Original Article

Clinical implications of Eclipse analytical anisotropic algorithm and Acuros XB algorithm for the treatment of lung cancer

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ABSTRACT

The aim of the present study was to investigate the dose-volume variations of planning target volume (PTV) and organs at risks (OARs) in 15 left lung cancer patients comparing analytical anisotropic algorithm (AAA) versus Acuros XB algorithm. Originally, all plans were created using AAA with a template of dose constraints and optimization parameters, and the patients were treated using intensity modulated radiotherapy. In addition, another set of plans was created by performing only dose calculations using Acuros algorithm without doing any reoptimization. Thereby, in both set of plans, the entire plan parameters, namely, beam angle, beam weight, number of beams, prescribed dose, normalization point, region of interest constraints, number of monitor units, and plan optimization were kept constant. The evaluated plan parameters were PTV coverage at dose at 95% volume (TV95) of PTV (D95), the dose at 5% of PTV (D5), maximum dose (D_{max}), the mean dose (D_{mean}), the percent volume receiving 5 Gy (V5), 20 Gy (V20), 30 Gy (V30) of normal lung at risk (left lung- gross target volume [GTV]), the dose at 33% volume (D33), at 67% volume (D67), and the D_{mean} (Gy) of the heart, the D_{max} of the spinal cord. Furthermore, homogeneity index (HI) and conformity index were evaluated to check the quality of the plans. Significant statistical differences between the two algorithms, $P < 0.05$, were found in D95, D_{max}, TV95, and HI of PTV. Furthermore, significant statistical differences were found in the dose parameters for the OARs, namely, V5, V20, and V30 of left lung-GTV, right lung (D_{mean}), D33, and D_{mean} of the heart, and D_{max} of the spine, respectively. Although statistical differences do exist, the magnitude of the differences is too small to cause any clinically observable effect.

Key words: Acuros algorithm; analytical anisotropic algorithm; conformity index; homogeneity index; intensity modulated radiotherapy; planning target volume coverage

Introduction

The algorithm used for dose calculation plays a very important role in delivery of dose to patients undergoing radiation treatment.[1] The beam configuration of analytical anisotropic algorithm (AAA) involves precalculated Monte Carlo data to determine all parameters to match the measured beam data.[2] The AAA calculation uses accurate Monte Carlo-based three-dimensional pencil beam convolution superimposition for inhomogeneity correction. Algorithms can be divided into three classes based on their accuracy. Type "A" was proposed by Knöös *et al*.[3] which were based on measurements and accounts for correction for patient contours and heterogeneities. Type "B" was proposed by Ojala *et al*.[4] which were based on superposition and convolution techniques. The algorithm, Acuros XB (AXB), based on linear Boltzmann transport equation which was first implemented in the Eclipse treatment planning

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system (TPS) by Varian Medical Systems, Inc., (Palo Alto, CA, USA).[5] comes under more accurate type "C"[6,7] algorithms. The origin of AXB algorithm designed for radiotherapy dose calculations is Transpire, Inc., (Gig Harbor, WA, USA).[8-12] Lloyd and Ansbacher[13] showed that the performance of AXB was better than existing clinical algorithm, AAA in high-density materials. Kan *et al*.[14] showed the importance of options for dose to medium and dose to water in AXB in bone in the treatment of nasopharyngeal carcinoma by intensity modulated radiotherapy (IMRT) and RapidArc. Tomiyama *et al*.[15] showed that Voxel Monte Carlo algorithm and AXB were better than AAA in stereotactic body radiotherapy (SBRT) of the lung. Similarly, Liu *et al*.[16] showed that advantage of Acuros over AAA for treatment of SBRT lung. There were contradictory results on studies of lung cancers for planning target volume (PTV) coverage as well as sparing of the normal lung. Jiang *et al*.[17] reported that volumetric modulated arc therapy (VMAT) was better than IMRT with better PTV coverage and sparing of normal lung by evaluating V20, V30, and mean dose (D_{mean}) for the lung. Rao *et al*.[18] showed comparable PTV coverage using VMAT and IMRT. Ong *et al*.[19] reported that IMRT was better than VMAT by evaluating V5 for the lung. The current study evaluated the differences in PTV coverage and in sparing of OARs when using the two different dose calculation algorithms AAA and AXB in IMRT.

Materials and Methods

A 6 MV linear accelerator, Clinac 600C (Varian, Palo Alto, CA, USA) having forty-pairs multi-leaf collimator (MLC) with each leaf projecting 1 cm width at isocenter was used for the delivery of radiation treatments. A cohort of 15 patients diagnosed with non-small cell carcinoma of the left lung was taken for the study. All patients received a prescription dose of 50 Gy in 25 fractions. Thermoplastic sheet (Orfit) was used for immobilizing the patients. A Philips (big bore) computed tomography (CT) scanner was utilized for imaging patients, and CT images of 3-mm slice thickness were acquired with the patients lying in supine position. The CT images were transferred to the Eclipse TPS, version 13.6 (Varian Medical Systems, Palo Alto, CA, USA). The gross target volume (GTV), clinical target volume, the PTV, and the organs at risks (OARs) were contoured on the CT images by a qualified radiation oncologist following the guidelines of the International Commission on Radiation Units and Measurements report 83.[20] Since the tumor was at the left side, the beams were selected from the left side only. Initially, the plans were created in AAA using IMRT technique with a grid size of 2.5 mm, and 7 mm margin was given around the GTV to account for lung motion during the treatment. For this, a template of dose constraints was created, and plan optimization was done using the created template. In addition, these constraints were changed to obtain minimum possible dose to critical organs without compromising the PTV coverage of at least 95% dose to 95% of PTV volume. One more set of plans was created using AXB algorithm, only by performing recalculation without doing any reoptimization. Thereby, in both the plans (AAA and AXB), all the plan parameters, namely, beam shape, beam angle, beam weight, number of beams, prescribed dose, normalization point, region of interest constraints, number of monitor units (MUs), and plan optimization were kept constant, and only the calculation algorithm was changed. The dose distributions in the PTV and the OARs in both the sets of plans were compared. Table 1 shows dose constraints[21] for PTV and OARs used in treatment planning.

Plan analysis for dose-volume histogram parameters

The plans were evaluated and compared on the basis of following dosimetric parameters, namely, target coverage, dose to OARs, homogeneity index (HI), and conformity index (CI). In the current study, HI was evaluated using the formula:[22-25]

$$HI = D5/D95$$

where D5 is dose to 5% of volume of PTV and D95 is dose to 95% of volume of PTV.

A value of HI closer to 1 points to a more homogeneous dose inside the PTV.

CI was evaluated using the formula[26-29]

$$CI = (TV95/V95) \times (TV95/TV).$$

where TV95 is the volume of PTV receiving 95% of prescribed dose, V95 is the volume of tissue receiving 95% of prescribed dose, and TV is the volume of PTV.

A value of CI closer to 1 represents more a conformal dose around PTV with less spillage of dose.

Statistical analysis of the data sets for the two algorithms was done using paired, two-tailed *t*-test and computing the *P* value. When $P < 0.05$, the difference between the two algorithms was considered as significant.

Results

Table 2 shows the location and dimensions of PTV for 15 cases. Mean of PTV was found to be 203.69 cc with standard deviation (SD: 84 cc). Mean values of OARs were left lung-GTV, 1163 cc (SD: 363 cc), contralateral lung, 1612 cc (SD: 564 cc), heart, 482 cc (SD: 202 cc), and spinal cord, 35.5 cc (SD: 18 cc), respectively.

Tables 3 and 4 show the differences between the doses calculated by AAA and by AXB. Figure 1 shows the difference between dose coverage to PTV for a representative patient.

Figure 2 shows the deviation in mean dose (D_{mean}) for both the algorithms.

Of the various assessed dose-volume parameters for PTV, D95, maximum dose D_{max}, TV95%, and HI showed statistical significance between AAA and AXB algorithms (P = 0.01, 0.00, 0.01 and 0.04). Similarly, among the several assessed dose-volume parameters for various OARs, significant differences between the two algorithms were observed only for V5, V20 and V30 in left lung-GTV, D_{mean} in right lung, D33 in heart, and D_{max} in spine (P = 0.00, 0.00, 0.00, 0.00 and 0.00 respectively) as shown in Table 4.

Table 1: Planning target volume and organs at risks-dose constraints for treatment planning

PTV	*95% of prescribed dose to 95% of PTV volume*
Lung-GTV (V20 Gy)	<37%
Lung-GTV (D_{mean})	<20 Gy
Heart (33%)	<60 Gy
Heart (67%)	<45 Gy
Heart (D_{mean})	<40 Gy
Spinal cord (D_{max})	<45 Gy

GTV: Gross target volume, PTV: Planning target volume, D_{mean}: Mean dose, D_{max}: Maximum dose

Table 2: Location and volume of planning target volume for 15 cases

Case number	*PTV volume (cc)*	*Location of PTV*
1	282	Left upper lobe
2	209.4	Left upper lobe, anterior
3	268.2	Left upper lobe
4	301.4	Left upper lobe, anterior
5	252.9	Left upper lobe centrally located
6	138.3	Left lower lobe centrally located
7	167.4	Left lower lobe centrally located
8	151.8	left upper lobe, near to chest wall
9	177.6	Left upper lobe, posterior
10	128.8	Left upper lobe, anterior
11	51.7	Left lower lobe centrally located
12	381	Left upper lobe, anterior
13	137.3	Left lower lobe centrally located
14	163.3	Left lower lobe, posterior
15	145.8	Left upper lobe, near to chest wall

PTV: Planning target volume

Discussions

Dose at 95% of PTV, volume of PTV receiving 95% of dose, and HI were overestimated in AAA compared to AXB as reported previously.[15,16] Our results are comparable to that of Rana *et al*.[30] who showed that more number of MUs are required for AXB to achieve similar target coverage in comparison to that of AAA. This typical dose coverage to PTV showing the difference in both algorithms is shown in Figure 1 for a representative patient. As the plans were recalculated with the same number of MUs in both the algorithms (AXB and AAA), PTV coverage at 95% level with AAA was good whereas it was not so with AXB. This can be also seen by observing the variation in percent deviation in D_{mean} for AAA versus AXB from Figure 2. Even though there is a statistical significance between AAA versus AXB, the mean difference is very small for PTV coverage as shown in Table 3. Similarly, from Table 4, it can be observed that the OAR doses were slightly underestimated in case of normal lung (represents air) and slightly overestimated in case of the heart (represents muscle) and spine (represents bone) in AAA compared to

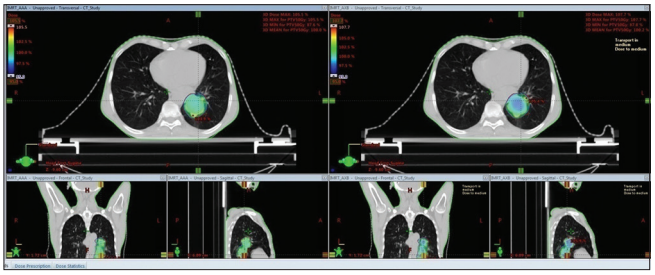

Figure 1: The difference between dose coverage to planning target volume for a representative patient (left side: Analytical anisotropic algorithm and right side: Acuros)

Table 3: Comparison of planning target volume coverage for analytical anisotropic algorithm versus Acuros XB algorithm using intensity modulated radiotherapy technique

PTV	*AAA*		*AXB*		*P*	*Difference*
	Mean	*SD*	*Mean*	*SD*		
D5 (Gy)	51.06	0.33	51.03	1.11	0.92	−0.03
D95 (Gy)	48.48	0.47	48.07	0.49	0.01	−0.41
D_{mean} (Gy)	49.90	0.41	49.87	0.45	0.72	−0.03
$D_{max.}$ (Gy)	52.96	0.69	53.56	0.66	0.00	0.60
TV95 (%)	98.91	2.23	98.10	2.91	0.01	−0.81
HI	1.05	0.01	1.06	0.02	0.04	0.01
CI	0.84	0.13	0.84	0.13	0.48	0.00

PTV: Planning target volume, AAA: Analytical anisotropic algorithm, HI: Homogeneity index, CI: Conformity index, SD: Standard deviation, AXB: Acuros XB, D_{mean}: Mean dose, D_{max}: Maximum dose

Table 4: Comparison of organs at risk doses for analytical anisotropic algorithm versus Acuros XB algorithm using intensity modulated radiotherapy technique

OAR	*AAA*		*AXB*		*P*	*Difference (%)*
	Mean	*SD*	*Mean*	*SD*		
Left lung-GTV, V5 (cc %)	48.68	8.85	49.19	8.91	0.00	1.03
Left lung-GTV, V20 (cc %)	27.58	6.70	27.88	6.72	0.00	1.08
Left lung-GTV, V30 (cc %)	15.41	3.82	15.59	3.85	0.00	1.21
Left lung-GTV, D_{mean} (Gy)	12.62	2.16	12.66	2.16	0.11	0.25
Right lung, D_{mean} (Gy)	3.64	0.84	3.69	0.84	0.00	1.24
Heart, D33 (Gy)	5.07	4.58	4.98	4.52	0.00	−1.87
Heart, D67 (Gy)	2.18	2.68	2.18	2.68	0.88	0.21
D_{mean} (Gy)	5.34	4.26	5.26	4.20	0.00	−1.46
Spine, D_{max} (Gy)	21.42	7.29	20.87	7.12	0.00	−2.57

GTV: Gross target volume, OAR: Organs at risk, AAA: Analytical anisotropic algorithm, SD: Standard deviation, AXB: Acuros XB, D_{mean}: Mean dose, D_{max}: Maximum dose

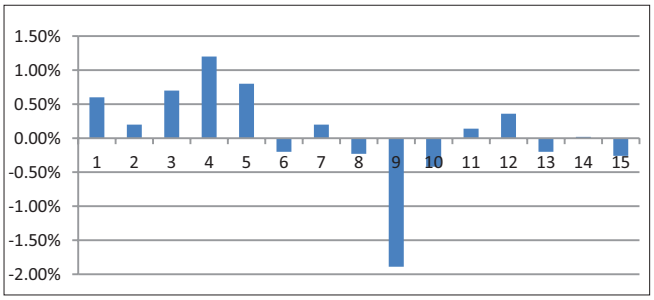

Figure 2: Percent deviation in mean dose for Analytical Anisotropic Algorithm versus Acuros for 15 cases. The X-axis represents case number

AXB. Even though statistical significance does exist for V5, V10, V30 of (Lt.Lung-GTV), Rt.Lung (D_{mean}), Heart (D33), Heart (D_{mean}) and Spine (D_{max}), the difference between the two algorithms is less than 3%. Accuracy of AXB over AAA is well documented in literature.[13-16] A limited study done by us, varying the size of PTV and OAR did not show any significant difference between the two algorithms.

Conclusions

This study concludes that overall minor overestimation of PTV coverage in AAA compared to AXB algorithm. In case of OAR doses, mixed results were observed. Doses to the normal lung were slightly underestimated, and doses to the heart and spine were slightly overestimated in AAA compared to AXB. Even though statistically significant differences were observed between the two algorithms, the magnitude of the dose difference is too small to cause any clinical significance.

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Conflicts of interest

There are no conflicts of interest.

References

1. Papanikolau N, Battista JJ, Boyer AL, Boyer AL, Kappas C, Klein E, *et al.* Tissue Inhomogeneity Corrections for Megavoltage Photon Beams. Report of Task Group No. 65 of the Radiation Therapy Committee of the American Association of Physicist in Medicine. AAPM Report No. 85. 2004.
2. Sievinen J, Ulmer W, Kaissl W. AAA Photon Dose Calculation Model in Eclipse (Whitepaper). Varian Medical System; 2005.
3. Knöös T, Wieslander E, Cozzi L, Brink C, Fogliata A, Albers D, *et al.* Comparison of dose calculation algorithms for treatment planning in external photon beam therapy for clinical situations. Phys Med Biol 2006;51:5785-807.
4. Ojala JJ, Kapanen MK, Hyödynmaa SJ, Wigren TK, Pitkänen MA. Performance of dose calculation algorithms from three generations in lung SBRT: Comparison with full Monte Carlo-based dose distributions. J Appl Clin Med Phys 2014;15:4662.
5. Failla GA, Wareing T, Archambault Y, Thompson S. Acuros XB advanced dose calculation for the Eclipse treatment planning system. Clinical Perspectives 2010. Palo Alto, CA: Varian Medical Systems; 2010.
6. Ojala J, Kapanen M, Sipilä P, Hyödynmaa S, Pitkänen M. The accuracy of Acuros XB algorithm for radiation beams traversing a metallic hip implant – Comparison with measurements and Monte Carlo calculations. J Appl Clin Med Phys 2014;15:4912.
7. Ojala J. The accuracy of the Acuros XB algorithm in external beam radiotherapy – A comprehensive review. Int J Cancer Ther Oncol 2014;2:20417.
8. Vassiliev ON, Wareing TA, McGhee J, Failla G, Salehpour MR, Mourtada F. Validation of a new grid-based Boltzmann equation solver for dose calculation in radiotherapy with photon beams. Phys Med Biol 2010;55:581-98.
9. Gifford KA, Horton JL, Wareing TA, Failla G, Mourtada F. Comparison of a finite-element multigroup discrete-ordinates code with Monte Carlo for radiotherapy calculations. Phys Med Biol 2006;51:2253-65.
10. Wareing TA, Morel JE, McGhee JM. Coupled electron-photon transport methods on 3-D unstructured grids. Trans Am Nucl Soc 2000;83:240-2.
11. Wareing TA, McGhee JM, Morel JE, Pautz SD. Discontinuous finite element Sn methods on three-dimensional unstructured grids. Nucl Sci Eng 2001;138:256-68.
12. Vassiliev ON, Wareing TA, Davis IM, McGhee J, Barnett D, Horton JL, *et al.* Feasibility of a multigroup deterministic solution

method for three-dimensional radiotherapy dose calculations. Int J Radiat Oncol Biol Phys 2008;72:220-7.
13. Lloyd SA, Ansbacher W. Evaluation of an analytic linear Boltzmann transport equation solver for high-density inhomogeneities. Med Phys 2013;40:011707.
14. Kan MW, Leung LH, So RW, Yu PK. Experimental verification of the Acuros XB and AAA dose calculation adjacent to heterogeneous media for IMRT and RapidArc of nasopharygeal carcinoma. Med Phys 2013;40:031714.
15. Tomiyama Y, Araki F, Kanetake N, Shimohigashi Y, Tominaga H, Sakata J, *et al*. Comparison of dose calculation algorithms in stereotactic radiation therapy in lung. Jpn J Radiol Technol 2013;69:663-8.
16. Liu HW, Nugent Z, Clayton R, Dunscombe P, Lau H, Khan R. Clinical impact of using the deterministic patient dose calculation algorithm Acuros XB for lung stereotactic body radiation therapy. Acta Oncol 2014;53:324-9.
17. Jiang X, Li T, Liu Y, Zhou L, Xu Y, Zhou X, *et al*. Planning analysis for locally advanced lung cancer: Dosimetric and efficiency comparisons between intensity-modulated radiotherapy (IMRT), single-arc/partial-arc volumetric modulated arc therapy (SA/PA-VMAT). Radiat Oncol 2011;6:140.
18. Rao M, Yang W, Chen F, Sheng K, Ye J, Mehta V, *et al*. Comparison of Elekta VMAT with helical tomotherapy and fixed field IMRT: Plan quality, delivery efficiency and accuracy. Med Phys 2010;37:1350-9.
19. Ong CL, Verbakel WF, Cuijpers JP, Slotman BJ, Lagerwaard FJ, Senan S. Stereotactic radiotherapy for peripheral lung tumors: A comparison of volumetric modulated arc therapy with 3 other delivery techniques. Radiother Oncol 2010;97:437-42.
20. ICRU Report No. 83. Prescribing, Recording, and Re- porting Photon-Beam Intensity-Modulated Radiation Therapy (IMRT). International Commission on Radiation Units and Measurements, Bethesda; 2010.
21. A phase II trial of combined modality therapy with growth factor support for patients with limited stage small cell lung cancer, RTOG task group report 0623, 2008.
22. Nutting CM, Bedford JL, Cosgrove VP, Tait DM, Dearnaley DP, Webb S. A comparison of conformal and intensity-modulated techniques for oesophageal radiotherapy. Radiother Oncol 2001;61:157-63.
23. Kataria T, Sharma K, Subramani V, Karrthick KP, Bisht SS. Homogeneity Index: An objective tool for assessment of conformal radiation treatments. J Med Phys 2012;37:207-13.
24. Pezner RD, Liu A, Han C, Chen YJ, Schultheiss TE, Wong JY. Dosimetric comparison of helical tomotherapy treatment and step-and-shoot intensity-modulated radiotherapy of retroperitoneal sarcoma. Radiother Oncol 2006;81:81-7.
25. Tyagi A, Supe SS, Sandeep, Singh MP. A dosimetric analysis of 6 MV versus 15 MV photon energy plans for intensity modulated radiation therapy (IMRT) of carcinoma of cervix. Rep Pract Oncol Radiother 2010;15:125-31.
26. Knöös T, Kristensen I, Nilsson P. Volumetric and dosimetric evaluation of radiation treatment plans: Radiation conformity index. Int J Radiat Oncol Biol Phys 1998;42:1169-76.
27. Gurjar OP, Mishra SP. Dosimetric analysis of intensity modulated radiotherapy plans having one or more pairs of parallel opposed beams among the set of beams in some special cases. Radiat Prot Environ 2013;36:138-42.
28. Bagdare P, Gurjar OP, Shrivastav G, Bhandari V, Gupta KL. Dosimetric analysis of intensity modulated radiotherapy (IMRT) and three dimensional conformal radiotherapy (3DCRT) for treatment of non-small cell lung cancer: A comparative study. Int J Cancer Ther Oncol 2015;3:3323.
29. Feuvret L, Noël G, Mazeron JJ, Bey P. Conformity index: A review. Int J Radiat Oncol Biol Phys 2006;64:333-42.
30. Rana S, Rogers K, Pokharel S, Cheng C. Evaluation of Acuros XB algorithm based on RTOG 0813 dosimetric criteria for SBRT lung treatment with RapidArc. J Appl Clin Med Phys 2014;15:4474.