MR Imaging–guided Prostate Biopsy with a Closed MR Unit at 1.5 T: Initial Results[1]

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Abbreviations:
PSA = prostate-specific antigen
RARE = rapid acquisition with relaxation enhancement
SE = spin echo

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The authors evaluated a magnetic resonance (MR) imaging–compatible biopsy device comprising a needle guide that can be visualized with MR imaging and manipulated mechanically from outside the MR unit. With approval from the local ethics committee and patient consent, this device was tested in 12 patients by using a closed 1.5-T MR unit and a body phased-array coil. Patients had elevated prostate-specific antigen levels (6–60 ng/mL) and one or more areas in the prostate that were suspicious for carcinoma at prebiopsy MR imaging. Biopsy was performed with transrectal access and with the patient prone. A 16-gauge MR imaging–compatible needle was successfully positioned with the device, and between six and nine tissue cores were obtained in each patient. In one patient, two suspicious basal areas could not be reached with the device. Histologic analysis showed prostate cancer in five patients and prostatitis in six. No complications were observed. The device enabled MR imaging–guided core-needle biopsy of prostate areas suspicious for cancer on MR images.

Prostate cancer is the most common malignant tumor in men in the United States and western Europe and is second in frequency among the tumors that lead to death in men (1). Prostate cancer typically occurs in older men (2). The incidence of prostate cancer has increased with life expectancy, and more cancers are detected as a result of wider screening and determination of prostate-specific antigen (PSA) level in serum. Determination of serum PSA levels is considered useful for the early identification of prostate cancer (3). The American Urological Association and the American Cancer Society recommend that all men aged 50 years or older undergo an annual digital rectal examination and determination of PSA level. Patients with PSA levels greater than 4 ng/mL or with suspicious findings at digital rectal examination are candidates for further diagnostic work-up by means of systematic biopsy guided with transrectal ultrasonography (US). Results of the first prostate biopsy, however, are negative in an estimated 66% of patients with PSA levels greater than 4 ng/mL (4). Thus, many patients require repeat biopsy.

Magnetic resonance (MR) imaging with T2-weighted sequences clearly depicts the zonal anatomy and capsule of the prostate. Prostate cancer in the peripheral prostate zone is delineated as an area of low signal intensity against the high-signal-intensity background. However, problems may arise because other changes in the peripheral zone (eg, hemorrhage, prostatitis, and fibrosis) also appear hypointense on T2-weighted MR images (5,6). Nevertheless, MR imaging with an endorectal body phased-array coil has been shown to be superior to both transrectal US and digital rectal examination in the detection of prostate cancer in patients who have elevated serum PSA levels and in whom findings at transrectal US–guided biopsy were negative (7,8). Previous studies of MR imaging–guided prostate biopsy have been performed with low-field-strength units (9,10) or in animal models at 1.5 T (11). In view of the improved detection of prostate cancer with MR imaging, the purpose of our study was to evaluate a biopsy device developed for MR imaging–guided prostate biopsy with a closed MR unit.

Materials and Methods

Patients

Use of the prostate biopsy device and our study were approved by the local eth-

ics committee. Twelve consecutive patients who consented to participate in the study underwent MR imaging–guided prostate biopsy between May 2001 and July 2003. Patients ranged in age from 55 to 72 years (median, 64 years). Eleven patients had previously undergone transrectal US–guided prostate biopsy, the results of which were negative in nine patients. In one of the 11 patients, the amount of tissue obtained was too small for histologic diagnosis. One patient had a borderline diagnosis of well-differentiated prostate cancer. One patient with an elevated PSA level and suspicious findings at MR imaging did not undergo transrectal US–guided prostate biopsy before the study. PSA levels ranged from 6 to 60 ng/mL (median, 10 ng/mL). The patients underwent diagnostic MR imaging with an endorectal body phased-array coil before undergoing MR imaging–guided biopsy. Prebiopsy MR imaging comprised, at minimum, a transverse T2-weighted turbo spin-echo (SE) sequence (3500/96 [repetition time msec/echo time msec]; echo train length, seven), a coronal T2-weighted turbo SE sequence (4522/112; echo train length, 15), and a transverse T1-weighted turbo SE sequence (530/10; echo train length, three). The oblique transverse and coronal T2-weighted images were evaluated for hypointense regions in the peripheral zone of the prostate. In patients in whom no high-signal-intensity areas indicative of hemorrhage were present on T1-weighted images, confluent hypointense areas on T2-weighted images were classified as suspicious findings, and diffusely and inhomogeneously hypointense areas were classified as inconclusive findings.

The prebiopsy MR imaging examinations were performed by one of two radiologists (D.B., M.T.), each of whom had at least 5 years of experience with MR imaging of the prostate. The two radiologists evaluated the images in consensus. T2-weighted images from all patients showed discrete areas of low signal intensity in the peripheral zone of the prostate, and images from six patients showed highly suspicious confluent areas of reduced signal intensity in the peripheral zone.

Inclusion criteria were informed consent to MR imaging–guided biopsy and demonstration of at least a slight decrease in signal intensity in the peripheral zone of the prostate at prebiopsy MR imaging. Further inclusion criteria were an elevated serum PSA level (>4 ng/mL), normal blood clotting parameters, and prophylactic antibiotic therapy. Patients were excluded from the study if they had any of the usual contraindications to 1.5-T MR imaging (eg, cardiac pacemakers or other metallic implants) or if they did not meet all of the inclusion criteria. Patients in whom no suspicious changes were seen in the peripheral zone of the prostate at prebiopsy MR imaging did not undergo MR imaging–guided biopsy.

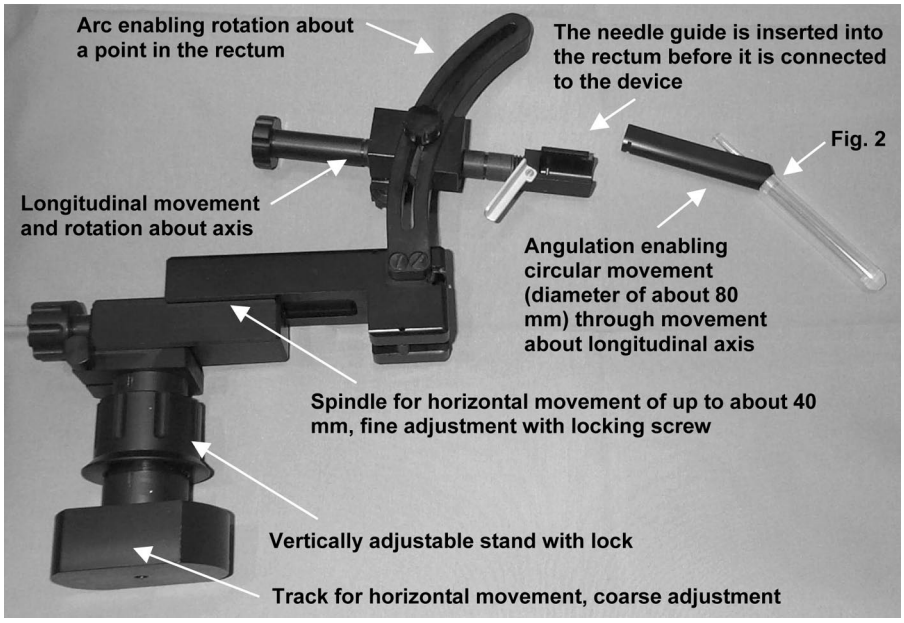

Figure 1. Photograph shows biopsy device without base plate and cushion for patient positioning. The stand is variable in height and rests on a base plate containing a track that enables movement of the device along the longitudinal axis of the MR unit. Except for small parts such as screws, the device is made of synthetic materials that are fully compatible with MR imaging.

Biopsy

Prostate biopsy was performed with the patient positioned prone in a closed MR unit (Magnetom Vision or Magnetom Sonata; Siemens, Erlangen, Germany). Five patients underwent MR imaging–guided biopsy immediately after diagnostic MR imaging, and seven patients underwent MR imaging–guided biopsy in a second session within 2 weeks after the initial MR examination. The procedure was performed by a radiologist with 1½ years of experience in performing prostate biopsy (D.B.). Imaging was performed at 1.5 T by using a body phased-array coil.

The MR imaging–compatible device used for obtaining tissue samples from the prostate was developed at Charité, Humboldt-Universität zu Berlin, in cooperation with MRI Devices/Daum, Schwerin, Germany. This device is made of polyoxymethylene and consists of a base plate, an adjustable arm, and a needle guide filled with contrast material gel that can be visualized at MR imaging. The device also includes a cushion for patient positioning. In this study, we used a prototype developed for clinical trial (Fig 1).

After the patient was positioned, the needle guide was inserted into the rectum and connected to the arm of the biopsy device (Fig 2). The arm enables the needle guide to be rotated, moved forward and backward, and adjusted in height. In addition, the insertion angle can be changed by rotating the needle guide about a point inside the rectum. The needle guide can be rotated and moved forward and backward from outside the MR unit by means of a telescopic rod. It is thus possible to direct the needle guide to the desired prostate region with MR imaging guidance.

To reproduce the prebiopsy diagnostic MR imaging findings, after repositioning of the patient or on a different day, an oblique transverse T2-weighted turbo SE sequence with a section thickness of 3 mm and a field of view of 20 cm was performed before biopsy. The biopsy device was positioned with imaging guidance by using a half-Fourier rapid acquisition with relaxation enhancement (RARE) sequence (∞/89; echo train length, 256; flip angle, 150°; image matrix, 256 × 256; section thickness, 4 mm), with

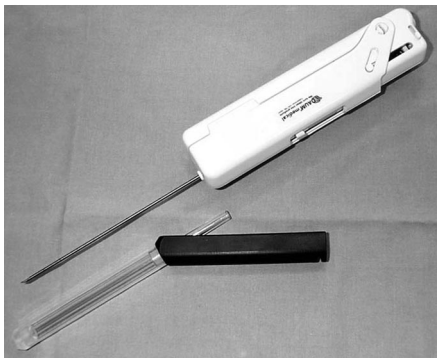

Figure 2. Photograph shows biopsy needle and needle guide used for MR imaging–guided biopsy. The needle is inserted after the contrast material–filled needle guide is locked in the desired position.

acquisition in two perpendicular planes along the needle guide. When there was no direct visualization of a suspicious area with the half-Fourier RARE sequence, the area was localized by using prebiopsy MR images: The location of the area was determined by measuring the distance from it to the apex and base of the prostate or to the urethra or prostate capsule on prebiopsy MR images and then marking the corresponding site on the images acquired with the half-Fourier RARE sequence.

Images were evaluated in consensus (D.B., M.T.). The readers determined the number of cases in which suspicious areas seen at prebiopsy MR imaging were directly reproducible on the half-Fourier RARE images versus those in which a suspicious area had to be identified indirectly with the use of other structures for anatomic reference. After direct or indirect identification of a suspicious area, the needle guide was locked in position for removal of tissue cores from the desired areas of the prostate in 12 patients by means of an MR imaging–compatible automatic ($n = 5$) or semiautomatic ($n = 7$) 16-gauge core-needle biopsy device (Double-Shoot Biopsy Gun or Semi-Automatic Biopsy Gun; MRI Devices/Daum). The needle guide has a defined length so that a corresponding needle of 150 mm in length that is advanced to the limit will extend a few millimeters beyond the guide before being discharged. The fact that the tip of the needle guide touches the bowel wall adjacent to the prostate ensures that a tissue specimen of a predefined length will be obtained from the peripheral zone of the prostate without the need to verify with MR imaging the position of the needle after release. A longer needle is required to obtain tissue from deeper sites, in which case MR imaging is required for verification of the needle position after deployment.

As a rule, eight biopsy cores were obtained in each patient, although a strictly systematic octant biopsy was not performed. Rather, the general scheme of systematic octant biopsy was used for orientation as the biopsy needle was directed at areas that showed suspicious changes in signal intensity at MR imaging. When considered necessary, two biopsy specimens were removed from the same suspicious area. This procedure is a combination of targeted and random biopsy. The aim of this procedure was to obtain at least one specimen from each area considered suspicious for prostate cancer at prebiopsy MR imaging, even if the site did not correspond to the area that would have been sampled in a systematic octant biopsy. With this procedure, we were able to cover at least those sites that would have been sampled in a systematic sextant biopsy.

With use of the octant scheme for orientation, we evaluated 96 areas on prebiopsy images from 12 patients. Altogether, 16 of these areas were highly suspicious for prostate cancer. Fourteen of these areas were reached with the biopsy device, and two were not. Two of the 14 areas were sampled twice at slightly different sites, which resulted in 16 biopsy specimens from highly suspicious areas. In addition, 23 moderately suspicious areas were targeted and reached. One of these areas was sampled twice. Thus, 24 specimens from moderately suspicious areas were obtained. The remaining 57 areas, which did not show suspicious changes at MR imaging, were sampled only once. If inspection of the biopsy core during the removal procedure in the radiology department showed no tissue or a small amount of tissue, a second tissue core was obtained from the same site without changing the position of the needle guide. The tissue core obtained with the second biopsy was put together with that of the first in these cases.

The 97 samples were separately placed in formalin solution and labeled for diagnostic evaluation by the Institute of Pathology at our hospital. Each specimen was evaluated by two of four pathologists, each of whom had at least 4 years of experience. The length of the tissue core was measured and documented after fixation. All patients received prophylactic antibiotic therapy before and after biopsy. The duration of the procedure, from the time the patient was positioned until the patient left the room, was determined. Complications were recorded during questioning of the patient after the procedure. Patients were instructed to present to the Department of Urology at our hospital if they developed complications such as prolonged hematuria, fever, or pain.

Results

MR imaging with the half-Fourier RARE sequence enabled visualization of the prostate in all 12 patients and depicted abnormal changes in the peripheral zone of the prostate in seven patients. In the other five patients, the sites that showed abnormal change on prebiopsy MR images were marked on the half-Fourier RARE images, which were then used for orientation during prostate biopsy. The needle guide was depicted and could be positioned with MR imaging guidance in all 12 patients (Fig 3). In 11 patients, biopsy specimens were removed from at least eight sites; in three patients, specimens were obtained from nine sites. In one patient, basal areas of the prostate that were suspicious for cancer at prebiopsy MR imaging could not be targeted with the needle guide. The six biopsy cores removed from other sites in this patient were negative for prostate cancer. Repeat transrectal US–guided octant biopsy performed 25 days later in this patient demonstrated prostate cancer in one area. Altogether, core biopsy specimens were removed from 97 sites at MR imaging–guided biopsy in the 12 patients.

Of the 16 biopsy specimens from areas that were highly suspicious for prostate cancer at prebiopsy MR imaging, eight were positive and eight were negative. Of the 24 biopsy specimens from moderately suspicious areas, four showed prostate cancer, and 20 showed no prostate cancer. Of the 57 specimens from nonsuspicious areas, two showed prostate cancer and 55 did not. In six cases, a second specimen was obtained from the same site without changing the position of the needle guide because the initial biopsy yielded little or no tissue. At macroscopic pathologic evaluation, the tissue cores from six sites were found to be less than 5 mm in length; three of those specimens were obtained at repeat biopsy from the same site. Three of the six specimens were inadequate for histologic evaluation. The length of the biopsy cores after fixation ranged from 3 to 22 mm (median, 14 mm). Histologic examination demonstrated prostate cancer in five patients, with eight positive biopsy

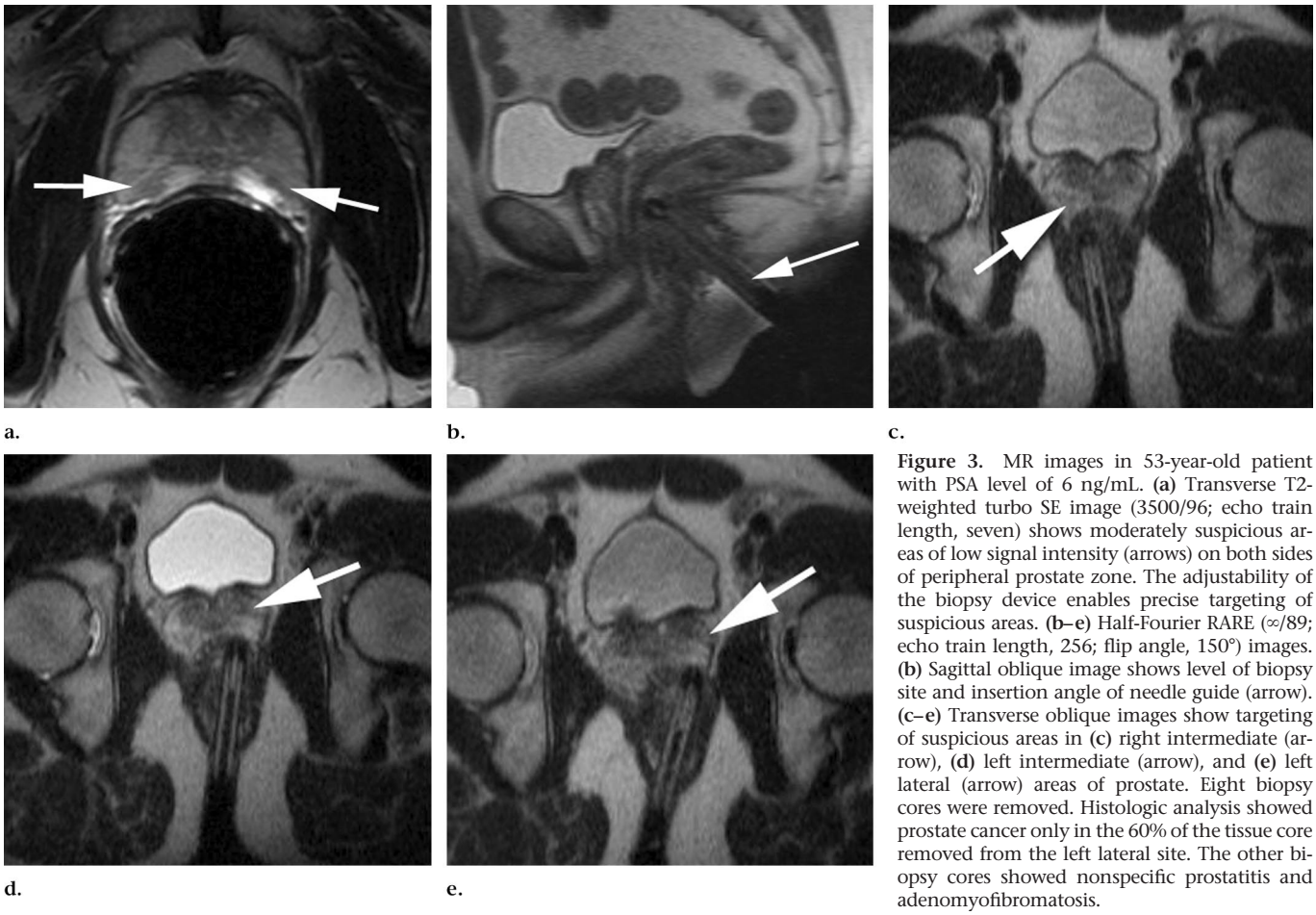

Figure 3. MR images in 53-year-old patient with PSA level of 6 ng/mL. **(a)** Transverse T2-weighted turbo SE image (3500/96; echo train length, seven) shows moderately suspicious areas of low signal intensity (arrows) on both sides of peripheral prostate zone. The adjustability of the biopsy device enables precise targeting of suspicious areas. **(b–e)** Half-Fourier RARE (∞/89; echo train length, 256; flip angle, 150°) images. **(b)** Sagittal oblique image shows level of biopsy site and insertion angle of needle guide (arrow). **(c–e)** Transverse oblique images show targeting of suspicious areas in **(c)** right intermediate (arrow), **(d)** left intermediate (arrow), and **(e)** left lateral (arrow) areas of prostate. Eight biopsy cores were removed. Histologic analysis showed prostate cancer only in the 60% of the tissue core removed from the left lateral site. The other biopsy cores showed nonspecific prostatitis and adenomyofibromatosis.

specimens in one patient and three positive biopsy specimens in another. Each of the other three patients had one positive tissue core. In specimens from the other six patients, histologic examination demonstrated prostatitis. In the patient in whom the suspicious basal areas were not reached, the remaining six specimens were negative. The duration of the procedure ranged from 40 to 60 minutes (mean, 55 minutes). No complications were observed.

Discussion

The prognosis and likelihood of distant metastases in prostate cancer correlate with the tumor volume, TNM stage, and degree of differentiation (12,13). Early detection of prostate cancer enables identification of the tumor at an early stage at which it can be treated with surgery. The determination of PSA level in serum is an important tool for identifying early prostate cancer (3). Nevertheless, in some patients with PSA levels greater than 4 ng/mL, the first transrectal US–guided prostate biopsy may yield no histologic evidence of tumor. Some improvement in targeting of suspicious areas at biopsy may be expected with the use of contrast material–enhanced US of the prostate (14). Results of previous studies suggest that T2-weighted MR imaging with an endorectal coil, which has a sensitivity of 83%–85% for the detection of prostate cancer, can help improve the planning of repeat prostate biopsy in this population (7,8). T2-weighted MR imaging as performed in these studies, however, had a poor specificity of only 51% for characterizing changes in the peripheral zone of the prostate (6,8).

Spectroscopic imaging of the prostate, which provides improved demarcation of prostate cancer beyond demarcation with T2-weighted MR imaging, may increase both the sensitivity and specificity of MR imaging for the detection of prostate cancer in this patient population (15–17). Site-by-site comparison has shown that, compared with core biopsy, both conventional MR imaging with the endorectal body phased-array coil and spectroscopic imaging have a higher sensitivity but lower specificity in the detection of prostate cancer (17). Another approach for improving tumor detection is dynamic contrast-enhanced MR imaging (18). At present, the lower specificity of MR imaging does not allow us to dispense with systematic prostate biopsy (8,17). The MR imaging–guided modified octant biopsy technique described in this article provides spatial coverage equivalent to that available with systematic sextant biopsy, and takes into account morphologically suspicious areas demonstrated at MR imaging, as well.

In our study, the peripheral zone was assessed for suspicious areas by using prebiopsy MR imaging with an endorectal body phased-array coil. The fast pulse sequences used in positioning of the needle guide for MR imaging–guided biopsy, therefore, only served to reproduce the previous findings and identify those regions already classified as suspicious. Al-

though the fast pulse sequences used to guide biopsy are unsuitable for tumor detection, they depict the zonal anatomy of the prostate in a manner similar to that of prebiopsy T2-weighted turbo SE imaging and thus facilitate orientation, compared with transrectal US, although the areas of reduced signal intensity in the peripheral zone cannot be reproduced in all cases. The poorer image quality with the fast sequences is acceptable for positioning of the needle and helps reduce the overall duration of the procedure. In most cases, imaging is not required during needle deployment, and the examination time thus can be kept short. We do not think that imaging guidance is absolutely necessary at this stage of the procedure, because the needle guide of the biopsy device has a defined length and is used with a needle of constant length, enabling needle deployment only in the preset direction and depth. With the needles used in this study, the notch for receiving the tissue specimen is 17 mm long and extends 5–22 mm beyond the tip of the needle guide. Although deeper areas can be reached with the biopsy device by using longer needles, that procedure would require MR imaging guidance during needle deployment, to prevent excessive advancement of the needle. If the needle position is monitored with MR imaging, it must be borne in mind that, depending on the phase-encoding direction and the position of the needle in the magnetic field, needle-induced artifacts may appear on the images (19).

Localization of the needle guide with the technique used in this study nevertheless is time-consuming because the contrast material–filled needle guide must first be identified on a localizer image. Then, imaging in two planes perpendicular to each other must be planned and performed. The foreseeable development of algorithms for the automatic identification of the needle guide on the image and subsequent section orientation will help shorten the duration of the procedure in the future (20).

The MR imaging–compatible needles used in this study are not attracted by the magnet, a characteristic that enables the avoidance of possible injury to the patient from a needle being drawn toward the magnet. Because of the intrinsic properties of the MR imaging–compatible materials used in the needle, however, the notch that receives the biopsy core is smaller than that in non–MR-compatible needles. In contrast to transrectal US–guided prostate biopsy (in which 18-gauge needles are most often used), for this MR imaging–guided procedure we used a 16-gauge needle to obtain biopsy cores of adequate size for histologic diagnosis (4,21).

MR imaging–guided prostate biopsy is usually performed by using open-configuration MR units with a lower field strength or poorer field homogeneity (9,10). Because such MR units provide limited diagnostic image quality, it is necessary to examine the patient with two different units. The biopsy device we describe enables MR imaging–guided biopsy with the same MR unit as that used for diagnostic MR imaging and with an endorectal body phased-array coil. The use of an initial T2-weighted turbo SE sequence with the same parameters as those used in diagnostic MR imaging ensures good reproducibility and spatial matching of the findings obtained in the diagnostic MR imaging examination. As an alternative to MR imaging–guided prostate biopsy in the MR unit, the MR imaging data sets can be fused with the transrectal US views. In this setting, the advantages of superior tumor detection with MR imaging could be combined with the faster and less expensive technique of transrectal US–guided biopsy, provided that adequate fusion of these images is possible. The few data available have been obtained in patients suspected of having a recurrence of prostate cancer after radiation therapy (22).

The complications associated with MR imaging–guided transrectal prostate biopsy are the same as those observed with transrectal US–guided biopsy. Our experience suggests that additional complications are unlikely. Minor complications of transrectal prostate biopsy are quite common, and severe complications are rare. Previous findings in large study groups (23) showed that hematuria persisting for more than 3 days occurred in 22.6% of cases, and hematospermia, in 50.4%. Fever was observed in 3.5% of patients; 0.4% of patients developed urinary retention. Less than 0.5% of patients were hospitalized for complications such as prostatitis or urosepsis. None of our patients developed complications.

Transrectal imaging-guided prostate biopsy with a closed MR unit, as performed in our study, requires the use of a specialized device that consists of a needle guide and support system, because the length of the magnet in body MR units does not allow free manual manipulation of the biopsy device. Another limitation of our study is the small number of patients who underwent prostate biopsy with this device. It is therefore necessary to investigate the performance of the biopsy device in a larger patient population and with use by different operators.

The biopsy device tested in this study enables the targeting of areas in the prostate that are suspicious for cancer at MR imaging. This device may hold promise for the evaluation of patients who have elevated PSA levels and negative findings at transrectal US–guided biopsy and in whom suspicious areas in the peripheral zone of the prostate are depicted on diagnostic MR images.

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