

INFLUENCE OF CT SLICE THICKNESS ON VOLUME AND DOSE UNCERTAINTY FOR DIFFERENT ORGANS DURING TREATMENT PLANNING FOR EARLY PROSTATE CANCER

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ABSTRACT

The purpose of this study was to evaluate influence of different computed tomography (CT) slice thickness on gross target volume (GTV) and volumes of organs at risk (OAR), impact on the quality of digitally reconstructed radiographs (DRR) and dose volume histograms (DVH) during 3-dimensional conformal radiotherapy treatment planning. Ten patients with early prostate cancer were selected and CT scans with 2mm, 3mm and 5mm slice thicknesses were performed in sequence. The GTV, bladder and rectum were contoured in all scans. 3-dimensional planning was performed for all three CT datasets. The target coverage and isocenter shift between treatment plans for different slice thickness were correlated with tumor volume. Further comparative and dosimetric analysis was done for resultant DRRs and DVH respectively. For the prostate, no difference in mean volumes was seen for 2mm and 3mm scans (43.11cc, 40.2cc respectively) and were found larger as compared to 5mm scans (35.8cc) p value 0.0001. Similarly mean rectal and bladder volumes were found larger on 2mm and 3mm scans as compared to 5 mm scans p=0.002. The DVH data showed target underdosage was 8% for 5mm slice thickness as compared to 2mm and 3mm slice thicknesses. The quality of DRRs was found better for 2mm and 3mm scans. **CONCLUSION:** GTV and organs at risk (bladder and rectum) volumes were found larger on 2mm and 3mm slice thicknesses as compared to 5 mm scans, similarly better quality of DRRs for 2mm and 3mm scans. Significant tumor underdosage was seen on 5mm slice thickness.

Key Words: CT slice thicknesses, organ volumes, Isodose curves, dose volume histograms, early prostate cancer.

Introduction

With the development of modern computer based radiotherapy and dose escalation, the need for precise delineation of target volume and organs at risk (OAR) has become a priority. The delineation of the target and the contouring of organs at risk depend on the judgement of the oncologist and imaging parameters,¹ such as window-level setting and slice thickness of planning computed tomography (CT). The latter factor, the CT slice thickness used, has not been extensively studied to date. E. Berthelet and his colleagues assessed the impact of CT slice index- thickness on

prostate and organ at the risk by taking 3mm and 5mm scans. This study concluded larger bladder volumes on the 3mm scans and any expected differences were accounted by the missing tissue effect and partial volume effect.¹

In order to further assess the influence of CT slice thickness on the prostate, bladder and rectal volumes, quality of digitally reconstructed radiographs (DRR) and any variation in dose volume histograms (DVH) of clinical benefit, we conducted a study by taking three scans (2mm, 3mm and 5mm) at the time of virtual simulation.

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Materials and Methods

The study was carried out in two phases. (i) Phantom phase (fig.1): Before study quality assurance for couch movements and laser alignment was performed by using Wilke phantom. During this phase, baseline scans were obtained on phantom to determine mean volumes and differences and optimal CT slice thickness; 2 mm was taken as reference slice thickness. (ii) Clinical phase: ten patients with early prostate cancer (T1 and T2) were selected after taking informed consent. By using modern helical SOMATOM Emotion6 CT scanner Siemens®, each patient underwent three CT scans of slice thickness 2mm, 3mm and 5mm with full bladder respectively as a protocol in one session with interval of average 2-3 minutes between each scan. In all cases care was taken to ensure same KV, mAs, Hounsfield range and couch parameters in CT window. After acquiring CT images, all data subsets were transferred to COHERENCE treatment planning system Siemens® through DICOM (Digital Image Communication in Medicine) network. All organs were contoured on all scans using free hand tool in COHERENCE system by single oncologist along with a radiologist. Care was taken for any contouring bias by a departmental protocol; (a) prostate was contoured from apex to base (b) outer wall of rectum was contoured caudally 1.5 cm below GTV upto the point of sigmoid (c) outer wall of bladder was contoured and (d) PTV (clinical target volume) by adding 10 mm margins around GTV in all different CT datasets.

To determine the organ volumes, the sum of polygons technique was applied (calculated as the sum of the organ area on each slice multiplied by the slices thickness). The mean volumes, differences, and maximum extension in craniocaudal, transverse and anteroposterior for 2mm, 3mm and 5mm from the isocenter were calculated and corrected with slice thickness. After the contouring process, all data was transferred to Prowess Panther Siemens® treatment planning system (TPS). The radiation beam portals were placed using beam's eye view (BEV) and multileaf collimator (MLC) leaves were fitted to the shape the PTV. The planning isocenter was placed at the center of target volume with help of tool available in Prowess Panther TPS. The grid size of 2.5mm was kept for all

planes. All necessart steps were taken to achieve same beam angles, wedge angles, monitor units for each case with different CT dataset.

Separate plans were made for 2, 3 and 5 mm CT datasets and dose was computed independently for each datasets. The prescribed dose covering 95% of target volume was noted on all plans. The resultant DVHs of 2mm, 3mm and 5mm were superimposed after dose computation.

All resultant DRRs for different CT slice thickness were sent to Linear accelerator for portal imaging. DRR quality was assessed by asking five radiographers radiotherapy to give a score 1, 2, 3 (1=better, 2=comparable, 3=bad) by looking at DRRs in anteroposterior (AP) and right lateral views in comparison to reference DRRs (made on 2 mm dataset) of different slice thickness, and further scoring was analyzed by binomial test to get a significance. All data was analyzed on SPSS version 16.0 utilizing paired samples T test.

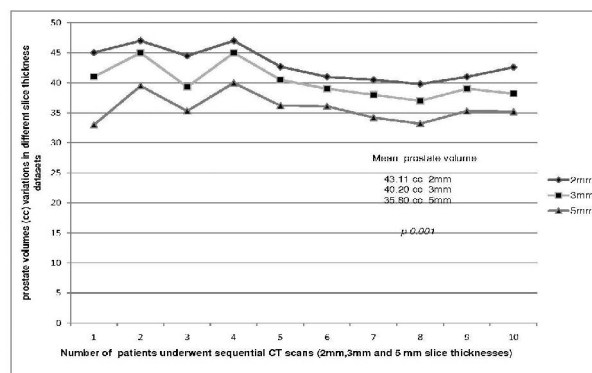


Figure 1a. Variation of prostate volume with different CT slice thickness

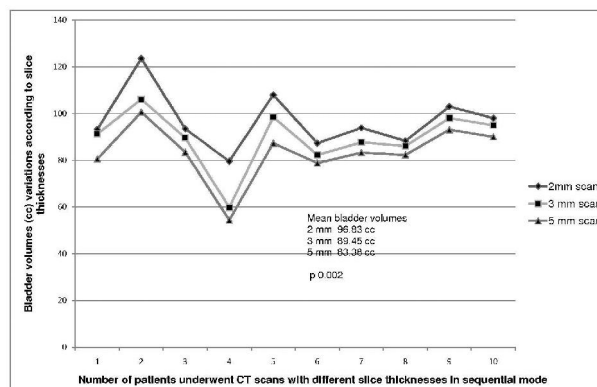


Figure 1b. Variation of bladder volume with different CT slice thickness

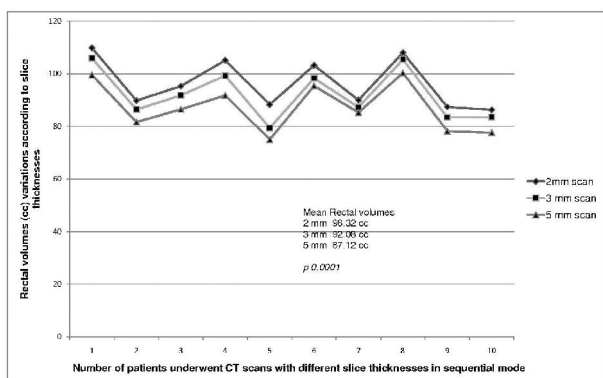


Figure 1c. Variation of rectal volume with different CT slice thickness

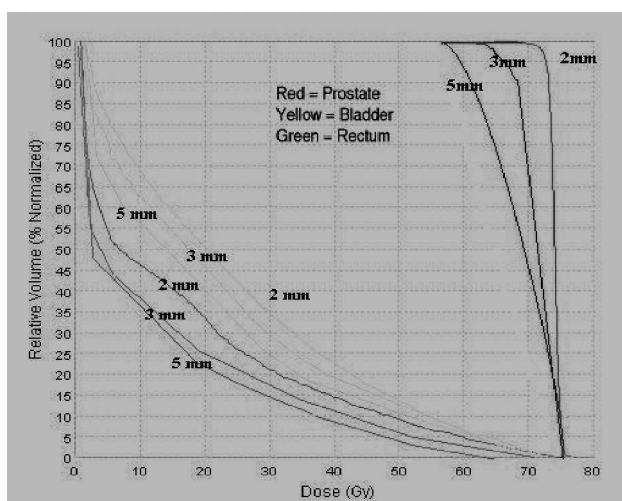


Figure 2. Histogram (Dose-volume) according to CT slice thickness

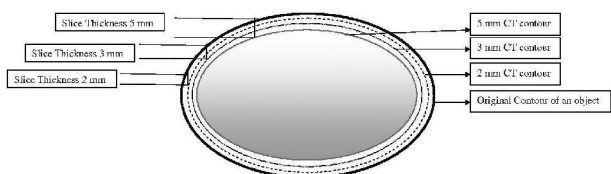


Figure 3. Schematic diagram of partial volume effect and missing tissue effect

Results

The results of ten patients with different CT slice thickness scans are as below:

1. *Prostate, bladder and rectal volumes* (Fig.1a, b, c). The comparative analysis was done by using T-test and value of $p < 0.05$ was selected as the level of statistical significance. Mean prostate volume was 43.11cc, 40.20 cc and 35.80 cc on 2mm, 3mm and 5mm scans respectively indicating larger volumes in 2mm and 3mm scans with p value 0.0001. Using paired T tests mean differences in measurement of prostate volumes were found 2.4 ± 0.77 (95% confidence

intervals (95%CI 1.87-2.94), 4.36 ± 0.76 (95%CI, 3.81-4.91) and 1.95 ± 0.16 (95% CI,1.83-2.06) between 2mm and 3mm, 2mm and 5mm and 3mm and 5mm CT datasets respectively.

Similarly using paired T test, mean differences in measurements of bladder volumes were found $7.38 \text{ cc} \pm 6.29$ (95% CI, 2.87-11.88) between 2mm and 3mm scans with p value 0.005. Mean difference in bladder volumes was $13.45 \text{ cc} \pm 6.85$ (95% CI, 8.54-18.35) between 2mm and 5 mm scans (p value 0.0001). Between 3mm and 5mm scans mean bladder volumes difference was $6.07 \text{ cc} \pm 2.69$ (95% CI,4.14-7.99) with p value 0.0001.

Mean Rectal volumes differences were found $4.24 \text{ cc} \pm 1.92$ (95%CI,2.86-5.62) p 0.0001, $9.20 \text{ cc} \pm 2.59$ (95% CI, 7.34-11.05) p 0.0001 and $4.96 \text{ cc} \pm 1.60$ (95%CI,3.81-6.10) p 0.0001 between 2mm-3mm, 2mm-5mm and between 3mm-5mm respectively.

Isodose curves and DVH data: (Fig. 2)

Comparative cumulative DVH for treatment plans made on 2, 3 and 5 mm CT dataset were superimposed and showed that in comparison to 2mm treatment plan 5 mm plan showed 10-12 % underdosage of PTV. Similarly PTV enclosed by 95% prescribed dose isoline was found less for 5mm scan than 2mm and 3 mm scans. Mean difference in 95% prescribed dose was $3.9\% \pm 0.56$ (95% CI, 3.49-4.30) p 0.0001 between 2 mm and 3mm treatment plans, $7.8\% \pm 1.13$ (95% CI,6.98-8.61) p 0.0001 between 2 mm and 5 mm treatment plans and $3.9\% \pm 0.73$ (95% CI, 3.37-4.42) between 3mm and 5 mm treatment plans. Since the bladder and rectal volumes were larger on 2mm followed by 3 mm scans, a smaller percentage of their overall volume received a given prescribed dose as seen in one sample case in.

2. *DRR quality.*

Comparative analysis of DRR quality was done by a scoring system. Five observers were asked to score each of 120 DRRs on AP, PA, right lateral and left lateral fields on a scale of 1 to 3 (better, comparable and bad) with respect to slice thickness. 80% (96) DRRs were rated better in 2mm and 3 mm scans than their counterpart 5 mm scans while remaining 20% (24) DRRs were rated comparable with 2mm and 3 mm scans. A binomial test showed a $p=0.05$ in the favor of 2mm and 3 mm scans.

Discussion

During three dimensional conformal radiotherapy, for early prostate cancer, radiation oncologists have to face many important challenges during target delineation and normal organ contouring. Various factors have been described which influence the contouring and dose distribution.^{3,4,5} The radiologic anatomy knowledge of radiation oncologist can also impact on target delineation. Several studies have shown intra observer and inter observer variability in target volume definition for prostate cancer.^{6,7,8} Regarding, the influence of a particular CT slice thickness on the organ contouring and dose distribution small work has been published.^{9,10,11}

In our study, mean prostate, bladder and rectal volumes were slightly larger in 2mm followed by 3mm scans in comparison to 5mm scans, showed statistical difference. The possible explanation for relatively larger volumes on small slice thickness scans may be the missing tissue effect and partial volume effect (Fig.3). Somigliana et al,¹² showed while conducting a phantom study for GTV less than 1.5 cm in diameter that small thickness CT scans can minimize the missing tissue effect. Since all organs volumes were larger on 2mm and 3mm scans as compared to 5 mm scans a smaller percent of their overall volume received higher prescribed dose which was found during DVH analysis. Better DRRs resultant from 2mm and 3 mm scans were achieved because surface irregularities in the DRRs become smoothed as slice thickness decreases.

However we believe that our study had few limitations:

- a. The isocenter shift between the target volumes delineated on different CT slice thickness was not calculated. As the center of GTV is a point at which all mass of tumor is concentrated, which is highly dependent on the shape of reconstructed tumor volume so isocenter shift can be expected with changes in slice thickness.
- b. Apart from the influence of partial volume and missing tissue effects, the bladder and rectal filling effects and internal organs motion may influence the reconstructed volume shape and prescribed dose, which can not be explained by DVH analysis; DVH studies only provide the dose-volume relationships.
- c. In our study target and organ delineation was carried by free hand contouring in COHERENCE system, which can be criticized for adding some delineation bias; we believe that if it occurs the impact of volume shaping is minimal as contouring process was performed by an experienced oncologist along with a radiologist.
- d. However all CT parameters (KVp, mA, exposure, collimation, helical pitch and CT numbers) were kept same while acquiring different CT dataset, variations in signal to noise ratio and intensity with slice thickness can not be completely ignored.
- e. The rating of DRRs by observers might be affected by subject bias owing to their different opinions.

Conclusion

Our study tried to answer many queries related to influence of CT slice thickness on different organ volumes and dose distribution. We conclude that the volumes of contoured organs increase with decreased slice thickness. We recommend 2 mm CT slice thickness for 3D-CRT for prostate cancer for better visualization of target and organs at risk; however it may appear time consuming to delineate organs on large dataset as compared to 5 mm dataset.

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