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Comparison of ITV Delineation using Intensity Projections Methods for Eclipse and iPlan Treatment Planning System : A Phantom Study

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ABSTRACT

Objective : To compare phase binning of 4DCT, evaluate respiration induced target changes and compare various methods of ITV delineation using intensity projection method for different planning system.

Methods: 3DCT scan of Anzai motion phantom, containing three targets was acquired in static and free breathing condition using Varian RPM and Siemens 4DCT scanner along with 4DCT scan of the same phantom in quasi respiratory mode. Images are retrospectively sorted into six phase bins from 0% to 100% inhalation in increment of 20%. All targets were delineated in each of the eight CT datasets using iPlan and Eclipse planning systems. The changes in shape, volume and HU of targets at different phases were compared with that of static phantom image. ITV and HU of each moving target estimated/delineated from combination of i) all phases ii) 4DCT series using maximum, minimum and mean/average intensity projection (IP) methods and were compared with automatic co-registration of all phases.

Results: Variation of each target volume at different phases was less than ±4%. When targets were set at free breathing, volume increases by a mean of 27%. Of the three IP methods, Mean/Average IP showed minimum deviation in both volume and HU. The ITV generated/delineated using various methods agrees within ±2% for both Eclipse and iPlan planning systems.

Conclusion : Both the systems were found to be accurate for phase binning and ITV delineation. The ITV delineated using Mean IP can be consider as fast, reliable and accurate for planning and delivery of dose to moving target.

Keywords: 4DCT, Intensity projection, ITV, Phase binning, Treatment planning system

I. INTRODUCTION

Respiration induced movement of tumors and normal anatomy can cause artifacts during image acquisition which manifest as target/normal tissue delineation errors. The adverse effect of respiratory motion on dose-calculation accuracy and averaging or blurring of the static dose deliver over the path of the target motion has been reported for thoracic-abdominal tumors [1] .The ICRU 62 introduced the concept of Internal Target Volume (ITV) to account for tumor motion which is defined as an additional margin to Clinical target volume to account for geometric uncertainties due to variable tumor motion [ICRU62] for gated and non-gated radiotherapy [2] . Incorporation of intra-fraction motion of target and normal tissue in treatment planning and delivery is particularly important for highly conformal radiotherapy techniques such as intensity modulated radiotherapy (IMRT) and high dose stereotactic body radiotherapy (SBRT). To assess the movement of tumor, a recent adaptation of 4D CT technique has allowed to generate Planning target volume (PTV) using motion information. Acquisition of respiration synchronized 4DCT can be perform either prospectively or retrospectively using 4DCT interfaced to various respiration monitoring systems [3-10] The patient breathes freely during acquisition and the 3D CT images are retrospectively sorted into 10 respiratory based bins. It is capable to obtain the information of motion of tumor along with deformation over a respiratory period. The ideal method to delineate the ITV in 4D CT is by contouring the CTV in 10 phases of respiratory cycle from the 4D CT dataset which is time consuming in clinical environment [11-16] An alternative to this is to generate Maximum, Minimum and Mean Intensity projection using different algorithms and image processing software from treatment planning systems. The Maximum intensity projection reflects the highest data value for each pixel throughout the respiratory cycle. The Minimum reflects the minimum data value and Mean/average encounters the mean/average data value for each pixel [17].

Varian has recently introduced the generation of intensity projection methods for 4DCT in Eclipse treatment planning system [18] .Till date there are no studies available on the comparison of ITV's generated with two different planning systems. The purpose of our study was to investigate respiratory synchronize 4DCT of moving targets for a) accurate phase binning, b) evaluation of motion induced changes in target shape, volume and Hounsfield unit (HU) for gated radiotherapy, and c) validation of intensity projection image processing software for accurate delineation of ITV for non-gated radiotherapy using different treatment planning system.

II. MATERIAL AND METHODS

A respiratory monitoring system (AZ-7332, Anzai medical system, Tokyo) consisting of a motion phantom was used for this study (Fig 1). The motion phantom consist of three targets (rubber: 4.7 cm dia, -161.6 HU; wood: 5 cm dia, -359 HU and acrylic: 5 cm dia, 118.2 HU).

Figure 1. Anzai AZ-7332 respiratory monitoring system a) motion phantom and b) Different Inserts

Conventional 3DCT scan of the phantom in a) static position and b) free breathing at 10 rotations per minute (RPM) was acquired using Scope Power CT (Siemens medical system) c) Respiratory synchronized 4DCT scan of the same phantom was set to move longitudinally in quasi respiratory mode at 10 RPM was acquired and the breathing pattern was measured with Real Time Position Management system (VMS, Palo Alto, USA) with 6 DoT infrared reflecting marker block placed on the moving platform of phantom during 4DCT scanning and retrospectively sorted into one of 6 phase bins ranging from 0% inhalation to 100% inhalation in step of 20% using the 4DCT Syngo application software on the Siemens Scope Power CT. A total of 8 CT datasets, all having 1 mm slice thickness at 1 mm inter-slice separation was imported into iPlan treatment planning system (TPS) (Brain Lab, Germany) and Eclipse planning system (VMS, USA). All the three targets were individually delineated in each of the CT datasets using the Smart Brush outlining tool available in the iPlan (v4.1)TPS and Smart brush adaptive tool available in Eclipse(v13.6) TPS. Same window level was set throughout the investigation. In order to eliminate the interobserver variability a single physicist performed all the delineations [19]. The change in shape, volume and HU of the three targets during free breathing condition and at different phases were compared against the values obtained from the CT dataset of the phantom in static position. Further, CT datasets of all phases were co-registered one over the other using the automatic image registration software, based on mutual information transformation available in iPlan and Eclipse [20-21] .Each target was delineated on the final fused CT dataset (T_fused) and considered as reference targets for comparison. A separate post processing 4D CT series was created from the CT datasets of all phases using maximum (T_MaxIP), minimum (T_MinIP) and mean (T_MeanIP) intensity projection (IP) method available in Eclipse and iPlan planning system. The 4D target volume and HU estimated using various methods was compared against the corresponding values estimated from automatic image registration method (T_fused) for both the planning system. The percentage deviations were calculated with respect to the ITV generated for Eclipse and iPlan from Intensity projections methods along with HU's and were statistically compared using Student's t-test(two-tailed) and the differences were considered to be significant for $P<0.05$.

Results: Phase binning of respiratory synchronized 4DCT was accurate within ±0.5 mm. The shapes of the moving spherical targets deform largely for free breathing condition and slightly for phase binning along the target motion and found to be independent of the phase cycle and type of the target (Fig 2).

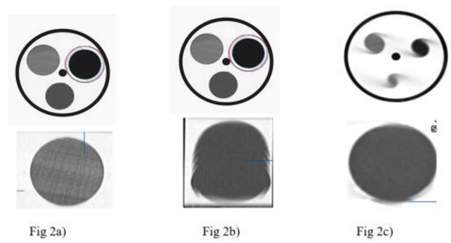

Figure 2 Shape of different target at different image acquisition conditions a) 3DCT when the phantom is in static phantom, b) 3D CT when the phantom is set at free breathing and c) 4D CT of moving phantom at 0% Inhalation.

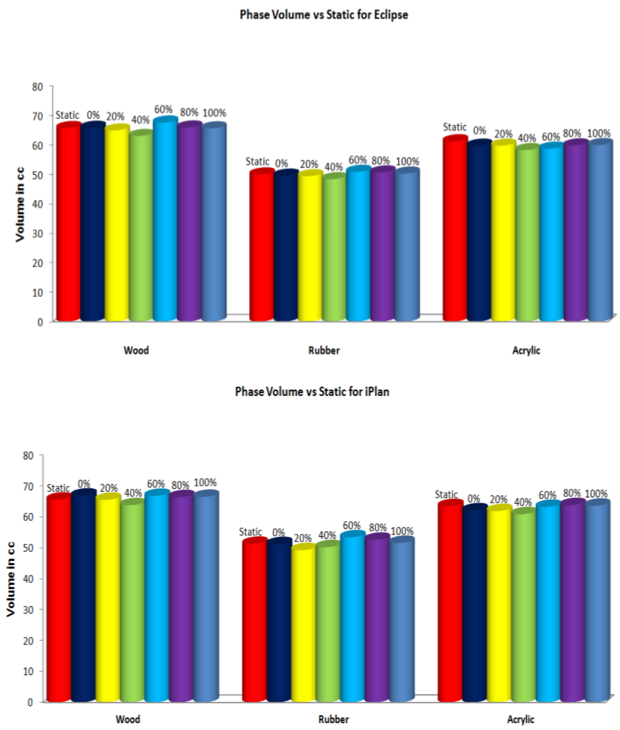

Figure 3 shows the target volume (in cc) in static condition and at different phases of the simulated respiratory cycle for both Eclipse and iPlan planning system.

In comparison to the volume of static target, the percentage variation of the volume of each target at different respiratory phases was less than ±4% for both the planning system. The mean (SD) percent variation of HU at different phases as compared to reference values were 19.6% (4.6) for rubber, 1.3% (1.4) for wood and -48.3% (9.8) for acrylic target respectively. When the targets were set at free breathing, the volume increases by a mean of 28% as compared to stationary target for iPlan and 26% for Eclipse planning system. The delineation of ITV for the moving targets using all 6 CT datasets acquired at 0%, 20%, 40%, 60%, 80% and 100% inhalation phases fused together using automatic image registration algorithm is shown in Figure 4.

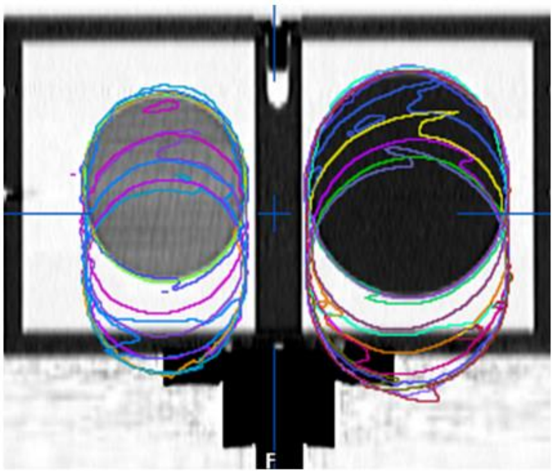

Figure 4: Delineation of ITV from all phases fused together using automatic image registration software

The conventional automatic image registration provides both target displacement and changes in the shape at different phase accurately but is very time consuming. Figure 5 depict the changes in the shape of one of the representative targets (rubber) resulted from different intensity projection image processing software. It reveals that appropriate intensity projection method need to be chosen for a type of target e.g. maximum intensity projection seem appropriate for rubber target. Figure 5 also demonstrates that more than one method (mean and maximum in fig 5a and 5b) may be required to accurately delineate a target especially when the motion of the target is extended in two medium having different Hounsfield units.

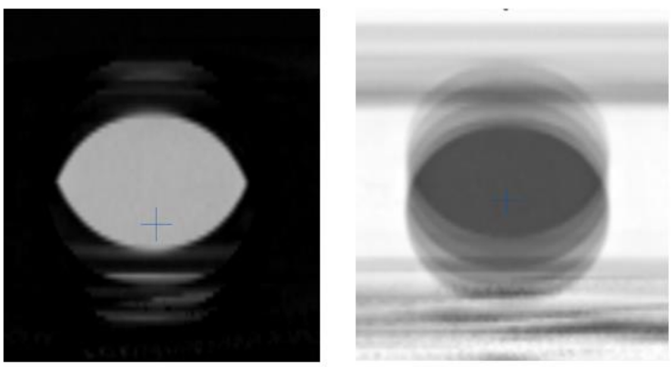

Fig 5a) Fig5b)

Figure 5: Shapes of one of the representative target (Rubber) resulted from different intensity projection methods a) Minimum, b) Mean.

The variation of ITV of different targets and HU delineated/generated using conventional 3D automatic image registration method and intensity projection methods are represented in Table 1.

Variation of target volume							Variation of Hounsfield Number						
ITV Mode	Volume in cc (Eclipse)			Volume in cc (iPlan)			ITV Mode	HU (Eclipse)			HU (iPlan)		
	Wood	Acrylic	Rubber	Wood	Acrylic	Rubber		Wood	Acrylic	Rubber	Wood	Acrylic	Rubber
3D Reg	73	73.5	62	73.4	73.2	62.8	3D Reg	-399	132	-259	-404	130	-250
Mean	70	68.8	58	70.2	71	58.6	Mean	-385	124	-284	-376	121	-283
Max.	71	70	59	71.4	70.3	59.5	Max.	-354	130	-211	-363	125	-200
Min.	50	44.8	34.9	49.8	42	34	Min.	-305	68	-136	-305	85	-148

Table 1: Variation of ITV and HU of different target delineated/generated using 3D automatic image registration and intensity projection image processing software.

The ITV's determined by intensity methods for both the planning systems did not show any significant difference (P=0.82) in terms of volume and HU (P=0.76) as shown in Fig 6

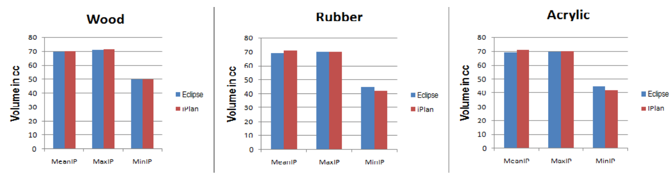

Figure 6: Target volume for iPlan and Eclipse from Intensity projection methods.

The percentage variation for target volume generated by intensity projection methods for both the systems were less than 2% and for HU was less than ±10 % as shown in Table 2.

Target volume and HU intercomparison for Eclipse and iPlan treatment planning system

ITV Mode	Eclipse Wood	iPlan Wood	% Var	Eclipse Acrylic	iPlan Acrylic	% Var	Eclipse Rubber	iPlan Rubber	% Var
MeanIP	70	70.2	0.2849	68.8	71	0.309859	58	58.6	1.02389
MaxIP	71	71.4	0.560224	70	70.3	0.042674	59	59.5	0.84034
MinIP	50	49.8	-0.40161	44.8	42	-0.66667	34.3	34	-0.88235

ITV Mode	Eclipse Wood	iPlan Wood	% Var	Eclipse Acrylic	iPlan Acrylic	% Var	Eclipse Rubber	iPlan Rubber	% Var
MeanIP	-385	-376	-2.39362	124	121	-0.24793	-284	-286	0.6993
MaxIP	-354	-363	2.479339	130	125	-0.4	-211	-200	-5.5
MinIP	-305	-304	-0.32895	68	85	2	-136	-148	8.10811

Table 2: Percentage Variation of ITV and HU of different target delineated for Eclipse and iPlan systems.

In comparison to the ITV delineated from the fused images (T_fused), the ratio of the ITV generated/delineated using various methods varies from 1 to 1.05 indicating good agreement in MeanIP and MaxIP methods for spherically target volume for both the planning system. However HU variation was as high as ±45% for rubber and acrylic for Minimum IP, ± 20% for Maximum IP for rubber and wood and ±10% for Mean IP for rubber and acrylic indicating possibility of large dosimetric variation.

III. DISCUSSION:

This study was done to compare the ITV generated by the treatment planning systems using the intensity projection method datasets for 4DCT delivery. Overall the volume obtained using both Eclipse and iPlan planning systems were found to be near perfect association for the phantom studied.

Target volume remains almost same in all phase of respiratory cycle indicating that any phase can be chosen to delineate target volume for gated radiotherapy. However in clinical practice, the phase having most stable and reproducible pattern should be selected for gated treatment. Both the planning systems showed an excellent agreement with ITV's derived by intensity projection methods and was found to be a fast and reliable tool for accurate target shape and volume delineation. The generation and contouring on the intensity projection generated CT datasets took less time as compared to contouring in all the phases. Our study was similar to that of Underberg et al,who compared the MIP generated using intensity projection methods using motion phantom and also suggested that in case of adjacent structure has equal or greater density the MaxIP may not be suitable and there is a need to use two different intensity methods for delineation. Our phantom study also suggest that in clinical practice, either one or two intensity projection methods, depending on target type and its movement region together with the HU from free breathing scan can be used to accurately delineate ITV and model dose distribution for moving target.Oechsner et al studied the dosimetric impact of different CT datasets and concluded that the Mean or Average IP for treatment planning is reliable for dose calculations [22].Several groups have also demonstrated the same for 4D dose calculations [23-29] In our study we also found that the Mean or Average intensity projection method is more reliable in terms of differences in HU's for dose calculations.

We found in this study that comparable and nearly equivalent results using contouring tools of both Eclipse and iPlan planning system in the delineation and generation of intensity projection datasets.

IV. CONCLUSION

The Mean or average intensity projection method seems to be suitable for ITV delineation and dose calculation. Both the planning systems showed no significant differences and were in good agreement in generating the ITV's from intensity projection methods in the context of 4DCT for treatment planning purposes.

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