

Role of Anisotropic Analytical Algorithm and Acura's XB Algorithm in the Treatment of Breast Cancer using Volumetric Modulated Arc Therapy Technique

Anisotropic
Analytical Algorithm
and Acura's XB
Algorithm in Breast
Cancer

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ABSTRACT

Objective: To compare and analyses the dosimetric parameters between the anisotropic analytical algorithm and acruos XB (AXB) algorithm in volumetric modulated arc therapy plans for breast cancers

Study Design: Retrospective study

Place and Duration of Study: This study was conducted at the Warith International Cancer Institute, Al Thaqalyn Cancer Hospital Iraq, from 1st January 2025 to 30th June 2025.

Methods: 30 women with left-sided breast cancer were enrolled. All the patients underwent for treatment by volumetric modulated arc therapy technique, where planning target volume dose calculation was using anisotropic analytical algorithm and acruos XB algorithms of the same optimisation parameters. The prescription doses to the target ranged between 4000 cGy and 5000 cGy.

Results: There is a highly significant difference between anisotropic analytical algorithm and acruos XB calculations, where P-value was less than 0.05. For planning target volume 95% (breast), the calculation of the mean doses with anisotropic analytical algorithm and acruos XB were 93.58% and 94.83%, respectively (P=0.001). As well as, For planning target volume 90% (breast), the calculation of the mean doses with anisotropic analytical algorithm and acruos XB were 97.52% and 98.02%, respectively (P=0.01). At the same time, the mean dose of the PTV 10.7% (breast) was 9.33% and 13.36% for anisotropic analytical algorithm and acruos XB respectively (P=0.003). There are no significant differences between anisotropic analytical algorithm and acruos XB of the Boost cases and of the organ at risk.

Conclusion: There is significant difference between anisotropic analytical algorithm and acruos XB calculation for breast cancer therapy. The dose delivered using acruos XB was higher than the anisotropic analytical algorithm while no significant difference was between anisotropic analytical algorithm and acruos XB analyses calculated using Boost. At the same time, no significant difference was between anisotropic analytical algorithm and acruos XB analyses calculated using volumetric modulated arc therapy with regard to lymph nodes and organs at risk (heart, lung, and spinal cord).

Key Words: Volumetric modulated arc therapy, Acruos XB, Anisotropic analytical algorithm, Breast cancer.

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INTRODUCTION

Recent advancements in radiation therapy, particularly volumetric modulated arc therapy (VMAT) and anisotropic analytical algorithm (AAA), have

significantly improved the treatment of larynx, rectum, and breast cancers¹. VMAT improved precision and efficiency by optimizing dose administration while safeguarding healthy tissue². The AAA enhanced its dose calculation using sophisticated modelling techniques^{3,4}. This comparative study, supported by patient data, provides insights into calculation algorithms, with the objective of enhancing therapy results for patients with laryngeal, rectum, and breast cancers the optimization of VMAT and the selection of appropriate dosage^{5,6}. The AAA method, renowned for its precision and widespread application in radiation treatment planning, exhibits limitations due to its exclusive reliance on tissue density parameters, thereby overlooking the critical factor of elemental composition^{7,8}. This impacts its accuracy in regions with differing tissue densities and implanted materials possessing high atomic numbers⁹. Acruos XB (AXB) is

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a sophisticated method that directly addresses the linear Boltzmann transport equation, providing Monte Carlo-level precision with greater efficiency¹⁰. AXB enhances AAA by dividing dose calculation into two stages: modelling the radiation beam within the accelerator head and subsequently calculating the dose distribution in the patient^{11,12}. AXB's distinctive characteristic is its comprehensive analysis of the elemental composition of tissues, integrating voxel geometry with mass density and material composition derived from CT scans. This guarantees elevated precision in varied density settings¹³. AXB primarily computes dose-to-medium but can convert it to dose-to-water, hence introducing some uncertainty^{14,15}. Nonetheless, dose-to-medium continues to be favored for treatment assessment and outcome analysis, with ongoing investigations into optimal clinical dosage reporting methodologies¹⁶.

METHODS

This retrospective study was conducted at Warith International Cancer Institute, Al Thaqalyn Cancer Hospital Iraq from 1st January 2025 to 30th June 2025 vide letter No. 32525/QM/Approval/54FG4 dated 14th December 2024. It was as part of the assessment of the. Thirty patients with left breast cancer represent the number of female samples between 35 to 55 years were enrolled. The heights were between 155 and 170 cm, as well as having weights from 50 to 85 kg. The left cancer patients with chemotherapy were included. The right breast and lung tumors, patients less than 35 years of age, large peripheral tumors located far from the heart and spinal cord, and tumors invading other organs such as the heart or vertebrae were excluded. All the patients underwent VMAT treatments with dual arc using AAA calculation, and then the dose plans of the same patients was calculated using AXB of the same optimisation parameters. This assessment utilized the institutional protocol's dose constraints, addressing both PTV coverage criteria and doses to Organs At Risk (OAR). The Prescription doses were 4000 cGy to 5000cGy for 30 patients in general most tumors detected early are between 1-3 cm (approximately 1-15 cm³), in advanced cases (before surgery or chemotherapy) the tumor may reach 50-200 cm³ or more. The volume of the PTV varied; the doses to OAR such as the maximum dose to the spinal cord PRV and total lung (V20 and V16 were the relative volumes of total lung receiving 20 Gy and 16 Gy, respectively). The dose calculations between AAA and AXB techniques depends on the treatment covered to the target area, it has closely matched to the shape of the target that was determined by CT-scan, and on the distribution of the dose within target area. At the same time, it depends on the doses received by sensitive areas like the spinal cord, heart and lung. The data was analyzed through SPSS-25. The significant difference depends on the evaluation using the paired t-test for the

difference between paired observations. The p-value was considered statistically significant when it was less than 0.05.

RESULTS

The mean averages of age was 42.25±4.5 years, height was 159.65±4cm and weight of 65.5±4.75kg. There is a highly significant (P<0.05) difference between AAA and AXB. For PTV 95% (breast), the mean doses with AAA and AXB were 93.58% and 94.83%, respectively (P=0.001). As well as, For PTV 90% (breast), the mean doses with AAA and AXB were 97.52% and 98.02%, respectively (P=0.01). At the same time, the mean dose of the PTV 107% (breast) was 9.33% and 13.36% for AAA and AXB, respectively (P=0.003) [Table 1, Fig. 1].

It was showing that there is no significant (P>0.05) differences AAA and AXB. For PTV 95%, the calculation of the mean doses with AAA and AXB were 95.25% and 95.1% respectively (P=0.312). For PTV 90%, the mean doses with AAA and AXB were 99.03% and 98.69% respectively (P=0.658). At the same time, the mean dose of the PTV 107% was 2.4% and 11.23% for AAA and AXB, respectively (P=0.295) [Table 2, Fig. 2].

Table 3 compared radiation doses to OAR from VMAT plans using AAA and AXB, showing no significant (P<0.05) differences for lung, heart and spinal cord maximum. The lung V20 maximum doses with AAA and AXB averaging 24.38% and 24.38% respectively (P=1). Lung V16 doses also showed negligible difference, with a mean of 29.28% for AAA and 29.26% for AXB (P=0.091). At the same time, the dose of the lung mean was 12.56% and 12.3% for AAA and AXB, respectively (P=0.57). Similarly, the dose of the heart mean was 2.27% and 2.69% for AAA and AXB, respectively (P-value= 0.133) while the dose of the spinal cord maximum was 12.48% and 12.12% for AAA and AXB calculations, respectively (P-value= 0.876) [Fig. 3].

Table No. 1: Comparison between AAA and AXB algorithms calculation for breast and lymph node within 15 fractions

Organ ID	Dose (cGy) AAA%	Dose (cGy) AXB	P-value
PTV95% (breast)	93.58±2.373	94.83±1.75	0.001
PTV 90% (breast)	97.52±2.16	98.02±1.76	0.01
PTV 107 (breast)	13.36±0.842	9.33±1.123	0.003
PTV 95% (LN)	95.48±3.89	94.1±5.55	0.616
PTV 90% (LN)	98.31±2.36	98.1±2.893	0.356
PTV 107 (LN)	6.28±0.562	3.42±0.894	0.42

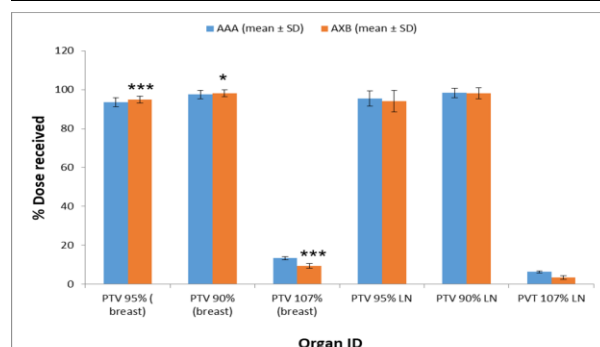


Figure No. 1: Comparison of the dose received by breast and lymph nodes (Dose 4000 cGy) of the breast cancer therapy between the two calculations algorithms (AAA and AXB). *Significant difference at p-value level equal to or less than 0.05.

Table No. 2: comparison between AAA and AXB algorithms calculation for breast within 5 fractions (Boos) dose1000 cGy; after 15 fractions (for breast and lymph node)

Organ ID	Dose (cGy) AAA%	Dose (cGy) AXB	P-value
PTV 95% (Boost)	95.25±2.426	95.1±2.992	0.312
PTV 90% (Boost)	99.03±1.304	98.69±2.218	0.658
PTV 107% (Boost)	2.4±0.658	1.23±0.314	0.295

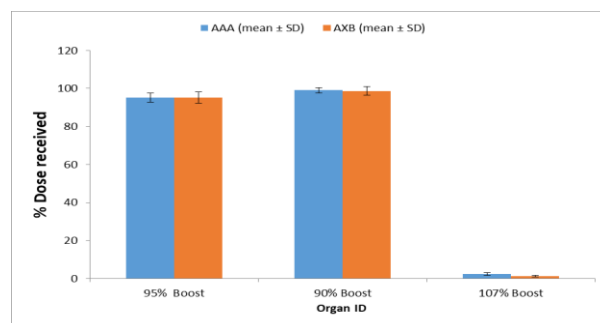


Figure No. 2: Comparison of the dose received by Boost case from 1000 cGy of the breast cancer therapy between the two calculations algorithms (AAA and AXB).

Table No. 3: Comparison between AAA and AXB algorithms of the critical organs at risk dose at the end of radiotherapy course

Organ ID	Dose (cGy) AAA%	Dose (cGy) AXB	P-value
Lung V20	24.38±3.02	24.38±3.07	1
Lung V16	29.28±3.056	29.26±2.97	0.91
Lung mean	12.56±1.337	12.3±1.404	0.57
Heart mean	2.27±1.051	2.69±1.008	0.133
Spinal Cord max.	12.48±2.72	12.12±2.76	0.876

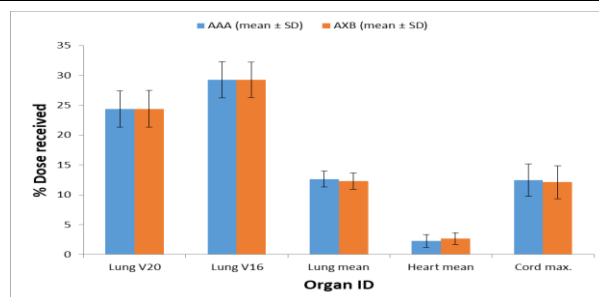


Figure No. 3: Comparison of the dose received by risk at organ (OARs) from total dose (5000 cGy) of the breast cancer therapy between the two calculations algorithms (AAA and AXB).

DISCUSSION

Dose calculation using the AAA and AXB algorithms is critical to determining the dose received by the target from VMAT. One study demonstrated that the clinical dose effects of both AAA and AXB were analyzed by VMAT plans in prostate cancer patients, confirming a slight difference in PTV D95% values (ranging from 0.21% to 0.67%).^{17,18} Additionally, another study noted that AXB estimations for PTV70 in nasopharyngeal cancer were inferior to those for aortic aneurysms, revealing considerable disparities in bone content dosages.^{19,20}

Some research explained that comparing the PTV dosage statistics of AAA and AXB, providing the mean doses with standard deviations, For D 99%, AAA has a little higher average dose than AXB, while AXB has a higher maximum recorded dosage. The average dosages are similar, with no significant differences as indicated by the p-values, showing that the two techniques have identical dosage distributions.²¹

Multiple studies validate that there are nuanced differences in dose of the volume dose estimation for cancer between the AXB and AAA algorithms, with p-values demonstrating the statistical importance of the variations in computations for breast cancer treatment using VMAT plans.^{22,23} These studies agree with the results of our study, where our study was a high significant difference between AAA and AXB calculations in PTV 90, PTV 95 and PTV 107 cases, the p-values were 0.001, 0.01, and 0.003, respectively for breast, and the p-values were 0.616, 0.356, and 0.42, respectively for LN (Table 1, Fig. 1). At the same time, for the Boost cases of PTV 95%, PTV 90%, and PTV 107%, the p-values were 0.31, 0.65, and 0.295, respectively, the results indicated that there are no statistically significant changes existed in the administered dose, although a slight difference in mean for AXB compared to AAA (Table 2, Fig. 2). As well as, our study, which compared dose statistics for OAR (lung, spinal cord, and heart) cases using two different calculation algorithms, AAA and AXB, the mean dose differences are minimal, where the mean dose showing

a slightly lower mean for AXB compared to AAA. However, this difference is not statistically significant, as evidenced by the p-values that are all well above 0.05 (Table 3, Fig. 3).

The findings correspond with the studies by Aamir et al²⁴ and Sandercock et al²⁴, indicating a p-value of 0.579, which signifies the statistical insignificance of the difference between the two sets of point dosage data. The computed point doses from the AAA and AXB methodologies aligned with the measured point dose. Their analysis revealed that both approaches exhibited similar accuracy in point dose measurement when compared to the dosage computed by the TPS.²⁵ Subsequent studies relied on the gamma analysis outcomes, which demonstrated a significant degree of concordance between the AAA and AXB dosimetry systems, with both satisfactorily fulfilling the gamma requirements. The p-value was above 0.05, signifying that the performance disparity was not statistically significant.²⁶

CONCLUSION

The significant differences in breast cancer treatment outcomes between VMAT plans calculated using AAA and AXB where the dose received using AXB was superior to AAA. There was no significant difference between AAA and AXB calculated using Boost. At the same time, there were no significant differences between AAA and AXB calculated using VMAT for lymph nodes and organs at risk (heart, lung, and spinal cord). This highlights the importance of selecting a suitable calculation algorithm for areas with high contrast in the surrounding tissue and could developed by performing in vitro dosimetry in heterogeneous phantoms.

Recommendation: Based on our research results, we recommend using the AXB technique instead of AAA to calculate the dose received by the breast tumor. We also recommend comparing these techniques for other body organs to determine which is better for calculating the dose received by the affected organ.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Reem Aref Abd Allateef, Numan Salman Dawood
Drafting or Revising Critically:	Reem Aref Abd Allateef, Numan Salman Dawood
Final Approval of version:	All the above authors
Agreement to accountable for all aspects of work:	All the above authors

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