Title: MR-compatible transrectal prostate biopsy robot: a feasibility study

J. Futterer[1], M. Schouten[1], T. Scheenen[2], and J. Barentsz[3]
[1]Radiology, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [2]Radiology, radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [3]radiology, radboud University Nijmegen Medical Centre, nijmegen, Netherlands

Introduction

The recent symbiosis between robotics and medical science has made a rapid development, particularly in imaging and interventions. Different imaging modalities provide feedback to interventional devices which are crucial in precise positioning tasks such as needle insertion, biopsy interventions and catheter placement. Prostate cancer is the most frequently diagnosed form of noncutaneous cancer in men. Despite the low sensitivity and high specificity of transrectal ultrasound (TRUS)-guided biopsy for prostate cancer detection, TRUS-guided biopsy is still the standard procedure. Magnetic resonance (MR) imaging can be used as a diagnostic tool to detect, localize and stage prostate cancer. The detection rate is improved in patients with elevated prostate specific antigen and repetitive negative TRUS biopsies using MR-guided prostate biopsies [1]. So far, the only commercially available MR-guided prostate biopsy device is a manually adjustable standard for needle guide positioning. A needle guide filled with gadolinium is inserted in the rectum of the patient, based on the acquired MR images the needle guide is manually positioned in the direction of the region of interest . This procedure is unpleasant for the patient, operator-dependent, and time-consuming for the radiologist [2]. For these reasons an in-house pneumatic actuated MR-compatible robot is developed where needle guide direction can be controlled inside the controller room. Consequently the patient remains in the scanner bore. It is therefore conceivable that this robot may improve procedure time, enhances patient comfort and improve needle guide positioning. Thus, the purpose of our study was to establish proof of principle of a transrectal MR- and robot-guided prostate biopsy using a phantom.

Methods

The system consisted of the robot and its controller unit. The controller unit included a computer, motion control elements and electro-pneumatic and electronic interfaces which are located outside the MR magnet room. Plastic tubes connected the robot to the control unit (Fig. 1). The robot itself is constructed of nonmagnetic and dielectric materials to achieve magnetic field compatibility, not causing any signal artifacts. The entire robot consisted of plastic. The robot is designed to interact with the patient within a standard closed-bore MR scanner.
To evaluate the ability of sampling with the biopsy robot, a phantom made of Agar-Agar was used. Small plastic beads located in the Agar-Agar represented targets. All beads were imbedded in the Agar-Agar at the same depth and distance between them. The size of the beads varied from 2 to 3 mm. After initial target selection on a 3D T1-VIBE sequence, a software package (Interactive front end (IFE); work in-progress package; Siemens, Erlangen, Germany) combined with a real-time MR sequence were used to orient and direct the needle guide in the desired direction. To evaluate the accuracy of the robot the in-plane error was measured.

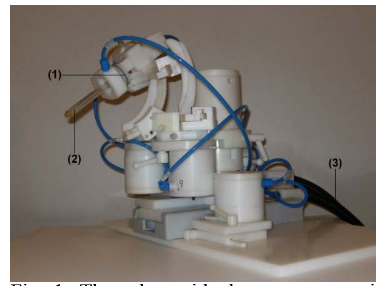

Fig. 1: The robot with the vacuum suction cup (1), needle holder/guide (2) and plastic tube to the controller unit (3)

Results

In total 19 biopsies were performed. No technical problems occurred during the procedure and all predefined targets could be reached. No artifacts from the robot were seen on the MR images. Total procedure time to perform a biopsy was less than 30 minutes for each sample. The interface for manipulation of the robot and needle guide was very easy to use and did not need a lot of experience from the radiologist. The simple interface for manipulation, 5 DOF and fast manipulation speed of the end effector made it effortless to reach a target. Therefore most of the manipulation time was spend in fine-tuning of end needle guide position, even when two predefined targets were far apart.
For needle placement the average in-plane error was 3.0 mm (range, 0 – 5.6 mm; Fig. 2). In 3 out of 19 measurements there was an exact hit of the needle and target. As a result the plastic beat moved with the needle in the Agar-Agar phantom and was seen on the needle tip. In the other 16 biopsies the needle missed the target or bounced off on the plastic beats (Fig 3.).

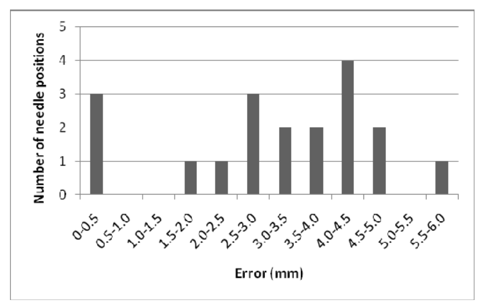

Fig. 2: Histogram shows distribution of needle placement error (n=19).

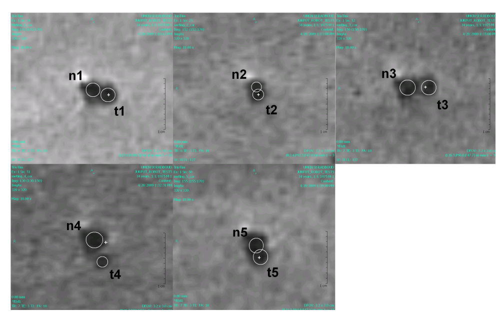

Fig 3. In-plane images of the first 5 biopsies, (n) represents the needle, (t) represents the target and (+) represents the expected needle position based on extrapolation of the needle guide direction. All images are shown with the same magnification (18x).

Conclusion and discussion

The new developed MR-compatible transrectal prostate biopsy robot demonstrated promising results with respect to the precise needle positioning and short manipulation time within a standard closed-bore. Furthermore, the robotic device prevented the need of moving the patient in and out of the scanner bore for manipulation and imaging of the needle guide.

References

1 Hambrock T et al. J Urol In press; 2 Beyersdorff D et al. Radiology 2004;234:576-581.