Real-Time Magnetic Resonance Imaging–Guided Focal Laser Therapy in Patients with Low-Risk Prostate Cancer


1. Case report

Patients 1 and 2 were 74 and 72 yr old, respectively, with National Comprehensive Cancer Network–defined low-risk prostate cancer (PCa). Patient 1 had stage cT1c cancer, a prostate-specific antigen (PSA) level of 4.79 ng/ml, and Gleason score 6 (3 + 3) in four cores in two adjacent sectors of the right mid gland. Patient 2 had stage cT1c cancer, PSA 2.74 ng/ml, and Gleason score 6 (3 + 3) in two cores from two adjacent sectors of the left base.

Both patients wished to have curative therapy but refused conventional surgery or radiation therapy because of concern for the known adverse effects. Institutional review board–approved experimental magnetic resonance imaging (MRI)–guided focal laser therapy (FLT) was offered and agreed to by the patients. Pretreatment multiparametric MRI confirmed a well-defined single area of carcinoma involving the right medial midprostate in patient 1 and a single lesion in the left peripheral zone at the base of the prostate in patient 2.
1.1. Surgical procedure

Under general anesthesia with intravenous propofol, fentanyl, and midazolam, the patients were placed in the bore of a 1.5-T GE Excite Twinspeed MR scanner (GE Healthcare, Waukesha, Wisconsin, USA) in semilithotomy position. All MRI was performed with a torso array and endorectal coil (Medrad, Warrendale, PA, USA). An axial T2 fast spin echo scan was combined with preoperative diagnostic MRI with diffusion weighted imaging. Combined T2-weighted and diffusion-weighted MRI for localization of prostate cancer was done for tumor localization (Fig. 1).

A modified MRI-compatible brachytherapy-like template containing saline-filled fiducials was secured against the patient’s perineum (Fig. 2). The locations of the magnetic resonance (MR)–visible fiducials in the insertion template were identified in an MR scan (Axial 2D FIESTA [Fast Imaging Employing Steady State Acquisition]; GE Healthcare, Waukesha, Wisconsin, USA), which allowed, using custom planning software, the position and orientation of the template. A virtual representation of the template and the insertion paths was superimposed onto the MR images and an insertion hole was selected based on the overlap of the insertion grid with the tumor (Fig. 3).

An open-ended, 14-gauge, 140-mm-long catheter with an MR-compatible titanium obturator was inserted through the selected hole of the template into the patient’s perineum. FIESTA-MRI series were acquired as the catheter was inserted. The images were loaded into in-house planning software as they were acquired (Fig. 4). By monitoring the image slice that was parallel to the catheter insertion path, the insertion depth could be tracked in real time to guide the insertion. Insertion could be performed by reaching into the bore of the magnet by hand (Fig. 4).

Once the catheter reached its target, the metal trocar was replaced by an optical fiber with a 1-cm-long cylindrically...
diffusing tip attached to a 980-nm diode laser (Visualase Inc, Houston, TX, USA).

During laser ablation, temperature was measured simultaneously on five 3-mm-thick image slices that covered the target volume (Fig. 5a). The thermometry scan was repeated every 6 s.

The MRI thermometry software (Visualase, Inc, Houston, TX, USA) allowed us to monitor temperature at specific points in the tissue. The temperature at those points was used as a feedback to control the laser. During the laser heating, the temperatures at the border of the rectal wall and urethra were monitored and maintained at safe levels by shutting down the laser automatically when the temperature at these critical points exceeded 45 °C. Thermal damage was calculated using an Arrhenius formula. Temperature and damage maps were superimposed onto anatomic images (Fig. 5b). Once the desired volume of tissue destruction was achieved, laser power was stopped.

1.2. Results

In both patients, a contrast-enhanced scan (CES) (axial fast spoiled gradient with fat saturation) [1] done immediately following treatment showed good correlation with the thermal damage calculations of the MRI-thermometry software. Residual vascularized target tissue prompted immediate repeat treatment with new fiber positions in both cases. A second CES after second ablation showed a larger damage volume with greater overlap of the tumor.
The patients were discharged home within 3 h. MR scans performed 2 wk post-treatment showed no evidence of complications with preservation of rectum and neurovascular bundles (Fig. 6). No adverse effects were noted at ≤1 mo after treatment. Six-month follow-up biopsies are pending.

2. Discussion

FLT of low-risk PCa is a reasonable and increasingly popular concept to control this disease in the appropriate patient population. FLT offers the opportunity for greatly reduced side effects compared with active treatments. The use of MRI guidance allows the clinician to accurately deliver the tip of the laser fiber to the desired target and to monitor the destruction of the target volume in real time.

Several studies have shown the feasibility of focal cryoablation of the prostate [2–4] and of high-intensity focused ultrasound (US) focal ablation [5].

We reported our initial experience with MR-planned, US-guided photothermal focal therapy in 12 PCA patients [6]. This study showed the feasibility of image-guided laser ablation of small volumes of PCa and demonstrated that the treatment would result in minimal morbidity. In a further study, we performed MR-planned, US-guided FLT followed by radical prostatectomy. No viable tumor was found in whole mount histopathologic examination of the ablated area.

Outpatient MRI-guided FLT as used in the present study allows for visualization of the tumor; real-time guidance of the thermal device to the target; monitoring and control of...
the zone of ablation and surrounding tissue during treatment; and the ability to immediately confirm the success of the treatment and, if necessary, immediately repeat therapy. The required skills are common to other minimally invasive procedures, resulting in a short learning curve for the surgeon. Refinement of this outpatient procedure may result in an inexpensive, minimally invasive alternative to current active therapies. Further trials will be necessary to define the safety and oncologic efficacy of this therapy, but our early results are promising.

Conflicts of interest: The authors have nothing to disclose.

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EU-ACME question

Please visit www.eu-acme.org/europeanurology to answer the following EU-ACME question online (the EU-ACME credits will be attributed automatically).

Question:

Which of the following statements is incorrect with regard to magnetic resonance imaging (MRI) for prostate cancer detection?

A. In dynamic contrast-enhanced MRI (DCE-MRI), the tumor demonstrates early enhancement and early washout of the contrast agent, enabling its detection. The higher the tumor grade, the more pronounced this effect tends to be.

B. Abnormal enhancement patterns in DCE-MRI can also be seen in patients with BPH, which can make assessment of the central gland difficult.

C. Diffusion-weighted MRI (DW-MRI) provides information derived from the molecular movement of water in biological tissues. It improves prostate cancer detection.

D. The apparent diffusion coefficient of a tumor is higher than that of benign tissue.

References


