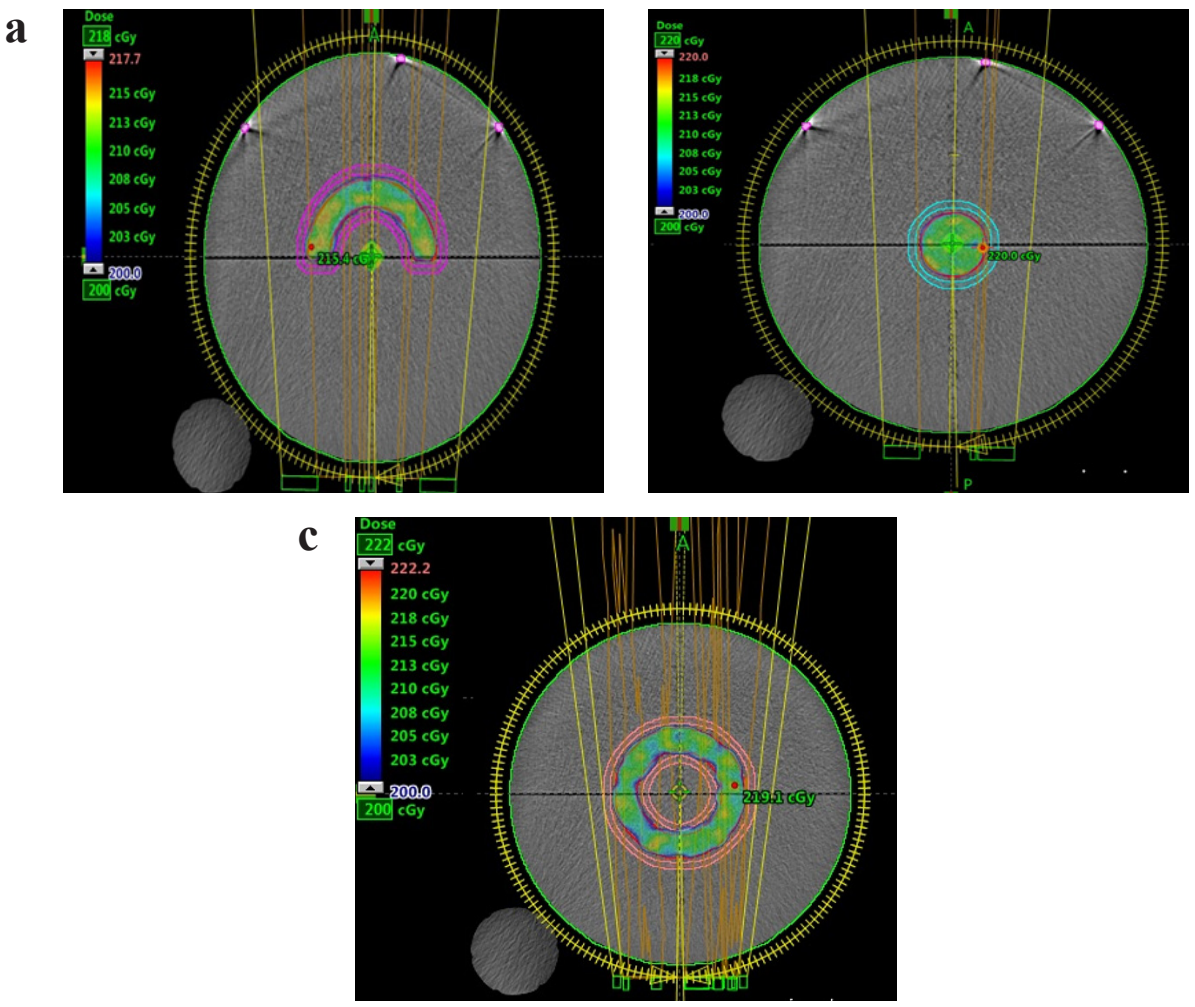

Figure 2. a, Cylinder shaped PTV and dose distribution; b, C shaped PTV and dose distribution; c, Torus shaped PTV and dose distribution

and (iv) CB-50% (MD=3.2%, p=0.034) (Table 3). In 10 MV FFF, the maximum difference in average maximum dose was found in CB-30% density plug (MD=2%) with statistically significant (p=0.007) and the other density plugs were less than 3% or the results were statistically insignificant. The maximum difference in average mean

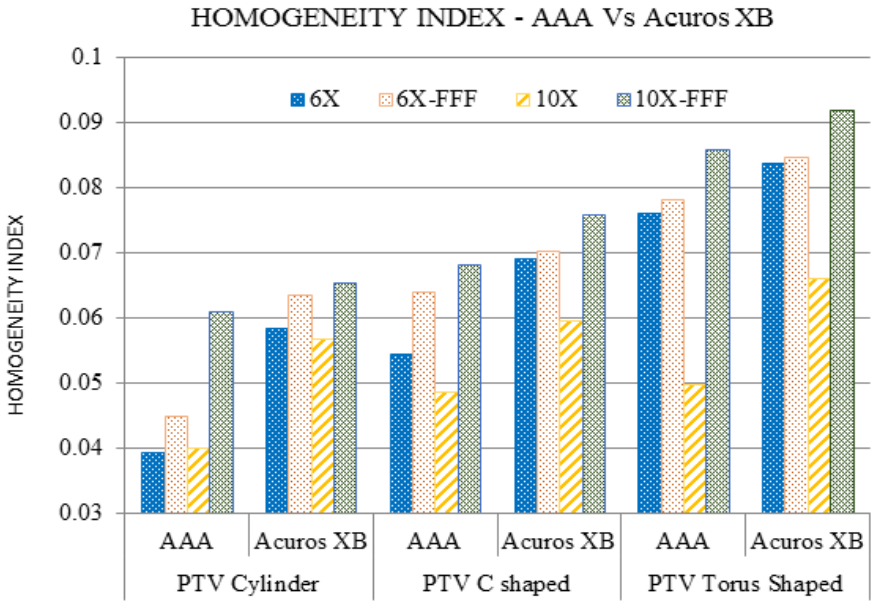

Figure 3. Homogeneity Index for Various Targets for 6MV, 6MV FFF, 10 MV and 10MV FFF with AAA and ACUROS based Plans

Table 3. The Maximum and Mean Dose Difference between AAA and Acuros XB Algorithm based Plans for 10MV with Various Density Plugs

Inhomogeneous Structures	Max Dose (cGy)				Mean Dose (cGy)			
	AAA	Acuros XB	Percentage difference	P value	AAA	Acuros XB	Percentage difference	P value
LUNG-450	73.8	73.2	0.8	0.369	27.8	27.2	2	**0.033**
ADIPOSE	168	166.5	0.9	0.129	66.3	65.1	1.9	0.115
BREAST	144.4	142.5	1.3	0.014	53.3	51.8	2.8	**0.020**
SOLID WATER	148.6	139.3	6.3	**0.037**	55.3	50.9	8	**0.041**
BRAIN	87.6	85.9	1.9	**0.032**	34.6	33.4	3.3	**0.014**
LIVER	92.3	90.5	2	0.129	31.6	30.6	3.2	0.102
INNER-BONE	71.1	69.7	2	**0.050**	26.1	25.5	2.4	**0.017**
BONE200	91.6	89.3	2.6	**0.003**	34.5	33.6	2.4	**0.049**
CB-30%	74	71.6	3.2	**0.026**	27.1	25.9	4.4	**0.020**
CB-50%	91.1	89.4	1.9	0.151	34.4	33.3	3.2	*0.034*
CORTICAL BONE	170.6	166.1	2.7	**0.008**	65.3	62.5	4.3	0.074
LUNG-300	132.4	133.2	-0.6	0.574	57.8	57.5	0.6	0.280
15_SS	90.4	76.7	15.1	**0.003**	32.2	26.6	17.2	**0.008**
PTV_Target	208.5	208	0.2	0.136	200.1	197.7	1.2	**0.007**

AAA, Anisotropic Analytical algorithm; SS, Stainless Steel

dose was observed in Solid water density plug (MD=6.3%, p=0.013%). The maximum difference for mean dose was found in Solid water density plug (MD=6.3%, p=0.013). The average dose difference with more than 3% was observed in brain (MD=3.5%, p=0.036) and CB-30% (MD=3.3%, p=0.031) (Table 4).

The max doses and mean doses of the different plugs having many variations in plugs of higher densities above 1.0 gm/cc and not much variation in the plugs of lesser densities below 1.0 gm/cc.

The HI (fig-3) for the AAA based plans was higher in all the different shaped target plans except 10MV FFF torus target. In 6MV, the mean difference in HI was 1.9, 1.46 and 0.76 for Cylindrical, C shaped and Torus target respectively. For 10MV, the mean HI difference was 0.45, 0.77, and 2.68 for Cylinder, C shaped and Torus target respectively. In 6MV FFF and 10 MV FFF plans, the difference between AAA and AXB was not statistically significant (Figure 3). The CI (Figure 4) for the AAA less than that of AXB, in all energies and for all the PTVs. The CI is better in AXB than AAA, but the CI is not having much variation due to change in beam energies particularly for Cylinder shaped PTV.

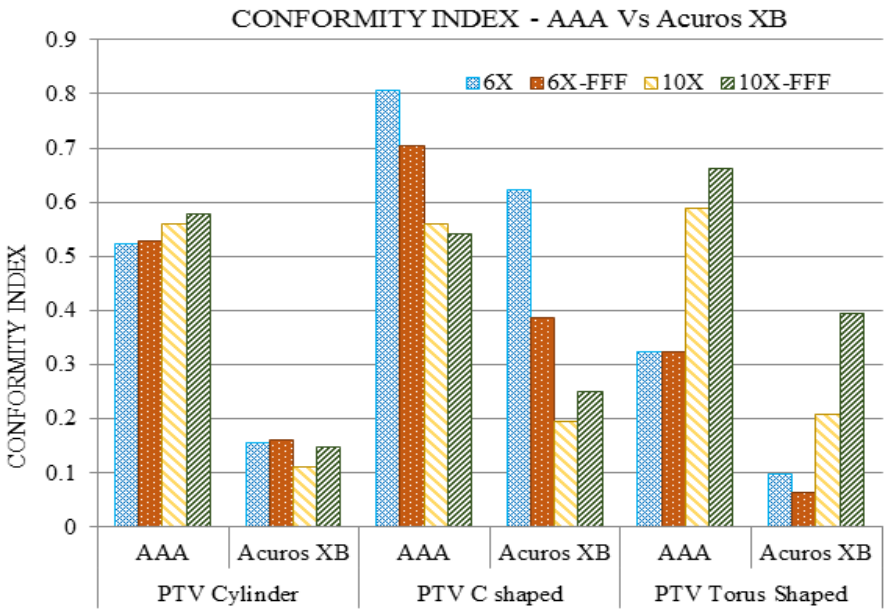

Figure 4. Conformity Index for Various Targets for 6MV, 6MV FFF, 10 MV and 10MV FFF with AAA and ACUROS based Plans.

Table 4. The Maximum and Mean Dose Difference between AAA and Acuros XB Algorithm based Plans for 10MV FFF with various Density Plugs

Inhomogeneous Structures	Max Dose (cGy)				Mean Dose (cGy)			
	AAA	Acuros XB	Mean Diff (%)	P value	AAA	Acuros XB	Mean Diff (%)	P value
LUNG-450	75.4	76.1	-1	**0.002**	25.7	25.2	2.1	**0.016**
ADIPOSE	171	168.4	1.5	0.189	58.6	57.1	2.6	0.098
BREAST	142.8	143.3	-0.3	**0.050**	48.8	47.7	2.1	**0.049**
SOLID WATER	147.5	145.9	1.1	0.363	48.5	45.5	6.3	**0.013**
BRAIN	82.8	82.3	0.5	0.816	28.7	27.7	3.5	**0.036**
LIVER	76.8	75.4	1.8	0.116	25.2	24.1	4.5	0.068
INNER-BONE	73.7	72.6	1.4	0.647	22.5	21.8	3	0.393
BONE200	78.6	77.6	1.2	**0.024**	26.5	25.6	3.3	0.077
CB-30%	83.9	82.3	2.0	**0.007**	29	28	3.3	**0.031**
CB-50%	92.9	92	1.0	**0.038**	47	30.3	35.5	0.07
CORTICAL BONE	171.6	166.2	3.1	0.651	57.4	54.5	5.1	0.414
LUNG-300	133.1	132.8	0.3	0.219	72.1	48.2	33.1	0.103
15_SS	83.8	75.4	10	0.43	27.6	22.5	18.4	0.255
PTV_Target	212.8	210.4	1.1	0.505	203.7	197.9	2.9	0.066

AAA, Anisotropic Analytical algorithm; FFF, Flattening filter free; SS, Stainless Steel

Discussion

In our study, we were compared the doses between AAA and AXB algorithms for the different density plugs and the PTVs of different shapes. We observed that the mean doses of different density plugs were lesser in AXB than AAA. The p values for HI for various target shapes (Cylinder, C Shape and Torus) for the energies of 6 MV, 6 MV FFF, 10 MV and 10 MV FFF calculated using AAA and AXB was 0.05, 0.125, 0.014, and 0.0472 respectively. In an earlier study by Vassilieve et al., 2008 discussed that the Grid Based Boltzmann solvers methods such as AXB with faster calculation times. However, AXB is still clinically relevant and this indicates that AXB may be well suited for optimization, where rapid calculation times are desired with clinically relevant accuracy. In their earlier study, they observed calculation time for Acuros is less than 5 min when compared to Attila having calculation time 19.6 min and 16.1 min for head and neck and prostate respectively.

In our Observation also, the calculation time for the AXB calculation was faster when compared to that of the AAA. Kumar et al., 2019 was investigated and studied about validation of AXB algorithm using ion chamber measurements in fabricated phantom along with dose calculation. From their study, they revealed that the AXB calculations were superior to AAA in low density region as well as in predicting doses beyond racemosa (to evaluate the radiological properties of racemosa wood for simulating the human lung)-PMMA interface, rebuild-up region. Zhenia et al., (2022) showed significant variation in the dose calculation between AAA and AXB for two different site of prostate and lung. They showed that for lung plans, the mean dose to PTV in the AXB-Dw plans was higher by 1.7% and in the AXB-Dm plans by 0.66% when compared to AAA plans. Also they showed that for prostate plans, the mean dose to PTV in the AXB-Dw plans was higher by 3.0% and in the AXB-Dm plans by 1.6% when compared to AAA plans. Bouyer et al., (2017) observed that the localizations on patient treatment planning, a mean loss of about 2% in PTV coverage was found with the algorithm Acuros XB with doses holes phenomena in air and/or in bone. They suggested that there would be an increase of delivered dose if there were no prescribed dose or coverage objectives adaptation, after the final dose calculation with AXB. Either in bone or in air cavity, decreases in PTV dose coverage for patients were in agreement with observations on phantoms. In their observation, the mean difference in dose coverage to PTV was in good agreement with the film measurements; they found mean dose difference of 1.8% and 2.6% for AXB and AAA in bone phantoms. They pointed out that the AXB algorithm was extremely sensitive to a small HU variation (HU correction, mean of -958 before correction against -1,000 after correction).

In our study, similarly, we observed that there was under dose in the central part of All PTVs area for the recalculated plans using AXB, for this reason plans were needed to reoptimize to build-up the doses in those under dose areas. Otherwise in actual patient treatment scenarios, this will lead to less dose deposition than the total planned tumour dose for entire course of the treatment.

Kaliyaperumal et al., (2017) used AAA for dose calculation in simple geometry as well as in IMRT. Dose difference in simple geometry was less than 1.5% and 1.2% for IMRT (phantom and patient) cases except in build-up region. Tajaldeen et al., (2019) observed that the AXB algorithm was better than the AAA as regards the investigation of the three treatment techniques (VMAT, IMRT, 3DCRT). They also shown as results of the indices used to compare the treatment plans (CI, HI and dose fall-off), the AXB demonstrated lower values for all these three parameters. In our study also observed similar results that the AXB has lesser value of CI and higher HI, when

compared to that of AAA. This was similar to the findings by Liu et al., (2013), when compared to AAA, small and significant dose distribution in the target was found in AXB algorithm, resulting in lower conformity (-2.1, $p<0.0001$) and higher heterogeneity ($p<0.0001$) of dose .

Sri Krishna et al., (2016) showed that there is more overestimation of PTV dose in AAA when compared to AXB. Our studies also showed the similar pattern of PTV coverage in AAA compared with AXB. Nonetheless, AAA showed higher mean dose than the Acuros XB. The highest relative mean dose difference was found for the lung-300 insert for 10FFF beam. Measurement result was not uniform over the beam energies, does not yield similar result for different inserts shows a dependency of the mean dose on the beam energy. Most unstable measurement results are observable for the stainless steel inset often appear as a prosthesis on implanted patients and while using the high energy for the spare density lung.

In conclusion, Our study showed the maximum difference between AAA and Acuros XB was found in steel insert and it's statistically significant for 6MV, 6MVFFF, and 10MV beam. All combination of beam energy AAA showed higher value in the maximum dose than the Acuros XB, except for the lung insert. Both lung inserts LUNG-450 and LUNG-300. In our study we have observed that the coverage in the PTV with AAA has good coverage and it is obvious that the AAA algorithm overestimate the dose deposition in the tumour area, which will lead to under dosage of the tumour and will affect the tumour control probability, when compared to AXB algorithm.

Author Contribution Statement

Concept and data collection by S. Sriram Prasath, Guidance and supervision by P. Ramesh Babu; Manuscript evaluation and modification by S. Sriram Prasath and P. Ramesh Babu

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This study is not involved with any patient related data studies, only phantom data has been analysed. No Ethical committee approval is not required.

Any conflict of interest

Authors declares no conflict of Interest

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