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Image Guided Radiotherapy (IGRT) Comparison between Cone Beam CT and Ultrasound System for Prostate Cancer

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Abstract The aim of this study is to evaluate two different Image Guided RadioTherapy (IGRT) methods during 38 fractions of one prostate cancer patient's treatment. Prostate cancer patient was scanned 3.0mm width by Siemens Biograph mCT and Elekta Clarity® Ultrasound system with transabdominal probe. Critical organs and targets were determined from fusion of these images on the CT data set. Volumetric modulated arc therapy (VMAT) planning were performed by using Monaco 5.1® treatment planning system. Reference images of CT scan and ultrasound images were sent to Elekta Versa HD® linear accelerator's treatment system. Before the prostate cancer patient's treatment, we had scanned prostate localization by Elekta Clarity® Ultrasound system. Then we compared ultrasound images with reference images and we adjusted position of couch. For checking the localization of prostate, we scanned patient by XVI 4.5 Cone Beam CT system and we determined the difference between Ultrasound scan and Cone Beam CT scan an average 2.8±1.6mm lateral direction, 2.9±1.1mm longitudinal direction and 2.6±1.4mm vertical direction during 38 fractions of treatment. The results show that comparison between Clarity® Ultrasound system and Cone Beam CT system less than 3.0mm in three directions. Therefore, we are treating prostate cancer patient with ultrasound IGRT method instead of Cone Beam CT scan method in our clinic.

Keywords Cone Beam CT, Ultrasound, Prostate Cancer

1. Introduction

The aim of radiotherapy is to obtain tumor control with low rates of acute and late side-effects and preservation of long-term quality of life. Most prostate cancers are diagnosed at an early stage, allowing for the high rate of success with localized treatment. Between 30% and 45% of men receive radiation as their primary treatment for prostate cancer depending on their age at diagnosis [1, 2]. In the treatment of prostate cancer, IMRT was introduced in the early 1990s at a number of centers, with the largest experience being detailed at the Memorial Sloan-Kettering Cancer Center. In the latest of a series of institutional case series, Zelefsky et al. [3] reported on the treatment of 1571 patients with IMRT at doses as high as 81Gy, with rates of GI and GU toxicity less than those reported from their institution for 3DCRT at similar or lower doses. Several studies have demonstrated the superiority of volumetric modulated arc therapy (VMAT) plans over the step-and –shoot intensity modulated (IMRT) approach in prostate cancer [4,5]. The prostate and seminal vesicles are located between the rectum and the bladder. The position of the prostate is affected by physiologic changes in the bladder and rectum volume. These variations in position and shape can be left unchanged and compensated for with margins or reduced by image guidance resulting in smaller irradiated volumes. Smaller margins reduce the dose to the organs at risk; therefore, effort has been directed at reducing uncertainties with the use of image guidance. In RT of prostate cancer the key OARs, the rectum and the bladder, display extensive motion due to variations in organ filling[6]. Recently, many studies have been reported on image guidance strategies to correct for prostate motion with daily offline or on-line position verification of the prostate. Most of these reports used implanted fiducial markers in the prostate [7, 8]. Although fiducial marker-based correction strategies are already an important step forward, they have some shortcomings. The implantation of markers is an invasive procedure. Marker-based strategies correct for translations but tend to neglect rotations, which are known to be a large component of prostate motion [9]. The use of high-frequency sound waves to produce images of internal anatomy, ultrasound is common IGRT approaches in current practice, also it could use in radiotherapy treatment. Clarity®

ultrasound system (Elekta, Crawley, England) obtains ultrasound images in both the treatment and simulation rooms, system helps for delineating target and critical structure and eliminating potential position errors inherent in cross-modality image comparisons. Localization with an optical guidance system tracks the position of the probe in the radiotherapy treatment room. System has got two different probes, one of them is transabdominal probe other one is transperinial probe. Intra-fraction motion management is possible by transperinial probe.

In the present study we have therefore compared kilovoltage computed tomography's (kV-CBCT) and Clarity Ultrasound system's position errors of prostate cancer patient with transabdominal probe during 38 fractions.

2. Materials and Methods

Prostate cancer patient was scanned 3.0mm width by Siemens Biograph mCT and Elekta Clarity® Ultrasound system with transabdominal probe in the CT room. Critical organs and targets determined from fusion of these images on the CT data set. The prescribed dose was 76Gy in 38 fractions to 95% of target volume. Volumetric modulated arc therapy (VMAT) planning performed by Monaco 5.1® treatment planning system. Patients were treated with 10MV beam from a Versa HD® (Elekta, Crawley, England) linear accelerator equipped with Agility® collimator system. The bladder volume receiving > 65Gy should be < 25%, and receiving > 40Gy should be < 50%. The rectum volume receiving > 65Gy should be < 17%, and receiving > 40Gy should be < 35%. The femur head volume receiving > 45Gy should be < 10% in our clinic's dose-volume criteria for OARs[10-12].

Reference images of CT scan and ultrasound images were sent to Elekta Versa HD® linear accelerator's treatment system [Figure 1]. We made sure about ultrasound system's coordinate correction with daily Quality Control (QC) phantom. Before the prostate cancer patient's treatment, we had scanned prostate localization by Elekta Clarity® Ultrasound system with transabdominal probe. Then we matched these ultrasound images with reference ultrasound images from CT room and we adjusted position of couch. This is done by an infrared imaging camera to detect the probe position on the ceiling during 38 fractions for prostate cancer patient. Figure 2. shows that transabdominal prostate scan and Figure 3. shows that transperinial prostate scan. For checking the localization of prostate, we scanned patient by XVI 4.5. Cone Beam CT system and we determined the differences in three dimension which are longitudinal, lateral and vertical directions between ultrasound scan and Cone Beam CT scan during 38 fractions of treatment.

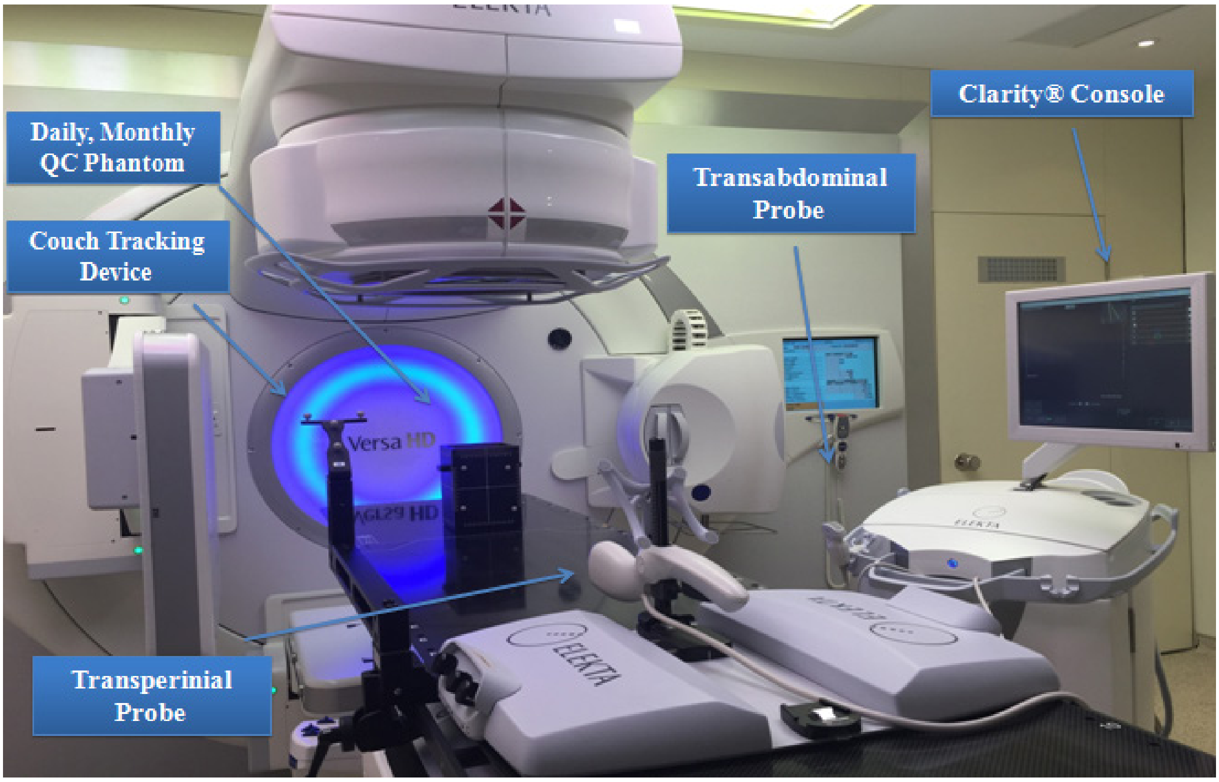

Figure 1. Elekta Versa HD® and Clarity® Ultrasound System

Figure 2. Prostate ultrasound scan by Transabdominal probe

Figure 3. Prostate ultrasound scan by Transperinial probe

Transperinial probe has got auto scan option and Intra-fraction motion management is possible by this probe. Especially this technique could be effective for hypo-fractionated prostate cancer treatment.

3. Results

An issue common to all is the necessity to map the ultrasound image coordinate system to the linear accelerator coordinate system, which itself is mapped to the simulation images. After mapping coordinates of both systems, Table 1 shows that position difference between Clarity ultrasound scan with transabdominal probe and XVI 4.5 Cone Beam CT scan. We determined the difference between Ultrasound scan and Cone Beam CT scan an average 2.8±1.6mm lateral direction, 2.9±1.1mm longitudinal direction and 2.6±1.4mm vertical direction during 38 fractions of treatment.

Table 1. Position difference between Cone Beam CT scan and Transabdominal ultrasound scan

Treatment Day	Lateral (mm)	Longitudinal (mm)	Vertical (mm)
1	1.1	0.6	1.0
2	1.0	1.6	1.5
3	3.9	2.8	2.2
4	3.5	1.0	2.4
5	3.0	4.2	3.0
6	4.9	4.1	3.2
7	5.3	2.0	1.5
8	0.9	2.8	3.2
9	0.9	1.3	0.2
10	6.2	1.7	0.0
11	4.5	2.8	1.7
12	1.7	2.2	1.3
13	1.3	1.8	3.4
14	1.6	3.7	4.7
15	5.0	3.9	3.7
16	3.6	3.9	0.6
17	2.0	4.2	5.8
18	1.8	4.4	2.5
19	2.2	3.9	0.4
20	4.3	2.7	4.0
21	1.0	2.8	4.5
22	3.9	3.2	2.7
23	3.1	2.8	3.4
24	3.0	3.9	3.5
25	4.2	2.1	4.0
26	4.5	2.0	3.5
27	1.7	3.2	2.9
28	0.9	1.5	1.5
29	5.3	2.2	2.4
30	3.5	1.4	2.5
31	1.7	3.2	3.8
32	1.3	3.8	2.5
33	1.6	5.0	1.7
34	0.6	3.5	2.8
35	5.8	3.8	1.4
36	2.0	3.6	5.6
37	1.5	3.5	2.1
38	2.0	3.0	1.7
Mean±SD	2.8±1.6	2.9±1.1	2.6±1.4

4. Discussion

Position differences between ultrasound system and Cone Beam CT system could consist of time difference between two systems scanning period. Also, we evaluated one patient when we are more familiar to ultrasound images, we could recognise prostate and OARs localization more precisely. If patient has got calsification or fiducial marker in the prostate, recognising prostate localization could be easier and more accurate for both systems. Ballhausen et al.[13] reported that 3D Ultrasound measurements were within 1.0mm of the consesus value on either axis. The linearity of 3D ultrasound was no worse than that of skin marker or Cone Beam CT on a phantom study.

The results show that an average position difference between transabdominal Clarity® ultrasound system and Cone Beam CT system less than 3.0mm in three directions for one patient's treatment during 38 fractions. These differences could be accaptable for scanning just by Clarity® ultrasoud system, because ultrasound doesn't produce a radiation and recognising the structure's border is easier than Cone Beam CT images by ultrasound. Therefore, we are treating prostate cancer patient with ultrasound IGRT method instead of Cone Beam CT scan method in our clinic.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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