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Clinical evaluation of soft tissue organ boundary visualization on cone-beam computed tomographic (CBCT) imaging

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Abstract

Purpose—Cone-beam computed tomographic images (CBCTs) are increasingly used for set up correction, soft tissue targeting and image-guided adaptive radiotherapy (IGART). However, CBCT image quality is limited by low contrast and imaging artifacts. This analysis investigates the detectability of soft tissue boundaries in CBCT by performing a multiple-observer segmentation study.

Material and Methods—In 4 prostate cancer patients prostate, bladder and rectum were repeatedly delineated by 5 observers on CBCTs and fan beam CTs (FBCTs). A volumetric analysis of contouring variations was performed by calculating coefficients of variation (COV: standard deviation/average volume). The topographical distribution of contouring variations was analyzed using an average surface mesh-based method.

Results—Observer- and patient-averaged COVs for FBCT/CBCT were 0.09/0.19 for prostate, 0.05/0.08 for bladder and 0.09/0.08 for rectum. Contouring variations on FBCT were significantly smaller than on CBCT for prostate ($p < 0.03$) and bladder ($p < 0.04$), but not for rectum ($p < 0.37$) (intermodality differences). Intraobserver variations from repeated contouring of the same image set were not significant for either FBCT or CBCT ($p < 0.05$). Average standard deviations of individual observers' contour differences from average surface meshes on FBCT versus CBCT were 1.5 versus 2.1 mm for prostate, 0.7 versus 1.4 mm for bladder, and 1.3 versus 1.5 mm for rectum. The topographical distribution of contouring variations was similar for FBCT and CBCT.

Conclusion—Contouring variations were larger on CBCT than FBCT, except for rectum. Given the well-documented uncertainty in soft tissue contouring in the pelvis, improvement of CBCT image quality and establishment of well-defined soft tissue identification rules are desirable for image-guided radiotherapy.

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Conflicts of interest:

None of the authors has any actual or potential conflicts of interest.

Keywords

Cone-beam CT; Image guided adaptive radiotherapy; Prostate cancer; Image quality; Segmentation

Introduction

Cone-beam computed tomography (CBCT) is currently used predominantly for on-line set up correction using both bony anatomy and soft tissue information (1–4). Soft tissue information from repeated CBCTs has also been used as the basis for adaptive radiotherapy planning (5, 6) and safety margin calculation (7,8). Cone-beam CTs play an important role in the development of image-guided adaptive radiotherapy (IGART) processes that require repeated updates of patient anatomy for treatment plan adaptation and dose summation over deforming anatomies (1,9,10).

Impaired image quality has compromised the current use of CBCTs for IGART. Streaking artifacts and low soft tissue contrast are major limitations for image interpretation. In the pelvis, soft tissue motion and deformation including motion of air-filled pockets in the rectum (11) occur regularly and result in relevant imaging artifacts that may render the identification of soft tissue boundaries difficult or impossible.

Different methods exist to quantitatively assess image quality. For clinical purposes, the most important criterion of CBCT image quality is the ability to accurately detect soft tissue structures and their boundaries. While the clinical routine use of CBCTs for patient set up in the pelvis utilizes mostly information of 3D bony anatomy or prostate position only, for IGART purposes, detectability of other pelvic structures such as rectum and bladder becomes important, as well, to accurately assess dose to the whole treatment volume.

Manual image segmentation is the current standard of organ volume delineation in radiotherapy. In the present study, multiple observer contouring variations were analyzed as a measure for image quality of kilovoltage CBCTs relative to standard fan beam CTs (FBCTs). Volumetric and spatial variations of prostate, bladder and rectum contours were compared between the two imaging modalities. To assess contouring variations with respect to organ topography an in-house surface mesh-based methodology was employed.

Material and Methods

Patients and imaging

A multiple observer-contouring study was performed on a set of FBCTs and CBCTs of 4 prostate cancer patients. Images were obtained as part of an IRB-approved protocol. Images of the first 4 patients who participated in this protocol were used for this study. All patients underwent primary external beam radiotherapy and had tumors that were confined to the prostate ($2 \times T1cN0$, $1 \times T2aN0$, $1 \times T3aN0$). Three patients had markers or dosimeters implanted into the prostate prior to treatment: Patient 1 had two dose verification system devices (DVS, Sixel Technologies, Morrisville, NC), patient 3 three gold markers and patient 4 three Calypso markers (Calypso Medical Technologies, Seattle, WA). The average anterior-posterior patient separation at the prostate level was 22 cm (range 19 – 26 cm).

Fan beam CTs of the pelvis were acquired with continuous 1.5 mm slices on a 16 slice scanner with a 60 cm field of view (140kV, 350 mAs, Brilliance Big Bore, Philips Medical Systems, The Netherlands). Kilovoltage CBCTs were acquired in half-fan mode with bowtie filter and anti scatter grid (125kVp, 80mA, 25 ms, Varian Medical Systems, Palo Alto, CA). 630 projections were acquired over a 360 degree rotation in approximately one minute resulting in

an imaging dose of approximately 8 mSv per scan. The field-of-view was $48 \times 48 \text{ cm}^2$ in axial plane and 14.25 cm longitudinal length. All organs of interest (prostate, rectum and bladder) were always completely covered by the field of view. A 512×512 matrix was used for both imaging modalities. Pixel size for CBCTs was either $0.059 \times 0.059 \times 0.15/0.1 \text{ cm}^3$ or $0.049 \times 0.049 \times 0.15 \text{ cm}^3$. For FBCTs pixel size was either $0.097 \times 0.097 \times 0.15 \text{ cm}^3$ or $0.117 \times 0.117 \times 0.15 \text{ cm}^3$. All imaging was performed without oral or intravenous contrast. FBCTs had contrast in the distal urethra from a retrograde urethrogram. Patients were instructed to have a comfortably full bladder. No diet or medication scheme was used to regulate bowel movement.

Structure delineation

On both imaging modalities prostate, bladder and rectum were delineated independently by 3 physicians (one attending physician and two residents after working on the prostate service) and 2 physicists (experienced in soft tissue contouring), all of the same department. A research version of a commercially available treatment planning software (Pinnacle version 8.1, Philips Medical Systems, Milpitas, CA) was used. In the CBCT of patient 3 massive imaging artifacts were observed that were attributable to huge moving air pockets in the rectum (see figure 1). The rectum was therefore not delineated in this patient.

After a training session that was lead by the attending physician and included both an interactive review of the contouring protocol as well as a contouring exercise on both the FBCT and CBCT of one patient by all observers with interactive feed back by the supervising attending physician, contouring of FBCT and CBCT images was performed independently without referring to other observers' contours. In an image-guided radiotherapy setting observers have the ability to review the higher quality imaging modality for reference. Since the goal of this study was primarily to use contouring variability as a measure for image quality, observers were not allowed to review contours performed on the other imaging modality. Observers were instructed to use the default pelvis window settings for contouring (window width 50, window level 75) on both FBCTs and CBCTs. At this window level, contoured prostate volumes were comparable between FBCT and CBCT.

A detailed contouring protocol was used that reviewed the anatomical position of the three structures in the pelvis. It included a description of the topographical anatomy of the prostate relative to bony anatomy and other soft tissue structures, e.g. the pelvic diaphragm and the penile bulb. Observers were asked to only include the prostate itself without seminal vesicles, neurovascular bundles, venous plexus or levator muscles. For the rectum, the upper border was uniformly defined as the lower edge of the sacroiliac joints and the lower border as the most inferior edge of the ischial tuberosities. The whole rectal wall was required to be included, but no sphincter muscles. All parts of the bladder wall were to be included in the contours. In the presence of partial volume effects, observers were asked to rather err on the generous side and in doubt to contour the larger volume.

To estimate intraobserver variation, repeated contouring of the same images was performed in general at least one week after contouring the first image sets without accessing the initial contours.

Contour analysis

Contouring variations in prostate, bladder and rectum volumes—*Coefficients of variation COV* (standard deviation/mean volume) for prostate, bladder and rectum contoured by the 5 observers were calculated for FBCT and CBCT and all patients. Absolute organ volumes of bladder and rectum were not comparable between the two imaging modalities due to different filling status.

- For obtaining the *interobserver variation*, the COVs of all observers' contours per patient were calculated and averaged over all patients.
- *Intermodality variations* were assessed by comparison of patient- and observer-averaged differences of the COVs between CBCT and FBCT.
- To assess *intraobserver variation*, the patient-averaged differences of the COVs from the first and the second contouring sessions were calculated. In addition, differences between initial and repeated contouring were expressed as a percentage change of the initial volume per observer and patient, averaged over all patients and all observers both for CBCT and FBCT.

Since prostate volumes are expected to not change at a relevant degree between FBCT and CBCT imaging, differences of contoured prostate volumes from repeated contouring on FBCTs and CBCTs were compared to differences in prostate volumes between CBCT and FBCT for each observer to assess the magnitude of intermodality versus intraobserver variation.

Volume coincidence ratio—Common and encompassing volumes were calculated for each of the three structures and each imaging modality. A common volume was defined as the largest volume on which all observers agreed per patient and structure. An encompassing volume was defined as the smallest volume that covered all contours per patient and structure. The ratio of common over encompassing volume (=volume coincidence ratio, VCR) per structure was averaged over all patients per imaging modality. The VCR was used as a measure for spatial agreement between observers.

Topographical distribution of contouring variations—In order to associate contouring variations with organ topography and to identify anatomical locations on the organ surfaces with high/low contouring variations, a mesh-based surface model was developed. Individual observers' contours were converted into meshes. From the individual meshes an average triangulated surface mesh was calculated per organ, patient and imaging modality. To calculate the average organ surface mesh per patient, an isocoverage voting approach similar to that used by Deurloo *et al.* was adopted (12). First, a binary image that represented the coverage of the structure was generated for each segmented structure boundary surface. Any voxels inside the structure surface have the value 1 and any voxels outside the value 0. Each voxel was a 1 mm³ cube. Then a composite image was created by adding together the binary images that represent the same structure. The average boundary was determined by finding the 50% isosurface of the composite image using the marching tetrahedron algorithm (13). The output average surface from this algorithm is represented by a triangle surface mesh. Since the structure surfaces can be very irregular with sharp edges and spikes, a discrete 3D Gaussian smoothing filter was applied to the composite image before running the marching tetrahedron algorithm. The variance of the Gaussian kernel was empirically set to 4 after weighting the tradeoff between the surface smoothness and the preservation of anatomical surface fine details. The next step was to calculate the standard deviation surface meshes (SDSM) per patient, organ, and modality. Firstly, the contours delineated by each individual observer were converted into triangle meshes. Then the surface distance mesh was calculated for each individual mesh. The surface distance was based on the perpendicular distances from each vertex on the average mesh to the interception point on the individual mesh along the vertex normal direction. The standard deviations of the distances that are associated with each vertex on the average mesh were separately calculated and were the vertex values of the SDSM. Standard deviations were color-coded and displayed three-dimensionally over the average surface mesh. An example for one patient is shown in figure 2.

Mean standard deviations on the average surface meshes were averaged over all patients and compared between FBCT and CBCT for all structures.

In a patient- and imaging-dependent evaluation anatomical locations with the largest and smallest degree of contouring variations were assessed qualitatively for FBCT and CBCT.

Statistical analysis

Differences in intermodality, inter- and intraobserver contouring variations based on coefficients of variation and volume coincidence ratios were tested for significance using a random effects ANOVA. The random effects were included to account for clustering of observations within patients, since the same patient data were used to calculate differences for imaging modalities and for repeated imaging. The statistical calculation was performed using PROC GLIMMIX in SAS, version 9.2. Differences of contouring variations on average surface meshes were tested for significance with a two-sample t-test for the null-hypothesis that the distribution of standard deviations on FBCT is the same as on CBCT. A p-value <0.05 was considered significant. This part of the statistical analysis was performed with software R, version 2.8.

Results

Contouring variations in prostate, bladder and rectum volumes

Prostate volumes averaged over all patients and observers were comparable on FBCTs and CBCTs (39.8 cm³ on FBCT and 39.1 cm³ on CBCT). The ratio of FBCT prostate volumes / CBCT prostate volumes was on average 1.02 for prostate (p>0.05). The patient-averaged standard deviations of contoured prostate volumes were 3.9 cm³ for FBCT and 7.5 cm³ for CBCT. Patient-averaged bladder and rectum volumes were 94.6 and 87.0 cm³ on FBCT and 98.2 and 64.4 cm³ on CBCT.

The patient-averaged COVs for prostate, bladder and rectum volumes (interobserver variations) were 0.09, 0.05 and 0.09 for FBCT and 0.19, 0.08 and 0.08 for CBCT. Intermodality differences between FBCT and CBCT were significant for prostate (p<0.03) and bladder (p<0.04), but not for rectum (p<0.37).

Repeated contouring of the same FBCT and CBCT data sets (intraobserver variations) resulted in the following COVs for prostate, bladder and rectum: 0.07, 0.04 and 0.06 for FBCT and 0.1, 0.08 and 0.12 for CBCT. Differences between repeated contouring sessions of the same imaging modality were not significant for all organs (p>0.05). Data of individual patients are shown in table 1. Volume differences from repeated contouring expressed as ratio of the difference between repeated contouring over the initially contoured volume were for prostate, bladder and rectum 0.09, 0.05 and 0.05 for FBCT, and 0.13, 0.07 and 0.10 for CBCT, respectively. Figure 4 shows that repeated contouring resulted in on average larger volumes for 9/15 structures (5 observers, 3 structures) on FBCT and 7/15 structures on CBCT. Volumes of all 4 patients were averaged per observer.

Intraobserver volume differences of repeated prostate contouring on the same image set calculated per observer averaged over all observers and patients were 3.2 cm³ for FBCT and 4.8 cm³ for CBCT, whereas differences in contoured prostate volumes on FBCT and CBCT (intermodality differences) were 10.3 cm³ calculated per observer and then averaged over observers and patients. Assuming on average identical prostate volume visualization on both FBCT and CBCT (see above), these results indicate lower intraobserver than intermodality contouring variation.

Volume coincidence ratios

Mean VCRs on FBCT versus CBCT were 0.58 versus 0.45 for prostate (p<0.0005), 0.72 versus 0.61 for bladder (p<0.01) and 0.59 versus 0.51 for rectum (p<0.01). For repeated contouring

the following volume coincidence ratios were obtained on FBCT versus CBCT: 0.60 versus 0.42 for prostate, 0.74 versus 0.61 for bladder, and 0.61 versus 0.42 for rectum). Differences between repeated contouring sessions of the same image sets were not significant ($p>0.05$). Data of individual patients are shown in table 1.

Figure 3 is showing a typical example of common and encompassing volumes in axial slices at the apex, mid prostate and prostate base.

Topographical distribution of interobserver variations

Mean patient-averaged standard deviations of individual observers' contour differences from the average surface mesh on FBCT versus CBCT were 1.5 versus 2.1 mm for prostate, 0.7 versus 1.4 mm for bladder, and 1.3 versus 1.5 mm for rectum. Repeated contouring of the same data set resulted in the following variations: 1.3 versus 1.9 mm for prostate, 0.7 versus 1.4 mm for bladder, and 1.2 versus 1.8 mm for rectum. Data of individual patients are shown in table 1. Contouring variations on CBCT were significantly larger ($p<0.001$) than on FBCT for all organs and patients except for rectum in patient 1. Figure 5 shows the cumulative distribution of all standard deviations for each structure on all mesh points of all patients for the two imaging modalities. While for rectum the FBCT and CBCT graphs closely overlap, for prostate and bladder standard deviations on CBCT-based meshes are clearly larger than on FBCT. These graphs indicate that differences between FBCT and CBCT contours do not result from a few outliers, but cover the whole mesh surface with differences between FBCT and CBCT meshes being evident even in the lowest range of standard deviations, particularly for prostate.

Anatomical locations of largest and smallest variations varied between patients. The locations with the smallest variations were in the lateral parts of the organs for prostate and bladder, and for rectum superior to the prostate. The largest variations were observed in areas of contact with other pelvic organs and other neighboring structures with similar gray values. Larger variations were most frequently identified superior and inferior posterior for the prostate (contact area with seminal vesicles, bladder base and apex), inferior posterior for bladder (contact area with prostate), and inferior anterior for the rectum (contact area with prostate, urogenital diaphragm, sphincter muscle) both for FBCT and CBCT.

Discussion

Contouring variations and their topographical distribution

In this multiple observer contouring comparison study of pelvic organs, contouring variability was used as a measure for clinically-relevant image quality. We observed that contouring variations using both a three-dimensional volume-based evaluation and an average surface mesh-based analysis were on average larger on CBCTs than FBCTs. Differences between average FBCT and CBCT prostate volumes were approximately 10 % in our study which compares well to a study by White EA et al. (14) who reported a value of 16%. This study found the standard deviation of contoured prostate volumes to be approximately 9 cm³ whereas in our study it was 7.5 cm³. With average volume coincidence ratios for prostate of about 60 % for FBCT, our results are very similar to results published by Rasch et al. (15) who reported mean VCRs of 67% for FBCT and 66% for MRI. While volume variations in FBCT and CBCT contouring were found to be statistically significant, smaller differences such as the ones observed in bladder are at present of limited clinical significance given the large physiological day-to-day variations in bladder filling.

The overall larger contouring variations on CBCTs also resulted in larger intraobserver contouring variability on CBCT than FBCT. Intraobserver variations on FBCT were smaller for prostate and bladder than intermodality variations indicating that the largest contribution

to the overall contouring uncertainty originates from differences in imaging modality rather than observer-dependent contouring uncertainties.

The topographical distribution of contouring variations was comparable between FBCT and CBCT. The smallest contouring variations of the prostate were found in the lateral parts. The largest variations were identified in the region of the seminal vesicles, and the posterior and anterior parts close to the apex (16,17). The retrograde application of contrast on FBCT via an urethrogram (no contrast in the bladder!) did not change the topographical distribution of contouring uncertainties between FBCT and CBCT in the evaluated patients. The largest variations for the bladder were observed in the contact area between prostate and bladder. Rectum contour variations were largest in the area close to the prostatic apex, the urogenital diaphragm and the sphincter muscle (16) and smallest superior to the prostate where the rectum is surrounded by low density tissue.

Surface meshed based data analysis

The topographical analysis of not only mostly spherical structures like prostates, but also potentially convex (bladder) and cylindrical shapes (rectum) required the development of the above mentioned average surface mesh-based method. For the development the approach by Deurloo et al. (12) was followed and expanded for bladder and rectum. Using this method, an average surface mesh can be generated and the perpendicular distances from the average mesh of one patient to the meshes of individual observers be calculated per mesh vertex for every patient. This allows detection of anatomical locations with highest and lowest variations in surface structure identification. This information is valuable for structure mapping purposes during adaptive radiotherapy processes where identification of reliable soft tissue landmarks is expected to render the adaptive replanning procedures faster and more reproducible. The present plan is to develop a population-based model of organ surface identification likelihoods that can be used in a more generalized fashion for surface uncertainty-weighted deformable image registration.

CBCT image quality

Limitations of soft tissue identification in CBCTs might restrict the clinical usefulness of CBCT information. Technical parameters for CBCT acquisition in the present study followed the standard clinical protocol. Improvements of image quality can be expected with modifications of technical imaging parameters such as higher mAs, however, at the cost of higher dose. The selection of slice thickness might also affect soft tissue contrast. In our study slice thickness was chosen to match FBCT slice thickness which is 1.5 mm in patients with implanted markers or dose measuring devices.

Various approaches have been undertaken to make CBCTs clinically more useful. For automated prostate alignment procedures, reductions of the field of view to cover the prostate only were suggested and resulted in a 10% higher success rate of automated prostate registration than uncollimated CBCTs (4). In another report, the performance of CBCT for set up was increased by including the information of prostate calcifications for soft tissue matching (18). Similarly, Moseley et al. (3) described that the targeting accuracy of the prostate using soft tissue information on CBCTs was improved by including implanted marker information. Our study supports these findings. All of our patients had fiducials implanted in the prostate except patient 2. Contouring variations for the prostate in this patient were larger for FBCT and in particular for CBCT compared to other patients. This seems to indicate that markers placed inside the prostate help with the definition of the outside organ contour.

Motion of bowel gas during CBCT acquisition has been described as particularly detrimental for image quality which was also observed in our study. A review of image sets with particularly

high contouring variations, such as CBCTs in patient 1 and 2 showed streaking artifacts from air either in small bowel loops that reached deep into the small pelvis or large air bubbles in the rectum that limited reliable structure identification. Dietary measures have been found to significantly improve intensity-based registration on pelvic CBCTs (11). The patients in our study were not provided with diet-related instructions.

While for current clinical purposes CBCTs are mostly used to identify the prostate, the identification of other pelvic soft tissue structures is important as well for the development of IGART processes such as deformable image registration and deformable dose summation which require the whole 3D data set information. IGART processes also require an automation of structure identification with sufficient image quality to enable reliable mapping of structures. Several methods have therefore been proposed to make CBCT soft tissue information more useful for IGART, by technically reducing imaging artifacts and by developing or applying tools for automated contouring such as feature-based image registration tools for automated rectum contouring (1,9,10,19–21).

As shown in the present study, limitations in CBCT image quality increase manual contouring discrepancies. The impact for IGART is, however, unclear. Murphy et al. (22) showed that accuracy of automated image registration and contouring processes, are likely not affected to the same extent by image quality as manual contours are. Further investigations are therefore required to test automated structure identification and contour mapping on CBCTs.

Conclusion

The present study on the clinical detectability of soft tissue boundaries on CBCT images shows that structures can be identified more consistently on FBCTs than CBCTs. Given the known uncertainty of soft tissue delineation in the pelvis even for FBCTs, the establishment of rigorous soft tissue delineation guidelines, improvement of CBCT image quality and use of surrogate markers for prostate volume definition need to be investigated further. The impact of CBCT image quality on automated structure identification and contour mapping for IGART processes needs to be tested.

Acknowledgments

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Figure 1.
Cone-beam CT of patient 3 with artifacts caused by moving air in the rectum.

Figure 2.

Example of topographical contouring variations on FBCT and CBCT of one patient: Standard deviations of contouring variations are displayed over the average surface meshes. Standard deviations up to the 95 percentile are color-coded in this figure.

CBCT: cone-beam computed tomography; FBCT: fan beam computed tomography; Lt: left; Post: posterior; Sup: superior.

Figure 3.

Example of inter-observer contouring variation on FBCT and CBCT of the same patient at different levels of the prostate. Each color represents one observer.

A large variation is observed at the prostatic apex on FBCT and even more on CBCT. Rectum contouring at this level shows also high uncertainty due to missing contrast from surrounding structures mostly in anterior and posterior direction.

Although at the same level of bony anatomy, bladder comes into view at mid prostate level on FBCT.

There is a high level of contouring uncertainty at the prostate base where the prostate is in close vicinity with the bladder.

Figure 4.

Patient-averaged differences between repeated contouring of the same FBCT and CBCT image sets per observer. Variations were calculated as percentage differences from the first contouring session.

a) Prostate

b) Bladder

c) Rectum

Figure 5.

Cumulative distribution function of standard deviations on average organ surface meshes of all mesh points summarized for all patients. Thin lines show standard deviations on FBCTs, thick lines standard deviations on CBCTs.

Table 1

Patient-specific results

Patient	Image	Mean volumes (SD) in cm ³			Common / encon- passing volume in %			Contouring variation (= mean SD) with surface mesh-based method in mm		
		P	B	R	P	B	R	P	B	R
Patient 1	FBCT 1	32 (3.6)	124.4 (4.2)	91.8 (6.8)	55.1	72.1	48.0	2.1	0.8	1.8
	CBCT 1	35.9 (8.9)	97.9 (13.2)	85.0 (3.3)	35.1	42.6	53.7	2.6	2.5	1.5
	FBCT 2	27.5 (2.5)	126.9 (2.7)	91.9 (9.3)	60.1	76.0	52.3	1.6	0.7	1.7
Patient 2	CBCT 2	30.2 (2.2)	95.1 (7.5)	90.5 (12.1)	42.2	42.8	36.5	2.0	2.2	2.4
	FBCT 1	62.9 (2.6)	90.6 (4.5)	134.3 (8.4)	62.7	65.4	70.2	1.2	0.8	1.1
	CBCT 1	62.2 (13.4)	87.6 (3.4)	72 (4.5)	49.2	62.9	59.4	2.2	1.1	1.3
Patient 3	FBCT 2	60.4 (2.6)	97.8 (6.5)	133.3 (2.9)	61.4	64.4	68.3	1.3	1.0	1.0
	CBCT 2	68.2 (8.3)	83.0 (6.0)	76.9 (5.5)	42.5	58.9	43.4	1.7	1.2	1.4
	FBCT 1	28.4 (2.9)	51.5 (5.0)		51.6	67.1		1.4	0.9	
Patient 4	CBCT 1	22.9 (6.0)	67.8 (7.2)		38.3	64.2		1.8	1.2	
	FBCT 2	30.8 (1.8)	53.5 (2.3)		56.2	70.2		1.3	0.7	
	CBCT 2	19.9 (3.2)	71.6 (9.7)		50.8	65.4		2.1	1.4	
Patient 5	FBCT 1	37.7 (3.6)	111.8 (1.8)	34.9 (4.6)	62.2	84.8	60.0	1.4	0.5	1.0
	CBCT 1	34.4 (1.7)	139.6 (6.2)	36.1 (4.6)	56.2	76.2	40.5	1.6	0.9	1.8
	FBCT 2	38.1 (2.8)	112.8 (3.4)	35.3 (2.5)	63.9	83.9	61.8	1.3	0.5	1.0
Patient 6	CBCT 2	37.3 (1.7)	140.5 (3.2)	35.1 (5.0)	36.3	78.8	45.0	2.1	0.7	1.7