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Defining a magnetic resonance scan sequence for permanent seed prostate brachytherapy postimplant assessment

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ABSTRACT

PURPOSE: We describe a magnetic resonance (MR) scan sequence for prostate brachytherapy postimplant assessment.

METHODS AND MATERIALS: One brachytherapy team at the British Columbia Cancer Agency has incorporated MR–CT fusion into their permanent seed prostate brachytherapy quality assurance procedure. Several attempts were required to ensure that the diagnostic MR scanner at the adjoining general hospital performed the desired sequence, providing many examples of suboptimal scans and underlining the pitfalls for a center trying to incorporate the use of MR scanning into their brachytherapy program.

RESULTS: The recommended sequence (Fast Spin Echo T2-weighted, repetition time [TR]/echo time [TE] 4500/90, echo train length [ETL] 10, 20 × 20 field of view [FOV], 80 bandwidth [BW]) is associated with superior edge detection when compared with those images in which a typical diagnostic sequence was used. The use of a low bandwidth sequence does not compromise edge detection or seed identification when compared with a higher bandwidth.

CONCLUSIONS: We have defined a magnetic resonance imaging sequence, which appears to optimize both prostate delineation and identification of seeds, lending itself to straightforward fusion with CT images and allowing for less uncertainty in permanent seed prostate brachytherapy quality assurance.

Keywords: Prostate neoplasms; Brachytherapy; Magnetic resonance imaging; Quality assurance

Introduction

Implant quality is an important determinant of outcome in patients with prostate cancer treated with permanent seed brachytherapy. Accurate dosimetry provides feedback to the brachytherapy team, fosters technical changes to improve quality, and identifies suboptimal implants that may require corrective measures. Programs with meticulous quality assurance (QA) report higher biochemical control rates than those where poor-quality implants predominate. Recent articles from Zelefsky *et al.* (1) and Henry *et al.* (2) report a large variation in implant quality with inferior biochemical control rates in patients with low postimplant *D*90's (minimum dose received by 90% of the prostate).

Postimplant dosimetry is very dependent on the quality of prostate imaging. Computed tomography (CT) imaging is the accepted standard for evaluation of implant quality, although the implanted seeds produce artifacts and obscure the outline of the prostate gland. Prostate volume determination by CT tends to overestimate the prostate volume (3, 4) when compared with either ultrasound or magnetic resonance imaging (MRI). Contrary to the situation with CT imaging, the presence of brachytherapy seeds does not affect the quality of prostate imaging using MRI, and consequently edge detection is superior to that achievable with CT. The use of MRI has been shown to reduce

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interobserver variation in prostate delineation for the purpose of external beam planning and in the postimplant setting (5–7).

When MRI is used for the purpose of quality assessment after brachytherapy, it is important that the optimal scan sequence be selected. The use of a nonoptimal scan sequence leads to disappointing imaging results that diminish the value of the scan. In the post brachytherapy setting, the chosen imaging modality should sharply define the edges of the prostate while allowing visualization of the implanted seeds. The use of the typical diagnostic magnetic resonance (MR) sequence does not meet these requirements and can lead to uncertainty in both contouring and seed identification. The purpose of this article is to demonstrate with case reviews what we have found to be an ideal MR scan sequence for postimplant assessment after permanent seed brachytherapy. We will also demonstrate the potential pitfalls that can be encountered with suboptimal imaging.

Methods and materials

The British Columbia Cancer Agency Center for the Southern Interior is one of four regional sites of the British Columbia Cancer Agency where prostate brachytherapy seed implants are performed. Four radiation oncologists at our center perform permanent ^{125}I seed implants, using either stranded or loose seeds. MRI and CT imaging are systematically performed at 30 days postimplant, and are manually fused using the seeds as fiducial markers. MR images are used to delineate the prostate gland and relevant normal structures, and CT is used to determine the location of the seeds. Both loose and stranded seeds are used, and patients receiving implants with loose seeds also undergo plain film imaging of the chest and pelvis. Our brachytherapy team meets regularly to review the postimplant dosimetry.

Imaging

Axial MR images of the prostate and lower pelvis are taken using a 1.5 Tesla Signa GE scanner with the patient supine. A Fast Spin Echo T2-weighted MR sequence is used with the following technical parameters: repetition time (TR) = 4500 msec, echo time (TE) = 90 msec, echo train length (ETL) = 10, pixel bandwidth (BW) = 80 Hz/pixel, field of view = 20 × 20 cm, 3-mm slice thickness, 0-mm gap, acquired matrix sixe = 320 × 224 with phase encoding direction along rows, flip angle = 90°.

CT images are likewise obtained in the supine position, imaging the prostate and all seeds visible on the scout image in 2-mm slices. Catheterization is performed for urethral localization when required by the oncologist. No specific bowel preparation is used before either scan but they are performed sequentially, with the CT following the MRI generally within half an hour.

Results

Figure 1 shows MR images on a patient in whom our standard sequence is used. Using this sequence, both the prostate edge and seed locations are easily detectable. Caudal to the prostate, the plane of fat separating the urethra and levator ani muscle displays high signal (white) on T2-weighted images. The prostate apex can be identified as the most caudal slice, where this ‘‘white’’ plane is lost and there is low-signal density apparent in this space. Superiorly, bladder neck has different signal intensity than prostatic tissue, allowing identification of the prostate base. Intraprostatic anatomy is not clearly identified with this sequence. For instance, the urethra is not as clearly visible as on a diagnostic scan and the distinction between the transition and peripheral zones is diminished. However, these features are not important for the purposes of implant evaluation. If urethral localization is desired, catheterization can be performed at the time of either the MR or the CT.

We have previously acquired MR images using this sequence with a longer bandwidth of 120 Hz/pixel. With a lower bandwidth of 80 Hz/pixel, there is a savings of about 2 min in image acquisition per patient. As our MR scans are performed at the adjoining general hospital where MR time is at a premium, this time saving was significant in obtaining the required number of MR bookings per week. Reducing the bandwidth reduces the noise and increases the chemical shift artifact that is expected to improve the visibility of implanted seeds. Our experience indicates that the increased static magnetic field (B0) distortions because of the lower bandwidth do not cause CT–MRI fusion issues for MR images acquired with the scan sequence identified in this study. The images obtained are indistinguishable for both the prostate edge detection and seed identification. Shorter imaging time also reduces motion artifact, and improves patient convenience. The images below (Fig. 2) demonstrate the lack of effect of this modification on image quality.

A diagnostic sequence is not optimal for the purposes of evaluating a brachytherapy implant, as demonstrated in Fig. 3. In a typical diagnostic sequence, the peripheral zone is relatively isointense with the periprostatic fat, diminishing prostate edge detection. Thus, the readily visible interface between the peripheral and transition zones (‘‘surgical capsule’’) can be mistaken for the prostate capsule. Even when one is aware of this issue, the outline of the prostate can be indistinct, particularly at the apex as shown in Fig. 3. Although intraprostatic pathology is more readily visible, this information is not essential to postimplant evaluation.

The prostate brachytherapy program at the British Columbia Cancer Agency previously explored the use of MRI in postimplant QA but did not appreciate the