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Original Report

Changes in penile bulb dose when using the Clarity transperineal ultrasound probe: A planning study

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Abstract

Purpose: The Clarity system allows monitoring of intrafraction target organ movements in external beam radiation therapy of prostate cancer by using transperineal ultrasound. The probe positioning at the perineum could lead to a compression and shift of the penile bulb (PB) toward the high-dose region. Dose to the PB has been reported to be associated with the risk of posttreatment erectile dysfunction. This planning study reports on PB translations and changes in volume and dose when applying the transperineal ultrasound probe.

Methods and materials: For 10 patients treated with external beam radiation therapy for prostate cancer between 2013 and 2014, a planning computed tomography scan with and without the ultrasound probe in place was acquired. The planning target volume and organs at risk including the PB were contoured in the computed tomography scan with and without the probe. Radiation therapy plans for both scenarios were calculated. In a second step, for planning with the probe in position, an additional objective for improved sparing of the PB was introduced.

Results: The median PB volume was 5.5 mL (range, 3.8-7.1 mL) without the probe and 3.5 mL (range, 2.0-5.8 mL) with the probe. The median shift of the PB was 1 mm in the posterior (range, 3 mm posterior-2 mm anterior) and 6 mm in the superior direction (range, 0–14 mm superior), with no relevant shift of the prostate. The median mean dose in 95% of the PB was 34.1 Gy (range, 6.0-50.4 Gy), 48.3 Gy (range, 7.2-56.8 Gy), and 39.4 Gy (range, 5.6-51.3 Gy) for plans without probe, with probe, and with probe and additional planning objective, respectively.

Conclusions: Dose to the PB increased when using the transperineal probe. After introducing an additional plan-optimization objective for PB sparing, dose-volume parameters were below Quantitative Analyses of Normal Tissue Effects in the Clinic thresholds for all but one patient.

Conflicts of interest: M.G. reports grants from Elekta during the conduct of the study. All authors report the free supply of the Clarity system from Elekta for scientific evaluation.

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Introduction

Prostate cancer is 1 of the most prevalent cancers in men in Western societies.[1] Erectile dysfunction (ED) is a substantial side effect in the treatment of prostate cancer with an enormous impact on quality of life. Reports on the incidence of post-radiation therapy (RT) ED vary from 15% to 62%.[2] However, external beam RT (EBRT) is preferred over other primary treatment modalities by many patients because of its comparatively lower risk of ED.[3,4]

There is an ongoing debate on the etiology of radiation-induced ED in the literature, and conflicting data about dose-volume effects on penile, neural, and vascular structures have been reported. Despite not being a key component of the erectile apparatus, the penile bulb (PB) has been suggested as a suitable anatomical surrogate because of its proximity to the prostate, the nerve, and vascular supply, and its easy definability by computed tomography (CT).[5,6] Correlations between the PB dose and impotence following RT were reported in several studies.[2,7-9] Additionally, animal model studies demonstrated a PB dose-related response.[10,11]

The Clarity system provides noninvasive inter- and intrafractional target monitoring in the RT of prostate cancer by transperineal ultrasound (TPUS) allowing for setup error correction before and intrafraction monitoring during radiation. However, positioning the US probe at the perineum might lead to a cranial shift of the penile bulb resulting from soft-tissue compression. This shift could result in an increase of dose to the PB during RT. A cranial shift of the PB by the Clarity probe could therefore increase the risk for ED. The Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC) Review performed by Roach et al. recommends limiting the mean dose to 95% of the bulb volume to 50 Gy.[6] The D70 and D90 should stay below 70 and 50 Gy, respectively.

Within this planning study the possible impacts of Clarity on PB translation, volume, dose, and observance of the QUANTEC recommendations are investigated as well as strategies in the planning process to improve the dose distribution with regard to the PB constraints.

Methods

For 10 patients treated with EBRT for prostate cancer between 2013 and 2014, 2 planning CT scans in the supine position were acquired: with and without the Clarity TPUS probe (Elekta, Stockholm, Sweden) in the transperineal position. The pressure of the TPUS probe against the perineum was minimized while still maintaining sufficient US image quality. Both CT scans were performed directly 1 after the other in the same supine patient position stabilized with knee fix and foot support. All patients gave informed consent. The TPUS probe and schematic setup is shown in Figure 1.

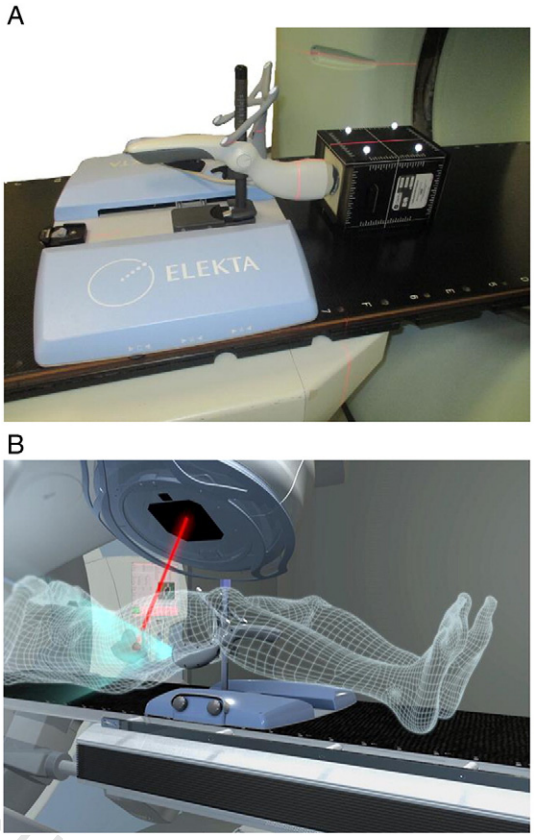

Figure 1 Transperineal ultrasound (TPUS) setup. (A) TPUS probe with phantom. (B) Schematic patient setup for TPUS image guided radiation therapy.

Pinnacle (Philips Radiation Oncology Systems, Milpitas, CA) was used for treatment planning. Treatment was planned for an Elekta Synergy Platform equipped with Agility Head/MLC (Elekta Oncology Systems, Crawley, UK). Our in-house target volume (TV) organ at risk (OAR) definition and treatment planning protocol has been described in detail previously.[12] The prostate and the seminal vesicles were contoured as the clinical target volume (CTV): Prostate including the proximal 2 cm of the seminal vesicles resulted in CTV-1 and the prostate and base of the seminal vesicles in CTV-2. A 3-dimensional margin of 10 mm was added to the CTV-1 resulting in planning target volume 1 (PTV-1); posterior, the margin was limited to 7 mm. CTV-2 was expanded by a margin of 5 mm without rectum overlap resulting in the boost target volume (PTV-2). A prostate contour was delineated for volume and shift analyses (CTV-2 minus base of seminal vesicles). The bladder, rectum, small bowel, femoral heads, and PB were delineated as OARs. PB delineation had not been, by default, done in our institution before and was performed in accordance with Radiation Therapy Oncology Group contouring guidelines within this study.[13] TVs and OARs were contoured in both planning CT scans with and without probe by 2 radiation oncologists by consensus method. Figure 2 shows the sagittal reconstructions of 1 exemplary patient case.