The performance of the AAA and Acurox XB algorithms in the case of lung cancer

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Abstract. The Anisotropic Analytical Algorithm (AAA) and Acuros XB algorithms in advanced technique therapy planning has been implemented for Intensity Modulated Radiotherapy (IMRT) and Volumetric Arc Modulated Radiotherapy (VMAT) techniques. This study aimed to verify the dose simulation of IMRT and VMAT in planning target volume (PTV) of lung cancer cases. All planning were created using TPS Eclipse version 13.0.47. The IMRT planning were created using 7 fields whereas the VMAT technique employed the double arc with target dose prescription of 200 cGy each fraction. The results showed that the small discrepancy between planning and measurements of PTV in left and right lung cancer has occurred in VMAT technique, whereas Acuros XB algorithm had better planning quality than Anisotropic Analytical Algorithm (AAA) with differences about of 0.56%. In the organ at risk of left and right lung cancer, there was no significant difference between Acuros XB and Anisotropic Analytical Algorithm (AAA) with the largest deviation range obtained in simulated heart organ with around of ±9%. We concluded that the Acuros XB algorithm has better performance than Anisotropic Analytical Algorithm (AAA) by a factor of approximately ±1%.

1. Introduction  
Lung cancer is the leading cause of death in both male and female patients. In 2012, an estimated 1.8 million new cases (12.9% of the total), 15.9 million deaths and 58% occur in less developed countries [1]. Furthermore, based on data from the International Agency for Research on Cancer (IARC) lung cancer was found in males by 34.2%, while lung cancer deaths in males by 30% [2]. In Indonesia, cancer slowly begins to shift the position of heart attack as the main cause of death. Rising cancer position as the cause of death due to the high number of new cancer cases that come at an advanced stage. Based on these data required efficient handling to minimize the spread of cancer each year. One of the most commonly used modern radiotherapy techniques is the Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT). IMRT (Intensity Modulated Radiation Therapy) technique which is implemented with a number of non-uniform radiation beams optimized to produce high doses of target volume and low doses of normal tissue. In addition, the VMAT is a development of the IMRT technique, in which the dose distribution of 3D is given precisely by providing the photon beam at a rotating gantry at one or more angles [3].
In planning of IMRT and VMAT techniques, Anisotropic Analytical Algorithm (AAA) and Acuros XB algorithm has been implemented in treatment planning system (TPS) for dose simulation in radiotherapy. Furthermore, Acuros XB is the development of the Acuros External Beam (AXB) algorithm and had been implemented in the Eclipse TPS (Varian Medical Systems, Palo Alto, CA) since 2010. Explicitly, the Linear Boltzmann Transport Equation (LBTE) equation numerical method has been solved in Acuros algorithm [4]. The LBTE equation also assumes that radiation particles (electrons, photons and protons) only interact with matter they are passing through, and not with other particles, an is valid for conditions without external magnetic fields [5].

Previous work on the use of the Acuros XB algorithm and Anisotropic Analytical Algorithm (AAA) on IMRT and VMAT radiotherapy techniques is to assess the dosimetric effects of the Acuros XB (AXB) algorithm compared to the Anisotropic Analytical Algorithm (AAA) in esophageal cancer using a slab of phantom [6]. They did the comparison of the calculated percentage depth dose (PDD) with AXB and AAA algorithms on a phantom slab with a 2 cm air gap thickness. The result of using AXB makes it possible to avoid overly high doses of esophageal cancer planning compared to AAA. The same pattern is also found in the study by Kan et al., who has assessed the dosimetric on IMRT and VMAT for nasopharyngeal carcinoma (NPC) by using acuros XB and AAA algorithm which used 7 field on IMRT planning and triple-arc on VMAT planning for 12 patients NPC using AAA and then recalculated using AXB algorithms [7]. As a result, the use of the AXB algorithm is highly recommended for IMRT and RapidArc in the case of NPCs. In this study, we explored the performance of AAA and AXB algorithms in lung cancer cases.

2. Experimental method

This study was conducted using Linac radiotherapy (Varian Medical Systems, Palo Alto, CA) at Siloam Hospital Semanggi (MRCCC). This Linac produces two X-rays photon energies that are 6 MV and 15 MV which is equipped with 120 MLCs. The TLD LiF 100 rod and TLD reader dosimeters (Thermo Scientific 3500 model Harshaw) were employed in this study. In addition, the gafchromic film EBT3 and Flatbed Scanner Epson V700 were used to evaluate optical density measurements on films and then converted into the dose. Dose verification of lung cancer was performed by scanning Rando Alderson thorax section phantom on CT Simulator Philips Brilliance 16 slice. Verification was done by placing the TLD and the Gafchromic EBT3 film for IMRT and VMAT techniques calculated using AAA, AXBDm and AXBDw algorithms. The use of Gafchromic EBT3 film was cut into size of 1.5cm × 0.5cm and positioned at coronal position orientation in rando phantom. The simulated images were sent to the treatment planning system (TPS) for contouring and dose planning.

All planning was created using the TPS Eclipse version 13.0.47. The IMRT planning were created using 7 fields whereas the VMAT technique employed the double arc with target dose prescription of 200 cGy each fraction. For dose verification, the TLD and gafchromic film were took placed inside Rando Alderson phantom. The dose evaluation was done by comparing dosimetry analysis of PTV and organ at risk between the AAA and Acuros XB algorithms for IMRT and VMAT techniques as shown in Figure 1. The point dose difference between planning and measurement can be calculated by following equation:

\[
\text{%diff} = \frac{D_{\text{measured}} - D_{\text{calculated}}}{D_{\text{prescription}}} \tag{1}
\]

where \(D_{\text{measured}}\) is the measurement dose, \(D_{\text{calculated}}\) is the simulated dose of the TPS, and \(D_{\text{prescription}}\) is the prescribed dose value at the reference point [8]. The performance of algorithms were evaluated using the comparison between the Acuros XB algorithm to AAA. Dose deviations from both algorithms can be calculated by the equation as below [6]:

\[
\Delta_{\text{avg}}(\%) = \sum \left( \frac{\text{AXB} - \text{AAA}}{\text{AAA}} \right) \tag{2}
\]
In equation (2), AXB and AAA represent the calculate dose in TPS as well as the measure dose with TLD dosimeter of 100 LiF and the Gafchromic EBT3 film.

Figure 1. TPS simulation of lung cancer a) VMAT technique b) IMRT technique.

3. Results and discussion
Dose verification of simulated lung cancer was performed by placing TLD 100 LiF rod and Gafchromic EBT3 film in Rando phantom. Measurements of TLD 100 LiF dosimeters and Gafchromic EBT3 films in right lung cases with IMRT and VMAT techniques is shown in Figure 2(a) and 2(b). It indicated the average deviation of the AXBDm algorithm for PTV tends to be smaller than AXBDm the same pattern as the left lung case. Furthermore, the difference between the two dosimeters is not very significant but the average deviation of PTV of the IMRT technique and the VMAT algorithm of Acuros XB gives a smaller deviation value than AAA. This result supported Kan et al., who performed the same dose verification with the IMRT and VMAT techniques in the nasopharyngeal cases and indicated the same pattern [7].

Similar to PTV, the measurement of organ at risk (OAR) using the 100 LiF rod TLD dosimeter and the Gafchromic EBT3 film is shown in Figure 3. The figures explained the percentage of spinal cord and heart deviation on the VMAT technique smaller than the IMRT technique as well as indicated in right lung. Based on the result it is known that the use of AAA and Acuros XB algorithms on VMAT technique is better performance than in IMRT technique. In general, the TLD 100 LiF dosimeter provides a much larger deviation value than the Gafchromic EBT3 film dosimeter. This indicates that the use of TLD dosimeters has considerable uncertainty with poor accuracy of -10.3% on target dosing with uncertainty ± 4.7% as proposed by Fitriandini et al. [11]. Meanwhile, the results of measurements obtained in both lung cases with IMRT and VMAT techniques obtained dosage values and standard deviation algorithm AXBDm tend to be higher than AXBDm algorithm. This result is also in line with Kan et al. and Rana et al. research which reported the AXBDm algorithm computations have high values when compared with AXBDm algorithm calculations [7, 10]. This is also supported by a study conducted that is to make measurements using films on phantom anthropomorphic alderson (for pulmonary planning on clinical IMRT) [9]. As a results, it is known that AXB is more accurate to predict dose when it comes to air than AAA.
4. Conclusion
Verification of PTV and OAR doses in both left and right lung cancers indicated that VMAT technique tend had a smaller mean deviation than the IMRT technique using either base on TLD or film dosimeters. Furthermore, the dose of at-risk organs in the left and right lung did not much different either the Acuros XB and the Anisotropic Analytical Algorithm (AAA) algorithms with the largest deviation range obtained by heart ± 9%.

Acknowledgment
We thanks to management of MRCCC for their support in this works. This study was supported by HIBAH PITTA University of Indonesia with contract number 688/UN2.R3.1/HKP.05.00/2017.
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