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Technical Notes

Evaluation of a new transperineal ultrasound probe for inter-fraction image-guidance for definitive and post-operative prostate cancer radiotherapy

Marie Fargier-Voiron [a], Benoît Presles [a], Pascal Pommier [b], Alexandre Munoz [b], Simon Rit [a], David Sarrut [a,b], Marie-Claude Biston [a,b,*]

[a] CREATIS, INSA, Université de Lyon, CNRS UMR5220, Inserm U1044, Lyon F-69622, France
[b] Léon Bérard Cancer Center, University of Lyon, Lyon F-69373, France

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ABSTRACT

Purpose: The aim of this study was to evaluate a new system based on transperineal ultrasound (TP-US) acquisitions for prostate and post-prostatectomy pre-treatment positioning by comparing this device to cone-beam computed tomography (CBCT).
Methods: The differences between CBCT/CT and TP-US/TP-US registrations were analyzed on 427 and 453 sessions for 13 prostate and 14 post-prostatectomy patients, respectively. The inter-operator variability (IOV) of the registration process, and the impact and variability of the probe pressure were also evaluated.
Results: CBCT and TP-US shift agreements at ± 5 mm were 76.6%, 95.1%, 96.3% and 90.3%, 85.0%, 97.6% in anterior-posterior, superior-inferior and left-right directions, for prostate and post-prostatectomy patients, respectively. IOV values were similar between the 2 modalities. Displacements above 5 mm due to strong pressures were observed on both localizations, but such pressures were rarely reproduced during treatment courses.
Conclusions: High concordance between CBCT/CT and TP-US/TP-US localization of prostates or prostatic beds was found in this study. TP-US based prepositioning is a feasible method to ensure accurate treatment delivery, and represents an attractive alternative to invasive and/or irradiating imaging modalities.

Introduction

Compared to invasive and/or irradiating modalities, US imaging appears to be an interesting image-guided radiotherapy (IGRT) strategy for prostate cancer treatment since it offers a 3D visualization of pelvic organs without any additional dose or surrogate implants [1]. Until recently, US-IGRT relied on a transabdominal (TA) acquisition followed by either an inter-modality registration [2,3] (daily US image registered on the reference CT image) or an intra-modality registration [4–7] (daily US image registered on a reference US image). Numerous discrepancies between the target volume localization observed with the US modality and other IGRT devices were reported [4–7]. An intra-modality registration improves accuracy [7] because it removes uncertainties due to differences in prostate delineation between CT and US [8] but does not impact other sources of uncertainties such as the operator variability, the impact of probe pressure [9] and speed of sound aberrations [10]. Furthermore, the acquisition is made with the probe manually placed above the abdomen, which prevents target monitoring during irradiation.

To overcome the previous issues, a new system based on acquisitions with a transperineal ultrasound (TP-US) probe and an intra-modality registration (Clarity, Elekta, Stockholm, Sweden) has recently been proposed [11]. It is made of a 2D US probe with an internal automated sweeping inside a casing. This device is a promising alternative to other US imaging systems since it is fixed on a base plate and it does not interfere with the treatment beam, which enables monitoring of intrafraction motions; it is likely to be less operator-dependent due to this base plate and to the automated sweeping and it should avoid the quality image issues encountered with TA-US probes linked to the bladder filling.

The objective of this study was to perform an evaluation of the system for pre-treatment positioning on definitive and post-operative prostate cancer patient irradiations. To our knowledge, this is the first study investigating the performances of this TP probe in clinical conditions. The performances of the system were compared to soft-tissue CBCT registration by quantifying the registration

* Corresponding author. Department of Radiation Oncology, Centre Léon Bérard, 28 rue Laennec, Lyon 69008, France. Tel.: + 33 4 78 78 26 75; fax: +33 4 78 78 59 98.
E-mail address: marie-claude.biston@lyon.unicancer.fr (M.-C. Biston).

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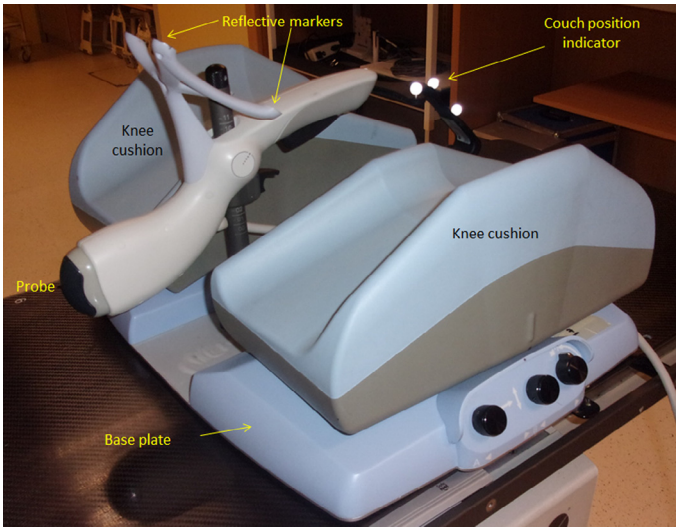

Figure 1. Clarity® Autoscan device.

discrepancies obtained with these 2 modalities for pre-treatment target localization and by evaluating the inter-operator variability (IOV) specific to each technique. The impact of probe pressure on target localization was also investigated.

Material and methods

TP-US system

The TP-US system (Clarity®, Elekta, Stockholm, Sweden) is based on a 2D TP-US probe. The TP-US probe is located in the room coordinates thanks to 4 reflectors fixed on the top of the probe which are tracked by an infrared camera fixed on the ceiling (Fig. 1). For each acquisition, several hundreds of 2D US slices are acquired during an automated probe sweep performed by a step-by-step motor and merged into a 3D image [11]. The sweep time is 2.5 seconds which gives a resolution of 0.35 mm (for a voxel size of 0.58^3 mm^3) in the middle of the prostate, assuming a typical prostate depth of 5 cm [11]. For patients' acquisitions, a specific immobilization device made of a base plate and 2 cushions for the knees enables the TP-US probe to be fixed between the patient legs (Fig. 1). During the planning CT session, a reference US image (US_{ref}) is acquired with the same patient set-up as during the CT acquisition. The US_{ref} image is superimposed to the CT image through a room calibration process, allowing a visualization of the US_{ref} and CT images in the same coordinates system. A reference positioning volume (RPV) is then manually delineated on the US_{ref} image (Fig. 2). Over the treatment course, a daily US image (US_{daily}) is acquired at the beginning of each fraction, and manually registered on the US_{ref} image by RPV projection. The accuracy of the system is checked daily by performing a quality control to warrant an uncertainty inferior to 1 mm and 2 mm for the reference and the daily US systems, respectively [11].

Patient data

Thirteen patients receiving a definitive irradiation of the intact prostate (cohort A) and 14 patients irradiated after prostatectomy (cohort B) were included in this study, which was approved by the hospital ethics committee. During the CT session, patients were immobilized using the above-described device and the reference US acquisition was performed just before the CT acquisition. The probe position of each patient was marked on the base plate to minimize the probe position variability between fractions during the treatment phase. Patients were scanned in supine position, with

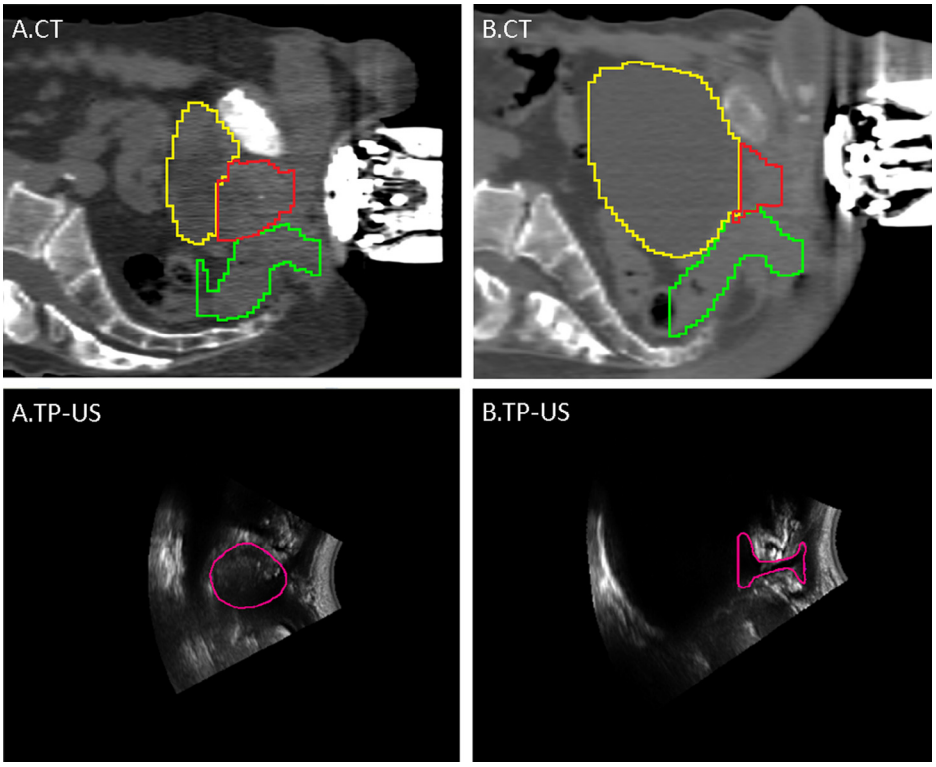

Figure 2. Sagittal slices of CT and TP-US images of prostate patients (respectively A.CT and A.TP-US) and of post-prostatectomy patients (respectively B.CT and B.TP-US). Red, yellow and green contours correspond to the CTV, bladder and rectum volumes, respectively, delineated on the CT image; pink contour corresponds to the RPV volume, delineated on the TP-US image.