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Differences between intraoperative ultrasound-based dosimetry and postoperative computed tomography-based dosimetry for permanent interstitial prostate brachytherapy

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ABSTRACT

PURPOSE: To compare the results of intraoperative ultrasound (US)-based dosimetry with those of postimplant computed tomography (CT)-based dosimetry after ^{125}I prostate brachytherapy.

METHODS AND MATERIALS: Subjects comprised 160 patients who underwent prostate brachytherapy using ^{125}I seed implants. Prescribed dose was set as 145 Gy to the periphery of the prostate. Implantation was performed using an intraoperative interactive technique. Postimplant dosimetry was performed on Days 1 and 30 after implantation using CT. Dosimetric results for the prostate, urethra, and rectum were compared among intraoperative US and CT on Day 1 (CT_1) and Day 30 (CT_{30}).

RESULTS: Mean minimal dose received by 90% of prostate volume was 133.7%, 115.6%, and 125.8% of the prescribed dose on US, CT_1, and CT_{30}, respectively: This value temporarily decreased on Day 1 and increased on Day 30. Other parameters for the prostate and urethra showed similar trends. Conversely, mean rectal volume receiving 100% of the prescribed dose was 0.69, 0.46, and 1.02 mL on US, CT_1, and CT_{30}, respectively. Rectal parameters tended to be underestimated on US relative to CT_{30}-based dosimetry. A positive linear relationship was identified between US and CT observations for every prostate parameter and the dose covering 30% of the urethra.

CONCLUSIONS: Our results demonstrate significant differences between dosimetric parameters obtained by US, CT_1, and CT_{30}. However, significant correlations also exist between US and CT, at least in prostate and urethral parameters. Clarification of the degrees of difference might make US planning more feasible.

Keywords: Prostate cancer; Brachytherapy; Dosimetry; ^{125}I; Ultrasound; Computed tomography

Introduction

Ultrasonography (US)-guided transperineal interstitial permanent prostate brachytherapy for prostate cancer is quickly growing in popularity as a therapeutic option for patients with early stage, localized prostate cancer (1–3). With prostate brachytherapy, treatment planning is performed using US, whereas postimplant analysis is performed using computed tomography (CT). Inherent dosimetric differences thus exist between the US plan and postimplant CT analyses because of the different modalities, timings, and body positions used.

Although one of the purposes of postimplant dosimetric analysis is to provide feedback to the clinician for improving implantation technique, few data have been reported regarding differences between these two modalities, making such feedback difficult to interpret. We believe that the lack of information regarding differences between

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preplan and postimplant analysis represents a crucial issue. The present study investigated differences in dosimetry between intraoperative US and postimplant CT analysis on Day 1 (CT_1) and Day 30 (CT_{30}).

Methods and materials

Patients

Subjects comprised 160 patients treated using intraoperative planning technique, with 43 patients treated at Iwate Medical University Hospital and the remaining 117 patients treated at Kitasato University Hospital. According to our treatment protocol criteria, patients with clinical stage T1c or T2a, prostate-specific antigen level ⩽10 ng/mL, and Gleason score ⩽7 are basically treated with permanent prostate brachytherapy as monotherapy. Patient characteristics are summarized in Table 1.

Intraoperative planning and implantation

Total activity and number of ^{125}I seeds for implantation were determined from preoperative prostate US using a nomogram (4). Intraoperative, real-time, interactive treatment planning was performed. Two radiotherapy planning systems (Interplant version 3.2; CMS, Tokyo, Japan and Variseed version 7.2; Varian Medical Systems, Palo Alto, CA) were used for planning and postimplant analysis, and all doses were defined using TG43 criteria (5). Both of these systems include a built-in optical encoder in the probe-stepping mechanism that permits real-time images from US to be spatially registered against the positions of the probe and template, allowing instant operator feedback on probe position within the prostate.

Transrectal US imaging was performed in the operating room and images were imported into the planning systems. The prostate, urethra, and anterior part of the rectum were contoured at 5-mm intervals. A Foley catheter or bubbled jelly was used to identify the urethra. Regarding rectal contouring, the anterior one-third of the wall was contoured because the US field is restricted to this area. Treatment planning was then performed and a dose–volume histogram (DVH) generated. Needles were inserted according to the treatment plan. After needle insertion, transrectal US imaging was performed once again and refinement of contour and treatment plan was done. Then, seeds were implanted to peripheral portion of the prostate using a Mick applicator (Mick Radio-Nuclear Instruments, Mount Vernon, NY). Dosimetry was updated according to the estimated position of deposited seeds along the needle track. If necessary, second refinement of treatment plan was performed before implantation to the central zone of prostate. The final US-based dosimetry and DVH were obtained in the operating room at the end of the procedure.

Table 1
Patient characteristics

Age (y)	68 (51–81)
Initial PSA (ng/mL)	6.0 (2.7–29.1)
Gleason score	
⩽6	86
7	72
8	2
T stage	
T1c	126
T2a	23
T2b	10
T2c	1
Neoadjuvant hormone	
Yes	46
No	114

Values represent median (range) or number.
PSA = prostate-specific antigen.

Postoperative dosimetry

CT with 3-mm slice thickness was performed for postoperative evaluation at 1 day and 30 days after implantation. The prostate, urethra, and rectum were contoured on each of the CT slices by the same physician in each hospital. A Foley catheter was used to identify the urethra on CT_1. However, we virtually contoured the urethra without catheter on CT_{30} by referring to US or CT_1 images. Thus, urethral doses on CT_{30} might not be reliable measurements. The entire rectum, including sphincter muscle and filling was outlined on the same slice to prostate. All seeds were identified and accounted for in CT-based dosimetry analysis using Interplant or Variseed. Dosimetric parameters, including the dose covering 90% of prostate volume (pD_{90}), prostate volume covered by 100% of the prescription dose (pV_{100}), prostate volume covered by 150% of the prescription dose (pV_{150}), dose covering 90% of the urethra (uD_{90}), dose covering 30% of the urethra (uD_{30}), rectal volume covered by 100% of the prescription dose (rV_{100}), and rectal volume covered by 150% of the prescription dose (rV_{150}) were calculated. DVH parameters were compared among intraoperative US, CT_1, and CT_{30}.

Because US, CT_1, and CT_{30} were performed in different timing, this comparison was inevitably influenced by volumetric change of prostate caused by edema. In addition, probe insertion could change the shape of prostate, urethra, and rectal wall in US-based dosimetry. Thus, our study was inevitably influenced by the effect of edema and probe insertion. However, with regard to feedback from CT-based analysis to US-based planning, we believe that simple comparison, including these influences in the same way as clinical practice is most useful.

Statistics

SPSS version 11.01.j (SPSS Japan, Tokyo, Japan) statistical software was used for data analysis. Dependent *t* tests