Detection of Prostate Calcification with Megavoltage Helical CT

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Rationale and Objectives: Prostate calcification is a noninvasive landmark for daily positioning of image-guided radiation therapy. However, detectability of prostate calcification with megavoltage helical computed tomography (MVCT) has not been evaluated. The purpose of this study was to evaluate the detectability of prostate calcification and to investigate how to predict detectability of calcification with MVCT.

Materials and Methods: Thirty patients with prostate cancer who were scheduled for helical tomotherapy were included in this study. The detectability of prostate calcification on MVCT was evaluated by comparing against kilovoltage multidetector-row CT (KVCT) as the standard of reference. Maximum signal intensity ($SImax$), area (A) of calcification, and the product of both ($SImax \cdot A$) were compared between undetectable and detectable calcifications. Then, the threshold values of $SImax$, A, and $SImax \cdot A$ were decided to achieve 100% sensitivity on MVCT.

Results: KVCT identified 49 calcifications in 28 of 30 patients. MVCT detected 19 (39%) of 49 calcifications in 15 (50%) of 30 patients. The minimum threshold values of $SImax$, A, and $SImax \cdot A$ to detect prostate calcifications were 953 HU, 20.98 mm^2, and 7784 HU mm^2, respectively. Using the threshold values of $SImax$, A, and $SImax \cdot A$, 20% (10/49), 18% (9/49), and 35% (17/49) of calcifications were in the detection range, respectively.

Conclusions: MVCT can depict about one-third of prostate calcifications detectable on KVCT. The product of maximum signal intensity and area of calcification is the most distinguishable index for predicting patients showing prostate calcifications on MVCT.

Key Words: Helical tomotherapy; CT scan; image-guided radiation therapy; image analysis; megavoltage imaging.

Dose escalation with three-dimensional conformal radiotherapy or intensity-modulated radiation therapy (IMRT) for prostate cancer improves long-term prostate-specific antigen (PSA) control (1–3). The tight margins will decrease the volume dose delivered to organs at risk, but accurate positioning of the prostate is required for the high precision of planned radiotherapy treatments. Recent advancements in image-guided radiotherapy (IGRT) technologies provide the opportunity to localize target volumes with the same x-ray beam used for radiotherapy (4–7). Helical tomotherapy (HT) is an innovative means of delivering IGRT and IMRT using a device that combines features of a linear accelerator and a helical computed tomography (CT) scanner. HT is one of the successful innovative intensity-modulated IGRT techniques that can perform megavoltage CT (MVCT) scan and can obtain highly tailored dose distributions. MVCT enables imaging of anatomic structures in the presence of metallic dental or orthopedic implants. This is advantageous in cases with metal implants but has a limitation of reduced contrast in soft tissues (8,9). During HT of prostate cancer, prostate glands cannot always be clearly distinguished on MVCT. Thus, soft tissue matching for the prostate will be challenging in such cases.

Prostate calcifications are a common finding and seem mostly to be associated with benign prostatic hyperplasia. However, calcifications can occur in direct association with prostatic adenocarcinoma, although the incidence of this association is reported to be as low as 1.3% (4/298) (10). Physiological calcification has been considered to be a reliable landmark of the prostate position and allows for precise image guidance with low observation variations (11). However, the detectability of prostate calcifications with helical MVCT and the clinical application to HT has not yet been investigated. The purpose of this study was to determine the detection limit of prostate calcifications and to investigate whether calcification might be a natural landmark to localize the prostate during HT treatment.

MATERIALS AND METHODS

Study Population

This study was conducted in a subgroup of patients with localized prostate cancer treated by HT in our institution between March 2009 and April 2009. Thirty consecutive patients (30 men, mean age 70 ± 6 years[standard deviation {SD}]) with localized prostate cancer (T1c-3a N0 M0) who were scheduled for IMRT by HT were included in this study. Sixteen (53%) patients had received hormone therapy as primary

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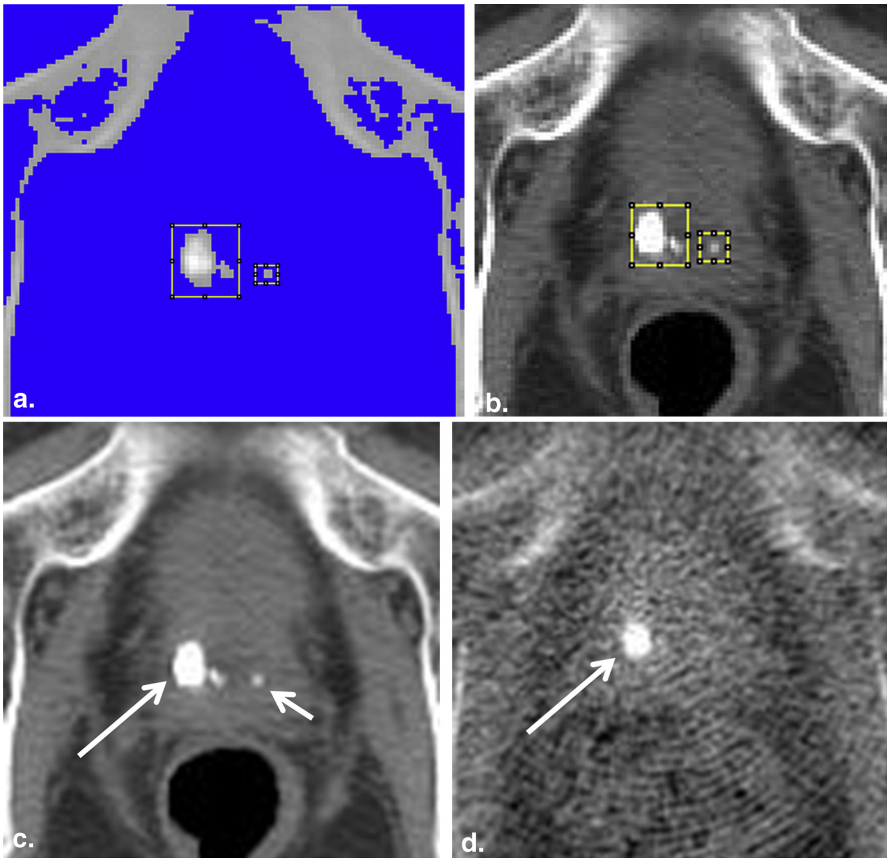

Figure 1. Assessment of prostate calcification on KVCT. **(a)** A region of interest (ROI) was placed at the calcification and the maximum signal intensity was measured using ImageJ software. **(b)** To avoid bias in ROI estimates, a threshold was set in the HU value, and the total number of pixels within the threshold range was counted. *Blue pixels* represent pixels with value out of the threshold range. **(c and d)** Two comparative sets of images of the same patient. On KVCT **(c)**, both large (*large arrow*) and small (*small arrow*) calcifications are detectable. However, only large calcification (*large arrow*) is detectable on MVCT **(d)**. KVCT, kilovoltage computed tomography; MVCT, megavoltage computed tomography. (Color version of figure is available online.)

treatment before radiotherapy. The initial mean value of serum PSA was 21.4 ± 25.7 ng/mL (SD). The mean Gleason score at biopsy was 7.1 ± 1.2 (SD). The local medical ethics committee approved this study, and all participants gave written informed consent. All procedures followed were in accordance with the Helsinki Declaration of 1975, as revised in 1983.

Imaging Protocol

MVCT imaging was performed with a HT unit (HI-ART II; TomoTherapy Inc., Madison, WI). In HT, the megavoltage x-ray was used for dual purposes: for creating CT images with the linear accelerator detuned to about 3.5 MV and for providing delivery of therapeutic doses at about 6 MV with the tuned linear accelerator. MVCT images were acquired with 3.5-MV x-rays using a narrow jaw width and a pitch of 1.333 to verify the patient position before each fraction of radiation therapy in a helical fashion. The MVCT images taken at the first fraction were used in this study. The detection system for the fan-beam photons consisted of a pressurized array of ion chambers filled with xenon gas manufactured by GE (Milwaukee, WI). The scan times varied between 2 and 3 minutes. Images were obtained through the entire true pelvis. The radiation exposure associated with the MVCT scanning was ~20 mSv. Scan data were reconstructed with a 400-mm field of view (FOV) using a 512 × 512 matrix and with a slice thickness of 4 mm.

All participants underwent diagnostic kilovoltage CT (KVCT) for radiation therapy planning 2 weeks before the start of IMRT. KVCT images were used as the standard of reference. KVCT images were acquired by a multidetector CT scanner (LightSpeed 16; GE, Milwaukee, WI), with 120-kV x-rays using a pitch of 1.375. KVCT images were reconstructed at 2.5 mm slice thickness and 2.5 mm slice interval with a 500-mm FOV using a 512 × 512 matrix.

Calcification Scoring Method

Calcifications detected on axial KVCT images were quantified using ImageJ software (http://rsbweb.nih.gov/ij/). A calcification was defined as a minimum of two adjacent pixels (area of 1.9 mm^2) with attenuation above 100 HU on KVCT. The calcified lesion detectability on MVCT was then assessed visually by one radiologist (Y.H.) and one radiation physicist (M.U.). A region of interest (ROI) was placed at the calcification in the prostate or adjacent to the prostate on KVCT (Fig 1a). To avoid bias in ROI estimates, the threshold method was used to calculate the area and the maximum HU value in each calcification (Fig 1b). In brief, a threshold was set in the HU value (>100), above which a pixel is counted. The total number of pixels within the threshold range was counted, and the area (A) of calcification was calculated. The maximum signal intensity ($SImax$) was measured within the calcified lesion using ImageJ software.