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Comparison of MRI sequences in ideal fiducial maker-based radiotherapy for prostate cancer

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ABSTRACT

Aim: Prostate contouring using CT alone is difficult. To overcome the uncertainty, CT/MRI registration using a fiducial marker is generally performed. However, visualization of the marker itself can be difficult with MRI. This study aimed to determine the optimal MRI pulse sequence for defining the marker as well as the prostate outline among five sequences.

Materials and methods: A total of 21 consecutive patients with prostate cancer were enrolled. Two gold fiducial markers were placed before CT/MRI examination. We used the following five sequences: T1-weighted spin-echo (T1WI; TR/TE, 400–650/8 ms); T2-weighted fast spin-echo (T2WI; 4000/80); T2*-2D-weighted gradient echo (T2*2D; 700/18); T2*-3D-weighted gradient echo (T2*3D; TR/TE1/deltaTE, 37/14/7.3); and contrast-enhanced T1-weighted spin-echo (CE-T1WI; 400–650/8). Qualitative image analysis of the sequences was performed by three observers. These observers subjectively scored all images on a scale of 1–3 (1 = unclear, 2 = moderate, 3 = well visualized). A higher score indicated better visualization.

Results: T2WI was significantly superior to the other sequences in terms of prostate definition. T2*2D and T2*3D were strongly superior to the other sequences and were significantly superior in terms of fiducial marker definition.

Conclusions: T2*2D and T2*3D are superior to the other sequences for prostate contouring and marker identification. Therefore, we recommend initial T2*3D and T2*2D examinations.

1. Background

External beam radiotherapy (EBRT) is being more widely used for prostate cancer owing to the development of computed tomography (CT) and magnetic resonance imaging (MRI). However, prostate contouring using CT alone is difficult.[1–6] To overcome the uncertainty of prostate contouring with CT images alone, CT/MRI registration using a fiducial marker is generally performed. However, visualization of the marker itself tends to be difficult using MRI. T2-weighted spin-echo (T2WI) and two-dimensional T2*-weighed gradient echo

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(T2*2D) sequences can clearly show the prostate outline.[1–3] T2*2D has been reported to sensitively detect fiducial markers as well as T2WI.[2,3] However, T2*3D-weighted gradient echo (T2*3D) and contrast-enhanced T1-weighted spin-echo (CE-T1WI) sequences have not been evaluated in this setting. T2*2D is better than T2WI and is an accepted sequence for detecting fiducial markers. Additionally, it provides soft tissue contrast for the prostate; however, no precise comparison study has been conducted previously.

We previously reported that CE-T1WI is the best sequence to precisely detect both the seeds and prostate outline in postimplant dosimetry of low-dose-rate I-125 prostate brachytherapy.[7] Recently, three-dimensional T2-weighted images (T2*3D) have been used for pelvic examinations.

This study aimed to determine the optimal MRI pulse sequence for defining the marker, as well as the prostate outline, among five sequences, including T2*3D and CE-T1WI.

2. Materials and methods

Between April 2015 and September 2015, 21 consecutive patients with prostate cancer were treated with intensity-modulated radiation therapy (IMRT) at our hospital. All patients provided written informed consent to participate in this study. Additionally, all patients were pathologically diagnosed with prostate adenocarcinoma and were classified as having low-to-high risk according to the D'Amico classification system.[8] This study was registered in the UMIN Clinical Trial Registry. IMRT was performed in the low-risk, intermediate-risk, and high-risk groups at 74 Gy, 76 Gy, and 78 Gy, respectively. Patients allergic to the MRI contrast agent were excluded from this study.

Two gold fiducial markers (VISICOIL, RadioMed Corporation, Bartlett, TN, USA) were placed on the prostate before CT/MRI examination at three weeks. We placed two gold markers on the central meddle of the prostate, but sometimes in a different place. Two, and not three, gold markers were used because markers were 10 mm linear, and their ends are treated as points. To decrease artifacts in the CT image and the amount of bleeding in the prostate, we selected markers measuring 0.35 mm in diameter and 10 mm in length for all patients. We selected the smallest marker with the thinnest 22 G (in Japan) needle to prevent bleeding, tumor seeding, and pain. The markers were well visualized on cone-beam CT using the Novalis Tx system (Varian Medical Systems, Inc., Palo Alto, CA, USA).

2.1. Image acquisition

All patients ingested 200 ml of water 30 min before CT/MRI to accumulate a certain volume of urine in the bladder. External beam planning CT (Optima CT580, GE Medical Systems, Milwaukee, WI, USA) and MRI (Intera 1.5 Nova, Philips Medical Systems, Eindhoven, The Netherlands) scans were performed. MRI was performed within 20 min after CT. MRI was performed using a 5-channel sense cardiac coil (3-mm section thickness with no intersection gap and a 16-cm field of view for all sequences). The approximate scan time for the sequences was 4–6 min in all cases.

2.2. MRI sequences

We used the following five MRI sequences in all patients: (Fig. 1) T1WI, T2WI, T2*2D, T2*3D, and CE-T1WI. The phase-encoding direction was right–left in all sequences. CE-T1WI MRI was performed using gadopentetate dimeglumine (Magnevist; Bayer, Berlin, Germany). Quality comparison of the five sequences was conducted by one radiation oncologist and two radiation technologists.

2.3. Image scoring

First, we checked the two fiducial markers in CT images for all cases. We did not used blind scoring systems for MR images. Because we do not make a treatment plan only with an MR image in clinical situation, we confirm a position of marker with a CT image earlier. Thus, we thought that it was not necessary to make blindness. Additionally, we assessed the markers on MRI with the guidance of CT images. The three observers (observer 1: brachytherapy radiation oncologist with 15 years of experience; observer 2: radiation oncologist with 20 years of experience; observer 3: radiological technologist with 10 years of experience) subjectively scored all images according to the following five evaluation items: definition of the prostate outline; apex vs. soft tissue; base vs. bladder; base vs. seminal vesicle; and gold fiducial marker detection. A score from 1 to 3 (1 = unclear, 2 = moderate, 3 = well visualized) was assigned to all items. A higher score indicated better visualization. We then compared the mean scores for each item.

2.4. Statistical validation

Statistical analysis was performed using analysis of variance. Among the five sequences, the sequences that scored better than the other sequences were studied, and a p-value < 0.05 was considered statistically significant. The Excel statistics 2015 (Social Survey Research Information Co., Ltd. Japan) software was used for statistical analysis.

3. Results

The study included 21 consecutive patients with prostate cancer. Our findings are shown in Table 1 and Fig. 1. The evaluation of image quality varied among the three observers. T2WI was significantly superior to the other sequences in terms of prostate definition ($p < 0.05$). T2*2D and T2*3D were strongly superior to the other sequences and were significantly superior to the other sequences in terms of fiducial marker definition ($p < 0.05$). There were no significant differences between T2*2D and T2*3D. T1WI and CE-T1WI were not superior to the other sequences.

4. Discussion

T2WI and T2*2D are the gold standard for prostate contouring and detecting the intraprostatic fiducial marker and I-125 seed after low-dose-rate brachytherapy. For advanced EBRT, a fiducial marker is necessary to contour the prostate using CT/MRI registration. We previously reported that