Proof of concept for transrectal MRI-guided prostate biopsies using an optically referenced targeting device

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Introduction and Purpose

Prostate carcinoma (PCa) is one of the most common male cancers in the western world. While digital rectal examination, prostate-specific antigen (PSA) testing and transrectal ultrasound-guided biopsies are still the primary tools for prostate diagnostics, multiparametric MRI has an emerging role in both imaging diagnostics and procedural guidance. The purpose of this work is to present a virtual real-time navigation option for transrectal MRI-guided prostate biopsies, to estimate the targeting accuracy, and to report on the preliminary clinical experience.

Materials and Methods

The technical basis for MRI-guided biopsies was a passive interventional device (DynaTRIM, Invivo, Gainesville, FL) that uses an attachable, MR-visible needle guide for transrectal access to the prostate. Axial (patient head-feet) and vertical (anterior-posterior) positions as well as pitch and roll of the disposable guide can be accurately adjusted by corresponding knobs and dials. The rotation dial of the device was equipped with three reflective markers (NDI, Waterloo, Canada, Fig. 1a) that unambiguously define the 6 degrees of freedom (DOF) of the rigidly connected needle guide. A 3D digitizer (NDI) tracks this geometry in real-time with respect to three optical markers on a reference board (Fig. 1b). The corresponding custom-made base plate (Invivo Germany, Schwerin) is accurately aligned with the patient table via four tongues that fit tightly in equally spaced grooves on the side of the table (3+2 DOF). Three MR markers on the reference board are used to unambiguously define the remaining DOF (z-position along the table). A template board with optical and MR markers was used to calibrate the system (Fig. 1b).

Accurate registration of the biopsy device with the MRI coordinates only takes a fast one-time localization of the three MR markers. The navigation system (Localite Biomedical Visualization Systems, Germany) then computes (in real time) three orthogonal MR views centered at the tip of the tracked needle position and aligned along standard radiological planes or along the typically oblique needle axis. A prototype was implemented in a 3-T MRI with a bore size of 60 cm (Magnetom Tim Trio, Siemens, Erlangen). Targeting accuracy was estimated by 30 phantom biopsies taken *without* any needle corrections in a custom-made phantom (Fig. 1c). With IRB approval and written informed consent, 18 patients (52-72 y.o., mean 65) with previous negative TRUS biopsies (1-3) underwent MRI biopsy (Fig. 1d). Mean PSA level was 7.3 (1.2-56.0) ng/mL. Intervention time, complications, and biopsy findings were documented.

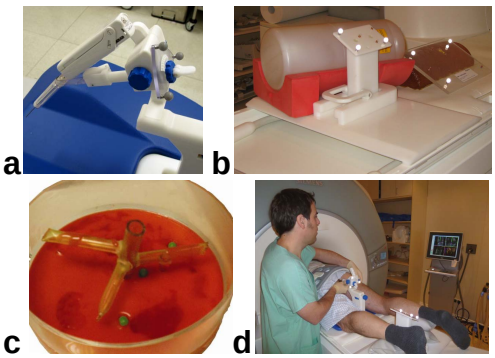


Figure 1: (a) Prostate device with modified rotation dial and fully automatic biopsy gun inserted into needle guide. **(b)** Table-aligned base plate and reference board with optical and MR markers. **(c)** Phantom with model vessel and 10 targets (peas, mean Ø 8.5 mm) embedded in opaque glaze. **(d)** Clinical setting during targeting.

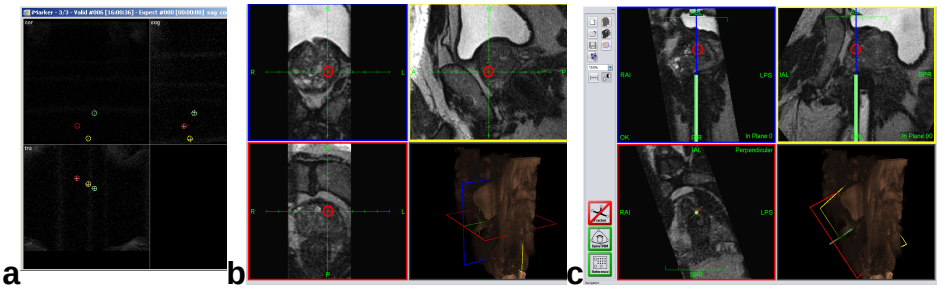
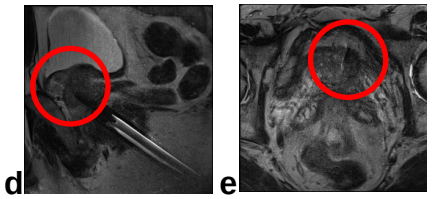


Figure 2: MRI biopsy in the left anterior (mid) central gland of a 62 y.o. patient with a PSA level of 11 ng/mL **(a)** Successful marker localization (total time < 30 s) for automatic device registration. **(b)** Planning screen using a 3D TSE SPACE sequence (0.74×0.74×1 mm^3, TR/TE 2,000/140 ms, TA: 5 min). **(c)** Navigation scene with virtual needle overlay. Verification of biopsy gun placement in **(d)** axial and **(e)** sagittal planes. Histopathology revealed a GS 6 (3+3) tumor.



Results

Image quality and patient comfort were not impaired by the additional components. Experimental biopsy samples contained pea material in 28/30 cases (maximum 3D error of 4.3 mm in 93% of the cases). The interventional radiologist considered the real-time feedback on the virtual needle direction to be helpful for procedural orientation. A sample biopsy case is shown in Figure 2. Median intervention time over all patients was 55 minutes (36-89 minutes) considering that two lesions were targeted in 7/18 patients (39%). No severe complications were observed, one mild complication (fever) was resolved within 24 hours. On average, 4 cores (2-6) were taken per lesion. The obtained specimens were diagnostic in all cases. In eight patients (44%), histopathology revealed prostate cancer (five GS 3+3, three GS 3+4).

Discussion and Conclusion

The presented virtual navigation option for MRI-guided prostate interventions was found to be technically feasible and sufficiently accurate. It should be stressed that clinical application always relied on control images to verify the placement of the biopsy device. Clinical setup and operation meant only a minor deviation from the established workflow of the original approach. Any multiplanar (3D) image data can be used as reference information. Stereotactic errors, in particular from prostate motion, can be rapidly detected and corrected for by simply updating the roadmap data. A software option to (elastically) fuse the diagnostic imaging data onto the interventional situation should be considered to improve interventional workflow. The presented technique can generally be implemented with other assistance devices and scanner models as well with relatively few modifications to the underlying hardware and software. Further experimental and clinical work is required to provide more reliable measures of performance.

Acknowledgement Grant support under BMBF 13N10360 is greatly acknowledged.