RESEARCH ARTICLE

Dose Calculation Accuracy of AAA and AcurosXB Algorithms for Small Central and Interface Lung Lesions - Verification with Gafchromic Film Dosimetry

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Abstract

Dose calculation for small field radiotherapy with heterogeneity often involves discrepancies, so that algorithms used by treatment planning systems (TPS) should be evaluated with reference to achieving optimal treatment results. Accuracy of two model based algorithms, AcurosXB (AcXB) and the analytical anisotropic algorithm (AAA) from Eclipse TPS, were here tested. Measurements are made using Gafchromic EBT3 films with indigenously generated lung phantoms irradiated with 6 MV photons. Lung phantoms contained two types of tumor plugs, one kept at an interface attached to the chest wall in right lung (RIT) and the other at the centre of the left lung (LCT). RIT and LCT were studied with two different tumor diameters, 1.5 cm and 2.5 cm. Scanned images were planned in TPS with 3D-CRT, IMRT and VMAT and individual plans for each tumor were irradiated keeping the Gafchromic film at the centre of the tumor to evaluate the dose distribution in the central plane. Both algorithms, irrespective of delivery techniques, showed more deviation with smaller than larger diameter tumors. Also, both demonstrated maximum deviation at the junction of tumor and lung in both RIT and LCT cases. However, the deviation observed was higher with AAA and a minimal acceptable deviation of within 4 % was achieved with AcurosXB.

Keywords: TPS algorithms- lung heterogeneity- dose plane

Introduction

In external beam radiotherapy of lung tumors, in-field relapses are observed even with modern technology dose delivery using Intensity Modulated Radiotherapy (IMRT), Stereotactic Body Radiotherapy (SBRT) and high dose ablative treatments. It may be due to the moving targets and limited accuracy of commercial treatment planning algorithms in dose calculation at low density organ like lung. If tumor is small, small field dosimetric inaccuracy also will be added in discrepancy of planned and delivered dose. Moving targets can be addressed through four dimensional gating and imaging techniques, but inaccurate dose delivery contribute local failure, irrespective of high doses and techniques (Wang et al., 2009).

The main aim of Stereotactic treatments (SBRT) of lung is to deliver high dose to the target with sub-millimeter positional accuracy and less than 3% dose accuracy along with sharp dose gradient outside the target volume. In case of small field geometries in homogeneous medium the absorbed dose changes rapidly with field size and depth due to the lack of both lateral and longitudinal electronic equilibrium when the field size is smaller than the maximum range of secondary electrons (Zhu and Bjärngard, 1995). Introducing the low density medium like lung inside such small field makes the dosimetry more difficult to predict the dose accurately. Hence the choice of Treatment Planning algorithms to predict the dose in small field and low density medium and the detector to verify the planned dose is important to achieve the results.

The Gafchromic EBT3 film is one of the more suitable detectors for dosimetry of small field with low density media because of its energy independence, wide range dose response, independent of developers, handling in room light, etc. can be found elsewhere (Borca et al., 2013; Wen et al., 2016).

The dose prediction accuracy can be improved only if TPS uses high standard algorithms where multisource modeling is included to keep track of every secondary scattered photon and electron and its further dose deposition in non-equilibrium conditions. It is proven that Model based algorithms significantly improve the dose calculation accuracy when the beam aperture size less than $3 \times 3 \, cm^2$ compared to simple algorithms using

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one or two dimensional density scaling (Khan and Gibbons, 2014). Hence two model based algorithms used in Eclipse treatment planning systems from same vendor Varian Medical systems such as AcurosXB (AcXB) and Analytical Anisotropic Algorithm (AAA) are taken to quantify the accuracy against the respective measured values. These two algorithms need same dose parameters for beam configuration and hence beam modeling accuracy is not compromised for comparisons.

In this study, we are comparing the tumor isocentre dose, dose coverage parameters, 2D Gamma values measured by Gafchromic films in the tumor isocentre plane of indigenous lung phantom irradiated with different delivery techniques with that of same setup dose predicted for each planned technique by each algorithms mentioned before. Indigenous Lung phantom is introduced with one tumor plug at the centre of left lung and another tumor plug at the periphery of Right lung sharing its one end with chest mimicking Lung-tissue interface.

Materials and Methods

A. Measurements
A.1 Lung Phantom
In this study, an indigenously designed Lung Phantom is used. It contains two thick plastic cylinders each of height 16 cm and diameter 13 cm. These two cylindrical cavities are filled with Lung equivalent Spongy Styrofoam fibre slabs with density of 0.27 g/cc taken as right and Left lungs. Each cylinder is covered with tissue equivalent melted wax sheets of 2 cm thickness all around mimics chest wall. Two tumor plugs of different diameters are taken for study to evaluate the effect of variation in small fields according to tumor size. Same tissue equivalent material of 1.5 cm or 2.5 cm diameter spherical tumor plug (1.77cc or 8.18cc) is introduced inside the right lung at the periphery with its one end touching the chest tissue mimicking Lung-tissue interface, referred as Right lung Interface Tumor (RIT). Another tumor plug of same dimension (1.5 cm or 2.5 cm diameter) is introduced at the centre of left lung fully surrounded by Lung equivalent material, referred as Left Lung Central Tumor (LCT). At any instant one tumor plug can be inserted for one side of lung. Central transverse CT slice of the phantom is shown in Figure 1. Also, tumor plugs are designed in such a way, it can be made into two equal halves and can accommodate Gafchromic films along with lung equivalent blocks to measure at central plane of tumor exactly as planned. Films are placed along the coronal section of the phantom, which is perpendicular to the direction of radiation at gantry angle zero degree.

A.2 Dose Calculation and Planning in TPS
Lung phantom is CT scanned twice, first scan is with both lungs RLIT and LLCT contains 1.5 cm diameter tumor and second scan with 2.5 cm diameter tumor. All scans are 1 mm slice thickness and planned in two different model based algorithms AAA and AcurosXB from Eclipse treatment planning system Version 13.5.3 of Varian Medical Systems, Palo Alto, USA. The beam modeling parameters required for algorithms in the study

are modeled for the same clinical 6MV photon beam of Novalis Tx Linear Accelerator with special attention given to small fields. Beam modeling parameters are same for both the algorithms in the study and the least field size modeled is 1x1 cm². Small fields beam data are taken with diodes and the extensive TPS QA is done to validate the modelling.Both RIT and LCT are planned separately with four different techniques 3DCRT, IMRT-dynamic, IMRT Step and Shoot and VMAT keeping the respective tumor as clinical target. Each of these plans are calculated twice with the algorithms in the study (AAA and AcurosXB) keeping the planning parameters same. Isocentre is kept at the centre of respective targets for all the plans in the study and 5 mm around the target is drawn as Planning Target volumes as PTV rit and PTV lct.

All the plans are done to achieve minimum of 85 to 90% coverage of dose prescription and maximum dose of up to 130% inside the target with the ablative SBRT 100% dose prescription of 54Gy in 3 fractions (18Gy/fraction). Since main aim of the study is to verify the accuracy of algorithms in calculating the dose to tumor and normal lung by comparing with the measured outcome of each plan , comparison of the plans of the same technique with other algorithm are not discussed here.

The AAA algorithm is used with calculation grid size of 1mm and inbuilt heterogeneity correction is applied. The AcurosXB Algorithm uses the deterministic radiation transport solutions of the linear boltsman transport equation (LBTE) to eliminate the statistical noise in the calculated dose. It directly accounts for the effect of heterogeneities by taking their chemical composition apart from density(Fogliata et al., 2011). Here also the calculation grid size is set at 1mm and Dose result is set at dose to medium. Spatial cutoff for photons below 1KeV and for electron energies below 500KeV is set inbuilt for patient dose calculation and below which it deposits dose at the voxel itself.

A.2.1. 3D CRT Planning
For the right side interface tumor RIT the 3D conformal planning is done with the gantry angles 0, 60,240,285, 320 degrees and for the Left side central tumor LCT the 3D conformal planning is done with the gantry angles 0, 60, 120, 180, 240, 320 degrees. For each target plan, minimum coverage of 90% is achieved to the respective PTV with the acceptable hotspot inside the target.

A.2.2. IMRT Planning
Two types of IMRT planning according to delivery technique like Dynamic sliding window (DSW) and multiple static segments (MSS) is planned.

For the Right side interface tumor RLT the IMRT, DSW and MSS technique planning is done with the gantry angles 0, 60, 240, 285, 320 degrees and minimum coverage of 90% to PTV rit keeping the normal lung dose minimum.

For LCT, DSW and MSS IMRT planning is done with the gantry angles 0, 60, 120, 180, 240, 320 degrees and minimum coverage of 90% to PTVlct keeping the normal lung dose minimum.

A.2.3. VMAT Planning

For the Right side interface tumor RIT the VMAT Rapid arc technique planning is done with two arcs of gantry angles, Counter clockwise (CCW) from 60 to 240 degree and clockwise (CW) 240 to 60 degree and minimum coverage of 90% to PTV rit is achieved.

For the Left side central tumor LCT the VMAT Rapid arc technique planning is done with two arcs of gantry angles CCW from 179.9 to 330 and CW from 330 to 179.9 degree and minimum coverage of 90% to PTV lct is achieved.

A3. Film dosimetry

The Gafchromic EBT3 films are used as detectors and Omnipro-IMRT film QA software Version 1.7 from IBA dosimetry AB, Sweden used for evaluation. Flatbed scanners with 200 dpi spatial resolution positioned in landscape direction with transparent mode used for scanning the films. Green channel is used so that higher dose regions can be evaluated accurately (Borca et al.,2013; Wen et al.,2016). Calibration of both the scanner and films are followed as per protocol. Films are cut in landscape orientation and marked for evaluation of scan.

A.4 Measurement Setup

The Lung phantom containing RIT and LCT tumor plugs is kept on couch of Novalis Tx Linear Accelerator (With HD MLC thickness of 2.5mm thickness at isocentre) for film irradiation according to the algorithm calculated plan. To verify the isocentre at the centre of tumor as per plan, 2D-2D orthogonal match using KV X-ray of OBI and the same is marked on the phantom to reproduce after placing the films.

Plans of four techniques (3DCRT, IMRT-MSS, IMRT-DSW and VMAT) calculated for 6 MV photon beam with each algorithm (AAA or AcXB) is used for irradiating respective tumor plugs (1.5 cm or 2 cm diameter of RIT or LCT) of the phantom. In each case, Gafchromic EBT-3 films are cut and marked for directions at the edge and placed exactly at the centre of tumor plane sharing the lung equivalent slices, so that film contain the dose information of the whole isocentric plane.

For each plan irradiated, one more film strip (apart from isocentric plane film) is also kept at the plane of

4 cm from the tumor centre, to evaluate the accuracy of algorithm in calculating normal lung dose.

The isocentric plane of each plan calculated by TPS is exported to Omnipro I'MRT software for comparing with the film irradiated in same setup. Resolution and grid size for both TPS image plane and film are kept same for evaluation.

A5. Comparison and Calculation

The film kept at isocentre plane and irradiated is matched with that of same dose plane from TPS and synchronized for evaluating the results. To evaluate the general matching of the measured and algorithm calculated dose planes, 2D gamma pass percentage with 3 criteria of delta dose and delta distance such as 2% and 2mm, 3% and 4% and 4mm are done. The last criteria of 4% and 4mm is to show the validity of algorithm in the extreme conditions.The central axis absolute dose deviation and correlation coefficient between the dose planes are evaluated for the criteria of delta dose 3% and delta distance 3 mm. Also, to evaluate the specific common error points in the dose planes with respect to measured, the central axis dose profile along the right to left direction is compared. The difference in dose with respect to measured along that axis is graphically plotted. As mentioned earlier, one more film irradiated at 4 cm from the isocentre is compared with TPS calculated dose plane for 2D gamma pass percentage with criteria of delta dose and distance 3% and 3mm.

Results

A. Left Central Tumor (LCT)

For LCT, the various comparative evaluation parameters are shown in Table 1 and Table 2. The central axis absolute dose deviations from measured for 2.5 cm diameter target calculated with AAA Algorithm plans of 3DCRT, IMRT-static, IMRT dynamic and VMAT target results in percentage are 5.1%, 4%, 3.8% and 2.8% respectively. Same for 1.5cm diameter target is 5.2%, 5.5%, 5.2% and 3.2% respectively. Central axis dose deviations from measured for 2.5 cm diameter target calculated with AcXB plans of 3DCRT, IMRT-static, IMRT-Dynamic and VMAT target are 3%, 1.5%, 1%,

Table 1. Results for Left Lung Central Tumor (LCT) diameter of 2.5 cm

| Evaluation Parameters		Percentage Dose Difference w.r.t. Measured							
		3D-CRT		IMRT-Static		IMRT-Dynamic		VMAT	
		AAA	AcXB	AAA	AcXB	AAA	AcXB	AAA	AcXB
CAX Absolute Dose deviation (in %)		5.1	3	4	1.5	3.8	1	2.8	0.8
2D-Gamma (Pass%) at Isocentre	2%& 2mm	92.73	94.88	92.8	95.7	2.54	95.33	90.65	94.72
	3%&3mm	93.65	96.24	95.3	97.2	97.56	98.82	93.93	97.47
	4%&4mm	95.57	98.33	97.1	98.8	99.12	99.34	96.56	99.04
Correlation Coefficient		0.951	0.965	0.932	0.973	0.9476	0.9772	0.9357	0.9781
2D Gamma (Pass% for 3%&3mm) at 4 cm from isocentre in normal lung		95.2	98	95	98.3	95.3	98.3	96.5	98.7
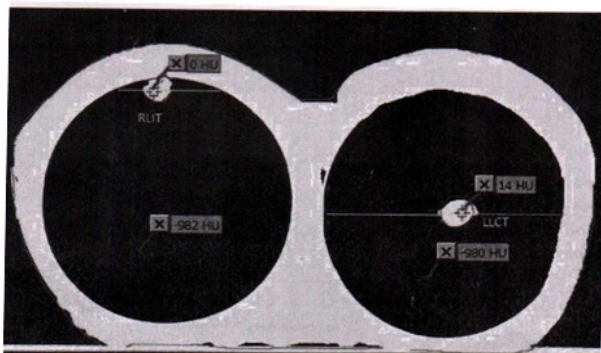
Figure 1. Central Slice of CT Image of Phantom Showing Normal Lung, RIT, LCT and Hounsfield Unit of Structures. Horizontal Lines Cutting Tumors are the Respective Film Planes
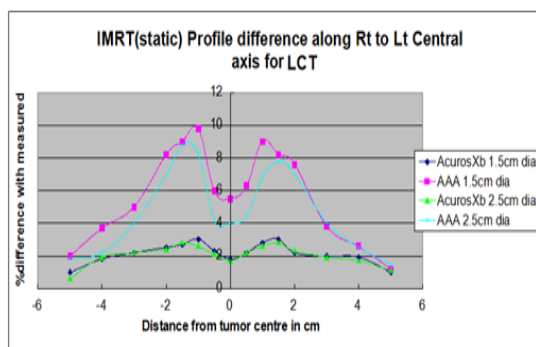

Figure 3. Dose Profle Difference between Algorithms Calculated MS Static-IMRT Plans and Film Measured along Right to Left Direction at Central Axis for Left Lung Central Tumor (LCT)

Table 2. Results for Left Lung Central Tumor (LCT) Diameter of 1.5 cm

Evaluation Parameters		Percentage Dose Difference w.r.t. Measured							
		3D-CRT		IMRT-Static		IMRT-Dynamic		VMAT	
		AAA	AcXB	AAA	AcXB	AAA	AcXB	AAA	AcXB
CAX Absolute Dose deviation (in %)		5.2	3.3	5.5	1.8	5.2	1.3	3.2	1.3
2D-Gamma (Pass%) at Isocentre	2%&2mm	91.8	94.3	91.9	95.8	92	95.1	90.4	94.8
	3%&3mm	93.2	95.8	95.2	97.4	96.7	98.2	93.2	97.1
	4%&4mm	96.1	97.9	96.7	98.2	98.1	98.2	96.3	98.9
Correlation Coefficient		0.94	0.959	0.9278	0.968	0.9423	0.979	0.924	0.975
2D Gamma (Pass% for 3%&3mm) at 4 cm from isocentre in normal lung		96.1	97.8	95.3	98.6	96.2	98.4	96.2	98.1

0.8% and for 1.5cm diameter target is 3.3%, 1.8%, 1.3%, 1.3% respectively.

In isocentric dose plane comparison between AAA and measured, 2D gamma pass percentage for criteria 3% and 3mm is between 93.2 to 96.7% whereas for criteria of 2% and 2mm is 90.4 to 95.3% only and least pass percentage with 1.5 cm diameter. The same comparison between AcurosXB and measured, for the criteria 3% and 3mm is between 95.8% to 98.8% whereas even for criteria of 2% and 2mm is between 94.7 to 95.8%. The 2D Gamma evaluation for the normal lung, with the film kept at the

plane 4cm from the tumor plane, for the criteria of 3% and 3mm is 95.2% to 96.2% for AAA and 97.8% to 98.7% for AcXB Algorithm.

Correlation coefficient for AAA with measured for 2.5 cm dia ranges between 0.9320 and 0.9510 and the same for 1.5cm dia varies between 0.9245 and 0.9423. Correlation coefficient for AcXB with measured for 2.5cm dia ranges between 0.9658 to 0.9782 and for 1.5cm dia between 0.9599 to 0.9790.

The central axis dose profile difference between measured and algorithm calculated, along the right to
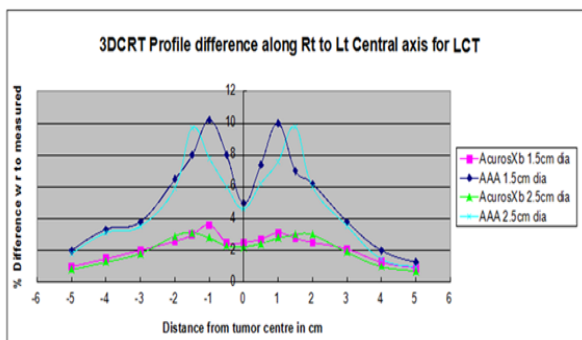

Figure 2. Dose Profile Difference between Algorithms Calculated 3D-CRT Plans and Film Measured Along Right to Left Direction at Central Axis for Left Lung Central Tumor (LCT).
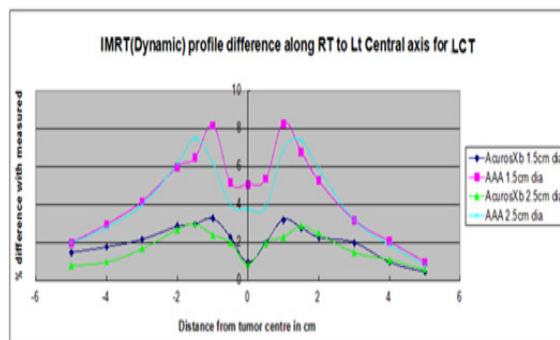

Figure 4. Dose Profile Difference between Algorithms Calculated Dynamic SW-IMRT Plans and Film Measured along Right to Left Direction at Central Axis for Left Lung Central Tumor (LCT)
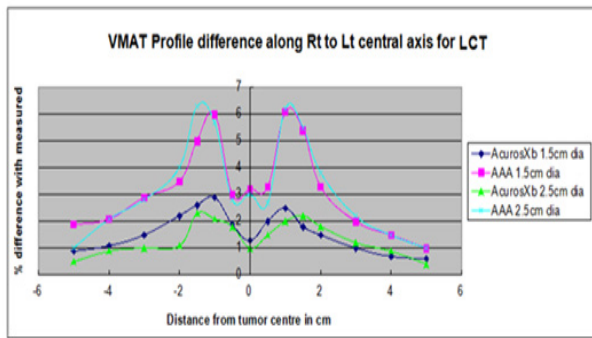
Figure 5. Dose Profile Difference between Algorithms Calculated VMAT Plans and Film Measured Along Right to Left Direction at Central Axis for Left Lung Central Tumor (LCT)
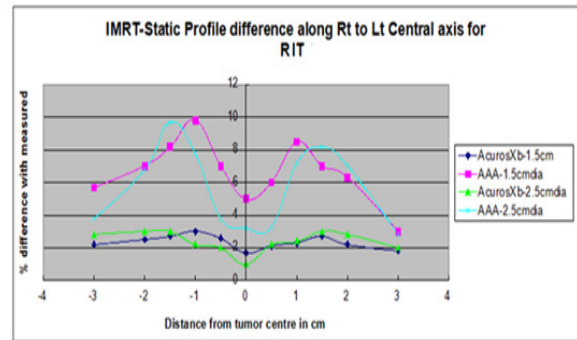

Figure 7. Dose Profile Difference between Algorithms Calculated MS Static-IMRT Plans and Film Measured along Right to Left Direction at Central Axis for Right Lung Interface Tumor (RIT)

Table 3. Results for Right Lung Interface Tumor (RIT) Diameter of 2.5 cm

Evaluation Parameters		Percentage Dose Difference w.r.t. Measured							
		3D-CRT		IMRT-Static		IMRT-Dynamic		VMAT	
		AAA	AcXB	AAA	AcXB	AAA	AcXB	AAA	AcXB
CAX Absolute Dose deviation (in %)		4	3	3	1.2	3.2	0.8	3.3	0.7
2D-Gamma (Pass%) at Isocentre	2%&2mm	92.3	94.1	91.7	95.2	91.9	95.58	90.1	94.1
	3%&3mm	93.5	96.1	95.1	96.8	96.32	97.32	95.1	96.37
	4%&4mm	95.2	96.93	96.1	97.8	97.35	98.14	96.3	98.04
Correlation Coefficient		0.9459	0.963	0.922	0.965	0.932	0.9689	0.946	0.988
2D Gamma (Pass% for 3%&3mm) at 4 cm from isocentre in normal lung		95.2	97	96.3	97.3	96.2	98.1	97.2	98.2

left axis of the central plane plotted by keeping the tumor centre as origin is shown in Figure 2 to Figure 5. All these graphs irrespective of delivery techniques and tumor size the maximum peak deviation is observed at the junction between tumor and lung. But the deviation is maximum observed in AAA as high as 10.2% in all the plots and with AcXB deviation is less and below 3%. Also maximum deviation is in AAA calculated 3DCRT for 1.5cm dia target and minimum deviation in AcXB calculated VMAT plan.

B. Right Interface Tumor (RIT)

For RIT, the various comparative evaluation parameters are shown in Table 3 and Table 4. The central axis absolute dose deviations from measured for 2.5 cm dia

target calculated with AAA Algorithm plans of 3DCRT, IMRT-static, IMRT-dynamic and VMAT target are 4%, 3%, 3.2% and 3.3% respectively. Same for 1.5cm dia target is 6.4%, 5.1%, 5.2% and 3.5% respectively. Central axis dose deviations from measured for 2.5 cm dia target calculated with AcXB plans of 3DCRT, IMRT-static, IMRT-dynamic and VMAT target are 3%, 1.2%, 0.8%, 0.7% and for 1.5 cm dia target is 3.3%, 1.5%, 1.5% and 1.6% respectively.

In isocentric dose plane comparison between AAA and measured, 2D gamma pass percentage for criteria 3% and 3 mm is between 93 to 96% whereas for criteria of 2% and 2mm is 90 to 92.3% only and least pass percentage with 1.5cm diameter. The same comparison between
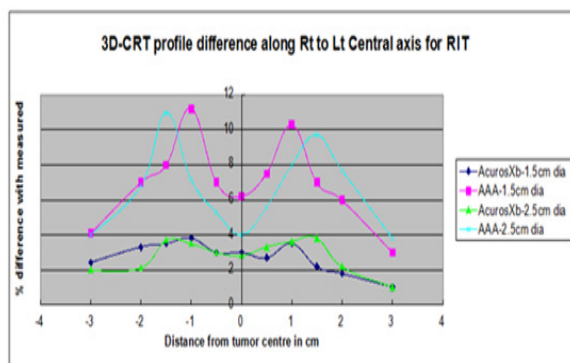

Figure 6. Dose Profile Difference between Algorithms Calculated 3D-CRT Plans and Film Measured along Right to Left direction at Central Axis for Right Lung Interface Tumor (RIT)
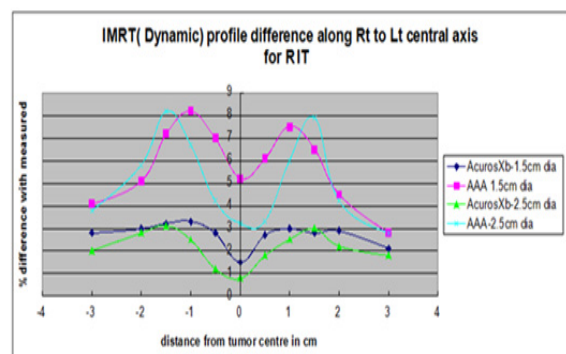

Figure 8. Dose Profile Difference between Algorithms Calculated Dynamic SW-IMRT Plans and Film Measured along Right to Left Direction at Central Axis for Right Lung Interface Tumor (RIT)

Table 4. Results for Right Lung Interface Tumor (RIT) Diameter of 2.5 cm

| Evaluation Parameters		Percentage Dose Difference w.r.t. Measured							
		3D-CRT		IMRT-Static		IMRT-Dynamic		VMAT	
		AAA	AcXB	AAA	AcXB	AAA	AcXB	AAA	AcXB
CAX Absolute Dose deviation (in %)		6.4	3.3	5.1	1.5	5.2	1.5	3.5	1.6
2D-Gamma (Pass%) at Isocentre	2%&2mm	95.3	95.3	92.7	95.7	92.1	95.5	90.2	94.5
	3%&3mm	93.6	96.8	95.4	97.1	96.3	97.7	94.3	96.4
	4%&4mm	96.9	98.9	96.9	98.7	97.4	98.7	95.9	98.1
Correlation Coefficient		0.9585	0.951	0.919	0.9698	0.94	0.971	0.9202	0.9703
2D Gamma (Pass% for 3%&3mm) at 4 cm from isocentre in normal lung		95.5	97.3	95.2	96.4	97.3	98.5	97.6	98.1
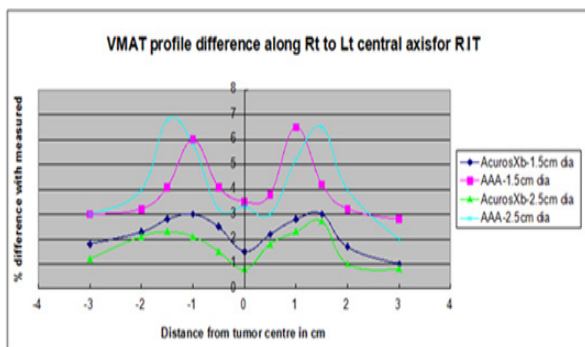
Figure 9. Dose Profile Difference between Algorithms Calculated VMAT Plans and Film Measured Along Right to Left Direction at Central Axis for Right Lung Interface Tumor (RIT)

AcurosXB and measured, for the criteria 3% and 3mm is between 96.1% and 97.7% whereas even for criteria of 2% and 2mm is between 94.1% to 95.7%. The 2DGamma evaluation for the normal lung, with the film kept at the plane 4cm from the tumor plane, for the criteria of 3% & 3mm is 95.2% to 97.3% for AAA and 96.4 to 97.6% for AcXB algorithm.

Correlation coefficient for AAA with measured for 2.5cm dia ranges between 0.9220 and 0.9468 and the same for 1.5cm dia varies between 0.9190 and 0.9585. Correlation coefficient for AcXB with measured for 2.5cm dia ranges between 0.9632 to 0.9882 and for 1.5cm dia between 0.9510 to 0.9710.

The central axis dose profile difference between measured and algorithm calculated along the right to left axis plotted by keeping the tumor centre as origin is shown in Figure 6 to Figure 9.

All these graphs irrespective of delivery techniques and tumor size the maximum peak deviation is observed at the junction between tumor and lung. But the deviation is maximum observed in AAA as high as 11.2% in all the plots and with AcXB deviation is less and below 4%. Also maximum deviation is in AAA calculated 3DCRT and minimum deviation in AcXB calculated VMAT plan.

Discussion

This study compared dose calculation accuracy of two model based algorithms AAA and AcurosXB against the EBT Gafchromic film measured data in Lung heterogeneties irradiated by 6MV photons with small fields. But the previously reported data compared some algorithms with theoretical Monte Carlo data or the dose measured for single tumor at the centre of lung only (Ojala et al., 2014 ; Wen et al., 2016). Hence this study is unique in comparing the accuracy of algorithms with the measurement done at the central plane of the target at the interface and at the centre of lung.

As the deviation in this study with respect to measured is for the full plane containing tumor and lung, the variation obtained may be on little higher side than the previous conventional Monte Carlo comparison studies. Generally in all the plans and tumor sizes of this study, more deviations from the measured is observed with smaller diameter 1.5cm tumor and with AAA algorithm. The 2D Gamma evaluation Pass percentage is good for AcurosXB even for stringent delta 2% and 2mm criteria. The graphical central axis profile comparison shows the failure of Algorithms is mostly at the interface of Lung and tumor. This difference is as high as 11.2% in AAA compared to 4% of AcXB Algorithm. This may be due to the inaccuracy of algorithms calculating the Forward and lateral Electronic disequilibrium which is the main cause of dose difference around tumor. Irrespective of algorithms, VMAT shows good pass percentage and less deviation in dose profile comparisons. Also there is a little more dose difference observed with the tumor at the interface than the tumor at the centre. As the tumor at interface in this study (RIT) is very near to the Depth of Dose maximum of 6MV, the difference observed may be due to the contribution of Forward electronic disequilibrium calculated by the algorithms.

The results obtained in this study may involve statistical uncertainties in the calculations of commercial algorithms and that may reflect in the calculation of dose deviation. Also it is difficult to report the random and positional error present in the measurements. Hence multi-institutional studies of same sort or different dosimetric evaluation parameters should be conducted to evaluate the accuracy of respective algorithms in small fields with heterogeneities present in extreme conditions, as more of SBRT treatments are becoming standard clinical practice in case of Lung tumors.

In conclusion, both the algorithms in the study, irrespective of delivery techniques shows more deviations in smaller diameter tumors than bigger ones. Also both

the algorithms show maximum deviations at the junction of tumor and lung in both Centralised and interfaced tumors. But the deviation observed is higher with AAA and minimal acceptable deviation of within 4% in AcurosXB. This may be due to the reduced accuracy of algorithms in modeling the increased lateral scatter phenomena in low density materials. Hence the plan evaluation for smaller tumors with high dose in Lung cases, like SBRT of lung, irrespective of delivery techniques, the dose evaluation at the periphery of tumor should be done carefully and the patient specific QA should be done in lung phantom rather than uniform density solid phantoms.

References

Casanova Borca V, Pasquino M, Russo G, et al (2000). Dosimetric characterization and use of Gafchromic EBT3 film for IMRT Dose verification. *J Appl Clin Med Phys*, **14**, 4111-23.

Fogliata A, Nicolini G, Clivio A, et al (2011). Dosimetric evaluation of acuros XB advanced dose calculation algorithm in heterogenous media. *Radiat Oncol*, **6**, 82.

Khan FM, Gibbons JP (2014). The physics of radiation therapy. in 'three dimensional conformal radiation therapy' lippincot Williams and Wilkins Philadelphia, PA, pp 413–29.

Jarkko J. Ojala, Mila KKapanen, Hyödynmaa SJ,et al (2014). Performance of dose calculation algorithms from three generations in lung SBRT:Comparison with full Montecarlo based dose distributions. *J Appl Clin med Phys*, **15**, 4-18.

Ning W, Siming L, Jinkoo k, et al(2016). Precise film dosimetry for stereotactic radiosurgery and stereotactic body radiotherapy quality assurance using Gafchromic EBT3 films. *Biomed Central Rad Oncol*, **11**, 132.

Wang L, Hayes S, Paskalev K, et al (2009). Dosimetric Comparison of stereotactic body radiation therapy using 4DCT and multiphase CT images for treatment planning of lung cancer - Evaluation of the impact on daily dose coverage. *Radiother Oncol*, **91**, 314-24.

Zhu TC, Bjärngard BE (1995). The fraction of photons undergoing head scatter in x-ray beams. *Phys Med Biol*, **40**, 1127–34.