Transperineal MRI-Guided High-Dose-Rate (HDR) Prostate Brachytherapy and Biopsy in a Standard 1.5T Scanner: Clinical Experience

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Introduction and Objective: MRI provides superior visualization of the prostate and surrounding anatomy making it the modality of choice for imaging prostate cancer (1). Given that accuracy in brachytherapy is largely dependent on the quality of images, there is a strong rationale for utilizing MRI during brachytherapy catheter placement and treatment planning. This clinical study was performed to determine the feasibility, needle placement accuracy, and dosimetric quality achieved when placing biopsy needles and high-dose-rate (HDR) prostate brachytherapy catheters under MR image guidance in a standard 1.5T scanner.

Methods: Patients with intermediate and high-risk localized prostate cancer received MRI-guided HDR brachytherapy boosts before and after a course of external beam radiotherapy. All eligible patients underwent a preliminary MRI in the treatment position prior to enrollment to confirm adequate perineal access and the absence of pubic arch interference. Preliminary MRI evaluations and procedures were performed on a Siemens Sonata 1.5T MRI scanner with a 60cm diameter bore (Siemens Medical Systems, Erlangen, Germany). Patients were placed under general endotracheal anesthesia for the entire procedure. An endorectal coil (USA Instruments, Aurora, OH) was modified with immobilization hardware and rigidly affixed perpendicular to a custom designed perineal template. The coil was inserted and placed against the anterior rectal wall adjacent to the prostate gland, centered on the urethra. Upon satisfactory device positioning, a parallel MR-imaging plane was determined and a 3D-SSFP image volume which comprises the template, pubic arch, and prostate gland was acquired. These images were immediately sent to an adjacent PC workstation with a custom written image-visualization and targeting program (2). Needle paths potentially encroaching on the pubic arch and urethra were identified and marked, and a peripheral brachytherapy catheter arrangement was designed with the assistance of the pre-plan. Fast-spin-echo images of the prostate gland (TR=741ms, TE=60ms, ETL=7, Pixel BW=125 Hz/pixel, FOV=25cm, ST=4mm, 256x256, 12 slices, NEX=1, scan time=28sec) were then acquired for improved target definition and to confirm the adequacy of the biopsy needle and brachytherapy catheter placements. These images were projected with an LCD projector within the MR room to allow the operator more timely feedback of catheter position. All images were corrected for nonuniform receiver coil sensitivity. HDR brachytherapy inverse treatment planning was performed using T2-weighted FSE images (TR=3500ms, TE=121ms, ETL=9, Pixel BW=130 Hz/pixel, FOV=25cm, ST=3mm, 256x256, 26 slices, NEX=2, Scan time=3:38) obtained at the end of the procedure.

Results: Eleven MRI-guided transperineal brachytherapy and biopsy procedures have been performed on 6 patients. Prostate gland sizes as determined by treatment planning MRI ranged from 29 to 65 cm^3. Analysis of biopsy needle targeting accuracy for the first eight procedures revealed a mean needle-placement accuracy of 2.1mm, 95% of needle placement errors were less than 4mm, and the maximum needle placement error was 4.4mm. Online image intensity correction allowed for improved visualization of structures within and around the prostate gland, despite the inhomogeneous sensitivity profile of the endorectal imaging coil. Brachytherapy dosimetric parameters were calculated for each procedure. The median percentage of the target volume encompassed by 100% or more of the prescription dose (V100) was 94%, with a mean of 92% (CI 89%-95%). Urethral V125 ranged from 0 to 18% (median 5%), and rectal V75 ranged from 0 to 5.1 % (median 0.5%). In all cases, lesions highly suspicious for malignancy could be visualized on the procedural MR images, and extracapsular disease (example Figure A- arrow) was identified in two patients. All visible lesions were encompassed in the high-dose regions (example Figure B).

Conclusions: HDR prostate brachytherapy and transperineal needle biopsy in a standard 1.5T MRI scanner is feasible, safe, and achieves accurate needle placements and favorable dosimetry with high-quality image guidance. Here we demonstrate that this procedure may offer a therapeutic advantage for those patients with extracapsular extension of disease, whereby extracapsular disease visualized on MR images is included in the radiation target volume. Because 1.5T MR images are directly acquired during the interventional procedure, dependence on deformable registration is reduced. This system establishes a procedural platform ideally suited to the evaluation and integration of anatomic, functional, and molecular imaging techniques in cancer radiotherapy. These new imaging techniques promise to improve the accuracy of tumor delineation within the prostate gland, and in turn, can be integrated with the procedure to deliver higher doses of radiation to tumor bearing regions within the prostate gland.

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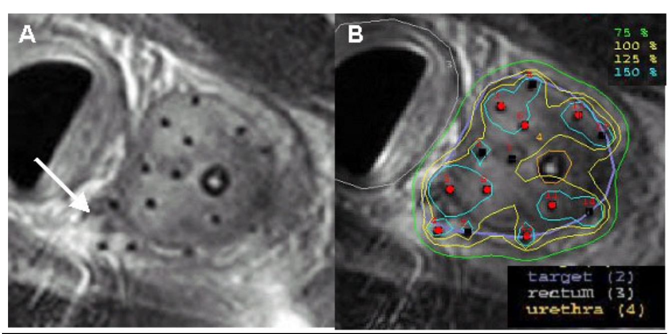

Figure A: Fourteen brachytherapy catheters (signal voids) were placed throughout the prostate gland and at sites of visualized extracapsular extension (arrow).
Figure B: Radiation was delivered according to a dosimetry plan whereby the target volume, including the prostate gland and extracapsular sites of disease extension (purple line), is encompassed by 100% of the prescription dose (outer yellow outline). The urethral dose (orange outline) is kept below 125% of the prescription dose, and the rectal mucosa (white outline) is kept below 75% of the prescription dose. The radiation dose prescribed is 1050cGy.