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Original paper

Is tissue harmonic ultrasound imaging (THI) of the prostatic urethra and rectum superior to brightness (B) mode imaging? An observer study

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ABSTRACT

Quality ultrasound images are an essential part of prostate brachytherapy procedure. The authors have previously reported that tissue harmonic ultrasound images (THI) are superior to brightness (B) mode for the prostate. The objective of the current study was to compare both imaging modes for visualization of the prostatic urethra and rectum.

B and THI mode transrectal ultrasound images were acquired for ten patients. The prostatic urethra and rectal wall were contoured by a radiation oncologist (RO) and five observers on randomly presented images. The contours on one patient were repeated four additional times by four observers. All the images were qualitatively scored using a *five-level Likert scale*.

The values of the *Pearson product-moment correlation coefficients* showed that the observers were in close agreement with the RO. *Two sample paired student t-test* showed that the rectum volumes with THI were significantly smaller than B-mode, but no significant difference for urethra. *Two-factor analysis of variances* showed significant observer variability in defining the rectum and urethra in both imaging modes. Observer consistency of the rectum volumes, estimated by *standard deviations as percentages of means* was significantly improved for THI. The Likert scale based qualitative assessment supported quantitative observations.

The significant improvement in image quality of the prostate (reported previously) and rectum with THI may offer better-quality treatment plans for prostate brachytherapy and potential improvement in local control.

Introduction

Prostate cancer is the most common malignancy in men in the developed world [1]. Prostate brachytherapy using iodine-125, palladium-103 and cesium-131 as permanently implanted seeds is an accepted form of treatment for low risk organ confined disease. Permanent seed brachytherapy offers the dosimetric advantage of confining the radiation dose to the prostate gland and sparing the critical organs. Clear visualization of the prostate and critical organs is vital for treatment planning and real-time image guidance during seed implantation. The use of the transrectal ultrasound (TRUS) imaging using brightness (B) mode as recommended in literature is currently considered as the standard modality for treatment planning and image guidance during needle implantation for prostate brachytherapy procedures [1–6].

One main limitation of B-mode TRUS is diffusive borders of anatomical structures, which may cause uncertainty in delineation of these structures. This uncertainty can have an effect on the important dosimetric parameters such as D90 (minimal dose delivered to 90% of the prostate volume) and V100 (% of the prostate volume receiving 100% of the prescribed minimal peripheral

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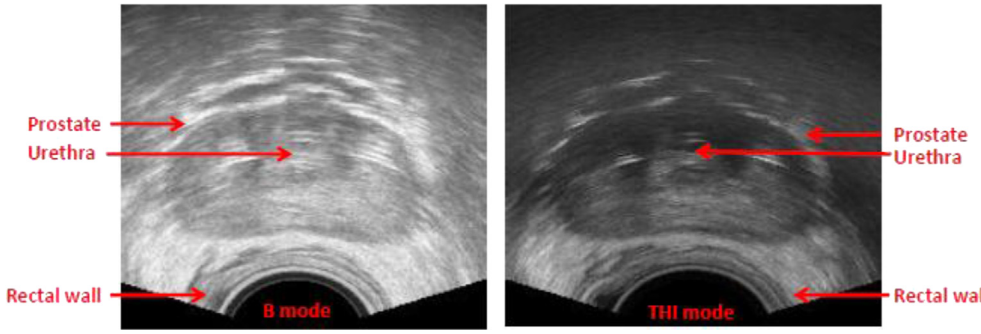

Figure 1. Transverse slice (30.0 mm from the base plane of the prostate) of the transrectal ultrasound, for one of the ten patients, comparing the B and THI mode images.

dose) which are used for the evaluation of an acceptable treatment plan [7]. Critical organs e.g. the urethra, rectum and bladder are located in close proximity to the prostate, and are at risk of being overdosed and developing treatment related complications. In addition, inaccurate contouring of the prostate may lead to a partial geographical miss, thereby increasing the risk of cancer recurrence. Significant observer variability in delineating the prostate has been reported due to the lack of clarity of the prostate periphery [8–11].

Proper education and training of the observers may improve the accuracy and uniformity in contouring of the prostate and critical organs [12–14]. Furthermore, enhancement of prostate image quality can improve volume assessment and a reduction in uncertainties in treatment planning. The superior image quality with harmonic mode compare to B-mode has been reported in the literature [15–17]. In B-mode sonography, it is the transmitted frequency that is subsequently used to produce the image, whereas, in tissue harmonic imaging (THI) an integral multiple of the transmitted frequency is used for image formation. In THI, higher harmonics are generated as a result of the nonlinear propagation of ultrasound through the tissue. THI is typically characterized by improved lateral resolution, improved slice thickness as a function of depth, clutter reduction and increased contrast resolution [16–20]. The improved image quality of THI, as presented in literature [21–27], could be applied to prostate and critical organs to explore the potential benefits in prostate brachytherapy.

In a previous study, we reported the improvement of image quality with THI results in an increased observer agreement in contouring the smaller to medium sized prostate volumes [28]. In the current study, we have investigated the impact of THI quality on critical organs by evaluating interobserver and intraobserver agreement in contouring the prostatic urethra and the rectal wall. This work furthers our knowledge on the potential use of THI for possible alternative of B-mode imaging in prostate brachytherapy.

Materials and methods

Patient cohort

Subjects in this study were ten men with early-stage prostate cancer who underwent prostate seed implant at our cancer centre. The clinical characteristics of the patients were: a median patient age of 65 years (50–78 years), Gleason score 6–7, and the median prostate-specific antigen level of 6.1 ng/cc (3.4–9.8 ng/cc). The TNM stage of the disease was T1c or T2a with low or intermediate risk. The study was approved by our institutional health research ethics board.

Patient set up and image acquisition procedure

A pre-treatment ultrasound was performed for each subject using a B-K medical ultrasound, PROFOCUS 2202 (B-K Medical Apls, Denmark). The TRUS probe (B-K 8848) was mounted on a calibrated stepper and attached to an electronic endocavity rotational mover. The ultrasound scanner was connected to the FIRST® (Nucletron an ELEKTA company, Sweden) brachytherapy treatment planning and delivery system to reconstruct the three-dimensional (3D) prostate volume. The patient was in the lithotomy position and under anesthesia. Two stabilizing needles were used to stabilize the prostate and a Foley catheter was used for visualization of the prostatic urethra. This aided in the delineation of the urethra for the planning, as well as for avoidance of the accidental insertion of the needle and seeds placement near the urethra.

The planning system captured the live feed from the ultrasound as the mover rotated the probe, capturing sagittal slices at 0.5° intervals in a 140° arc. For each patient, images of the prostate were acquired using B-mode (9 MHz), as routinely used for the brachytherapy procedure. Imaging parameters including depth, gain, focal zones, time-gain compensation, contrast and brightness were adjusted to optimally visualize the prostate as per the institution's protocol. An additional THI scan (transmitted frequency 5 MHz and received frequency 10 MHz) was acquired for each patient. The same set of imaging parameters were used for both modes except the gain of THI was reoptimized. Acquired images were implicitly registered, as they share a common coordinate system referenced to the ultrasound probe. The axial images were reconstructed as a 3D volume in the planning system and were used for contouring [29].

Study design

All image sets were transferred electronically to a research workstation, running the same version of software, SPOT PRO™ (Nucletron an ELEKTA company, Sweden), as used clinically for treatment planning and delivery. To simulate the operating room (OR) conditions, the contrast and brightness of the monitors of the research and clinical workstations were matched. The lighting conditions in the OR were measured using a light meter (EA30 Extech Instruments, MA) and were matched to the area where contouring study was performed.

A group of five observers (O) were selected for the study. These observers had experience with contouring the anatomical structures on other imaging modalities (e.g. CT, MRI etc.). They had basic knowledge about the ultrasound imaging based on their anatomy and imaging courses in previous years. All the observers were provided with an equal level of training and demonstration (using B-mode image set) of structure localization and contouring on ultrasound images by a radiation oncologist (RO), who had about six years of experience with the intraoperative prostate brachytherapy. All the observers completed a practice case for contouring on B-mode and THI mode image. Followed by the approval of these test contours by the RO, all of the image sets from B-mode and THI were