Experiences with Robot Assisted MR-guided Inbore Prostate Biopsies

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Background

Clinical management of prostate cancer is strongly challenged by the triangle of very high prevalence [1], heterogeneous and poorly understood tumor biology, and significant side effects of established treatments [2]. In order to contain the harms of therapy, we have to put great effort into the difficult task of identifying, from a huge pool of indolent prostate cancers, the patients that actually benefit from treatment.

In recent years, multiparametric MR imaging of the prostate (mpMRI) has evolved into a useful tool in the pursuit of better prognostic stratification. On the one hand, quality assured mpMRI has great potential for triage of patients for biopsies [3], i.e. omitting unnecessary biopsies [4]. On the other hand, mpMRI targeted biopsies, instead of or in addition to systematic biopsies, escalate the detection rate of cancer that might need treatment [5] and increase the likelihood and confidence of attaining optimally representative biopsies, i.e. sampling tumor tissue that can be expected to drive prognosis.

Diagnostic pathway

In the assessment for possible prostate cancer at our prostate center, mpMRI is the first test for all patients. For interpretation of the mpMRI we apply PI-RADS v2, but in some cases deviate from the scoring guidelines. Based on recent literature [4] and internal results (Table 1), our group refrains from biopsy in most patients with a negative mpMRI (PI-RADS 1–2). Systematic biopsies despite negative mpMRI are performed in selected patients on the basis of certain clinical alarm signals, since it is clear that prostate cancers can have growth patterns that make them more or less MR-invisible. Patients with a positive mpMRI (PI-RADS 3–5) are scheduled for either MR-guided inbore biopsy or TRUS-biopsy, the preferred method depending on the targets defined on the mpMRI, in the following manner: Lesions considered potentially deterministic for prognosis and treatment choice are defined as biopsy targets, with a maximum of three targets for practical reasons. In case of heterogeneous intratumoral signal characteristics on diffusion-weighted images (DWI) or dynamic contrast-enhanced images (DCE), the area that is suspected to correlate to highest tumor aggressiveness is defined as a separate biopsy target. Only in the case of a high probability of hitting all the defined targets is TRUS-biopsies considered the preferred method. At our institute this currently generates approximately 6 MR-guided biopsies weekly.

	PI-RADS 1+2	PI-RADS 3	PI-RADS 4+5
Group size	**43%**	**8%**	**49%**
% cancer	**1%**	**27%**	**91%**
Gleason score 6	1%	20%	33%
Gleason score 7a	0	7%	30%
Gleason score 7b or higher	0	0	28%

Table 1: Performance of diagnostic mpMRI at our institute. Retrospective data collected for quality assurance purposes (189 patients). Numbers represent highest Gleason score found during completed diagnostic workup or in prostatectomy specimens.

System and workflow

For the MR-guided biopsies we use a MAGNETOM Skyra 3T system and Soteria's Remote Controlled Manipulator (RCM)[1], a pneumatically driven robotic device that allows for precise needle guide steering from the operator room (Fig. 1).

Oral antibiotic prophylaxis and an enema are the only preparations for the biopsy procedure. For the procedure the patient is placed in the prone position on the MR table and a needle guide is inserted in the rectum and subsequently connected to the RCM (Fig. 2). Image guidance is done with TrueFISP, alternatively short T2w TSE, sequences and when deemed beneficial, diffusion-weighted imaging (Case 3). Images are send from the MR console to the RCM software, which then allows for quick and easy calibration and thereafter manipulation of the needle guide position (Fig. 3). When the images show satisfactory needle guide positioning, a biopsy needle is inserted into the needle guide at appropriate depth and the biopsy taken.

[1] The information shown herein refers to products of 3rd party manufacturers (Soteria) and thus are in their regulatory responsibility. Please contact Soteria for further information.

Figure 1: The RCM-system. **(1A)** MRI-compatible robotic device that holds and manipulates the position of the needle guide. **(1B)** Cart that is positioned outside of the MRI-room and connected to the robotic device by plastic tubing, containing a steering unit, compressor and vacuum pump. The system includes a portable laptop with the control and targeting software.

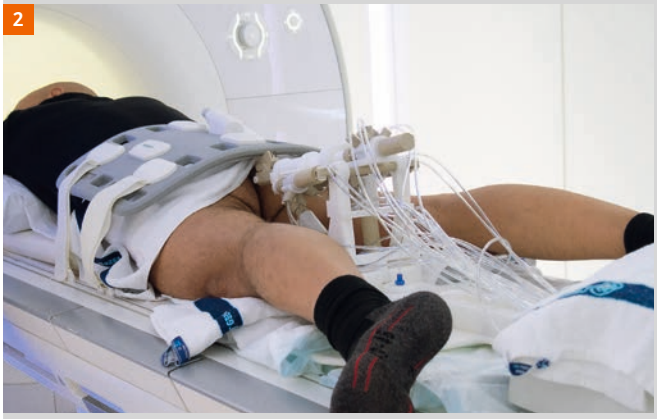

Figure 2: Patient and RCM positioning.

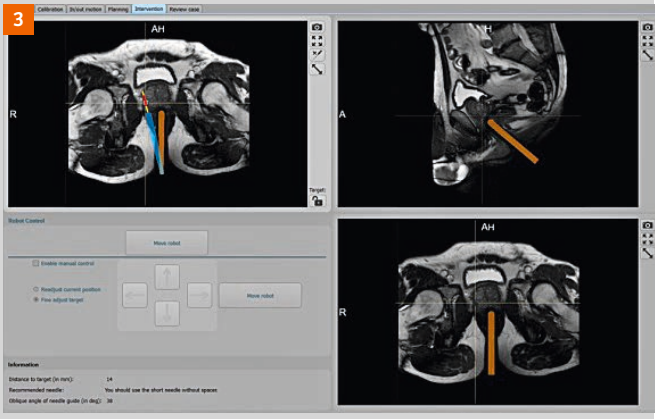

Figure 3: Software interface.

Usage of an MR-compatible biopsy needle permits for image documentation of the needle position. However, in our experience the procedure allows for such accurate needle positioning that this step is superfluous in most cases. By routinely using ordinary biopsy needles we save both time and money.

Procedure time varies with lesion size, location and especially number. In the majority of our cases a door-to-door time of 30 minutes is achieved, but since somewhat longer procedures do occur quite regularly, we currently schedule 40 minutes per patients.

Experiences

Patients generally tolerate the procedure very well. The prone position can become somewhat uncomfortable for the shoulders, but due to predominantly short procedure times this rarely creates significant problems.

Learning to use the RCM system has been quite easy and right from the start we have been able to perform accurate biopsies. Obtaining short procedure times required some experience for both radiologists and technologists, but was achieved rather quickly.

All our targets have been reachable with the system. Biopsy precision is logically dependent on the operator's ability to correctly identify the target and readiness to aim accurately, but the RCM enables the operator to achieve a very high level of precision. In our experience, even the smallest of targets, in all locations in the prostate, are consistently hit (e.g. Case 1).

In approximately 85% of our biopsy cases cancer is found. In the benign cases the mpMRI findings are usually equivocal and the confident needle positioning routinely allows for considering the benign histology to be representative.

In addition to high detection rates, we experience three further important advantages of the high accuracy. First, targeting of more than one lesion and precise targeting of the tumor center or intratumoral areas suspicious of higher-grade cancer regularly generates higher final Gleason scores (Case 2). Second, the technique clarifies mpMRI findings, which increases to total accuracy of the diagnostics. Third, concise learning feedback to the diagnostic imaging is generated, which is highly valuable given the evolving pivotal role of mpMRI in clinical management of probable prostate cancer.

Conclusions

The RCM facilitates targeted MR-guided biopsies of the prostate with very high precision and confidence in a time-efficient manner. Providing high-quality diagnostic mpMRI,

Case 1

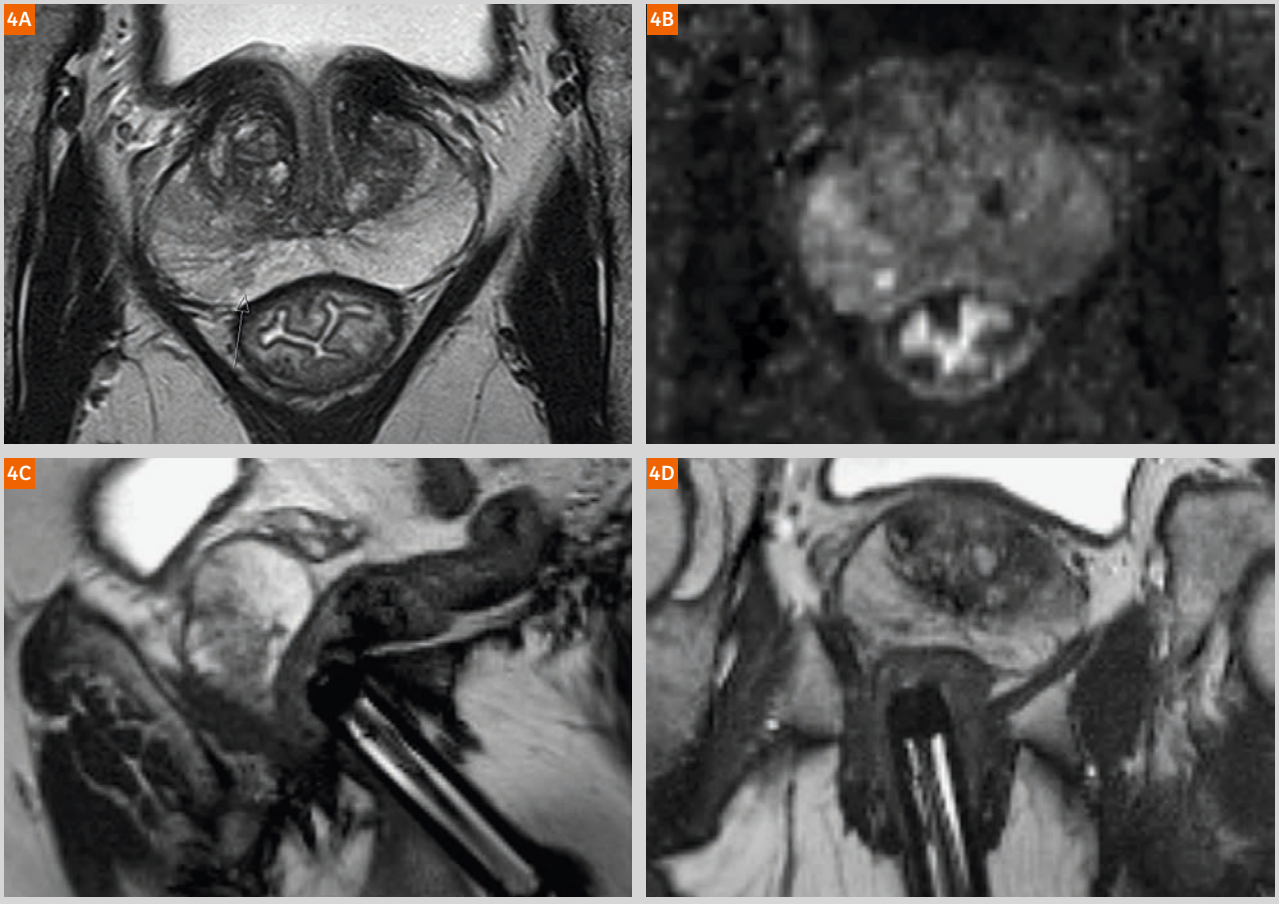

Figure 4: 65-year-old patient with PSA level 4.4.

Diagnostic mpMRI showed a 3 mm highly tumor suspicious lesion in the peripheral zone of the right midgland and additionally typical prostatitis changes anterolaterally mainly on the right side.

MR-guided biopsies revealed prostate cancer Gleason grade 4+3.

4A) Diagnostic mpMRI, transversal TSE T2w.
4B) Diagnostic mpMRI, transversal calculated b1500 images (RESOLVE diffusion).
4C) TrueFISP sagitally along the axis of the biopsy needle guide pointing at the target.
4D) TrueFISP transversally along the axis of the biopsy needle guide pointing at the target.

this allows for routine application of a one-stop, definitive biopsy strategy that aims at accurately mapping prostate cancer. Our center performs RCM-biopsies whenever they are expected to outperform TRUS-biopsies in the challenging task of detecting and delineating the clinical significance of prostate cancer, i.e. in the majority of our patients. With this, the system has revolutionized our practice and empowered us to improve and further develop stratification of our patients. A hope for the future is that improvements in histological grading and molecular testing of tumor tissue [6, 7], combined with optimized biopsies, will lead to further improvements in prognostication.

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Case 2

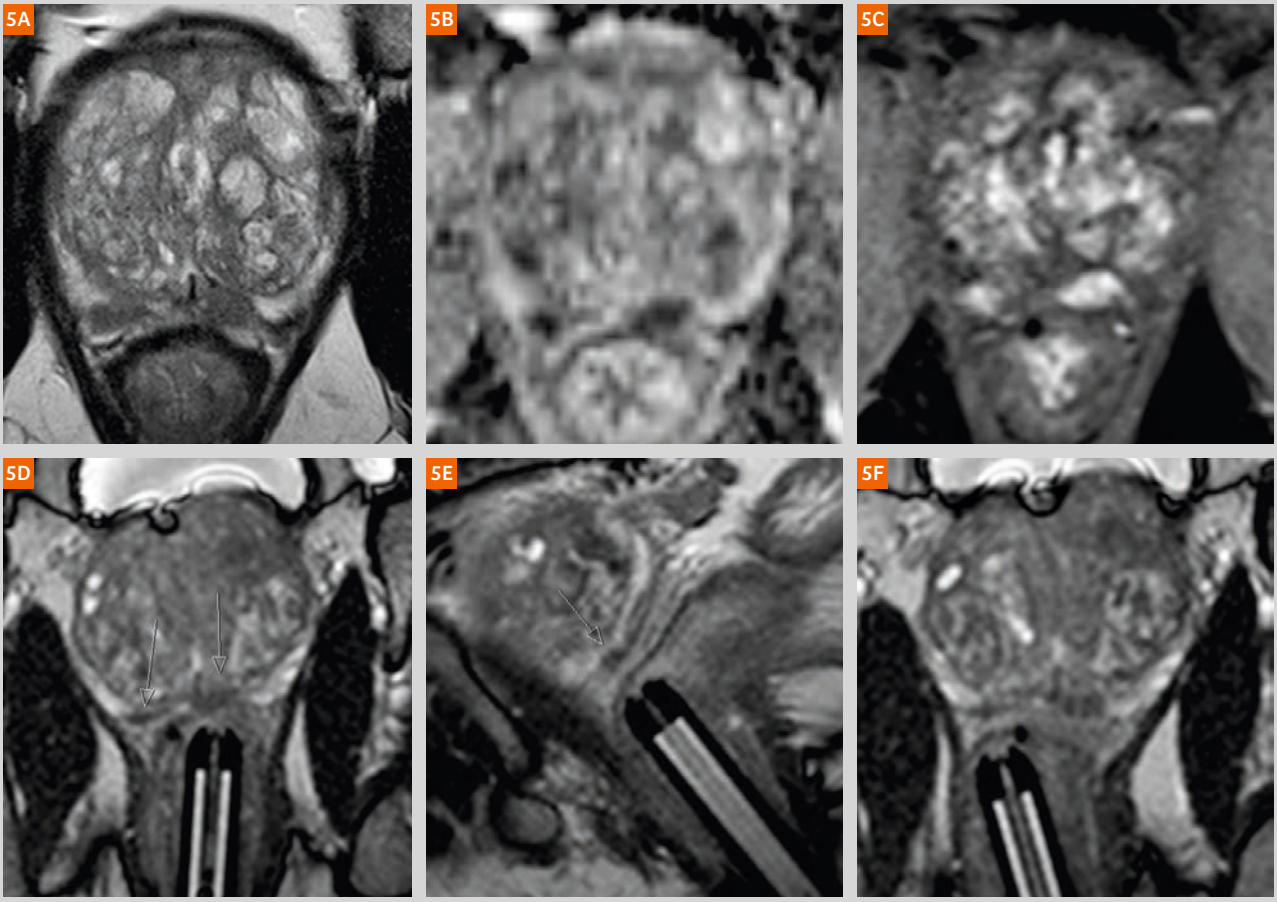

Figure 5: 63-year-old patient with PSA level 6.0, referred to our center for MR-guided biopsies after negative MR-US Fusion-guided biopsies at an external institute.

Diagnostic mpMRI showed a large prostate (estimated volume 128 ml) and apically bilateral relatively small, but highly tumor suspicious lesions.

Both lesions were targeted with MR-guided biopsies. Histology revealed prostate cancer Gleason grade 4+3 on the left side and Gleason grade 4+5 on the right side.

5A) Diagnostic mpMRI, transversal TSE T2w.
5B) Diagnostic mpMRI, transversal ADC map (RESOLVE diffusion).
5C) Diagnostic mpMRI, initial contrast uptake phase of transversal DCE (Twist VIBE).
5D) TrueFISP transversally along the axis of biopsy needle guide pointing at the target on the left side.
5E) TrueFISP sagittaly along the axis of the biopsy needle guide pointing at the target on the right side.
5F) TrueFISP transversally along the axis of the biopsy needle guide pointing at the target on the right side.

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Case 3

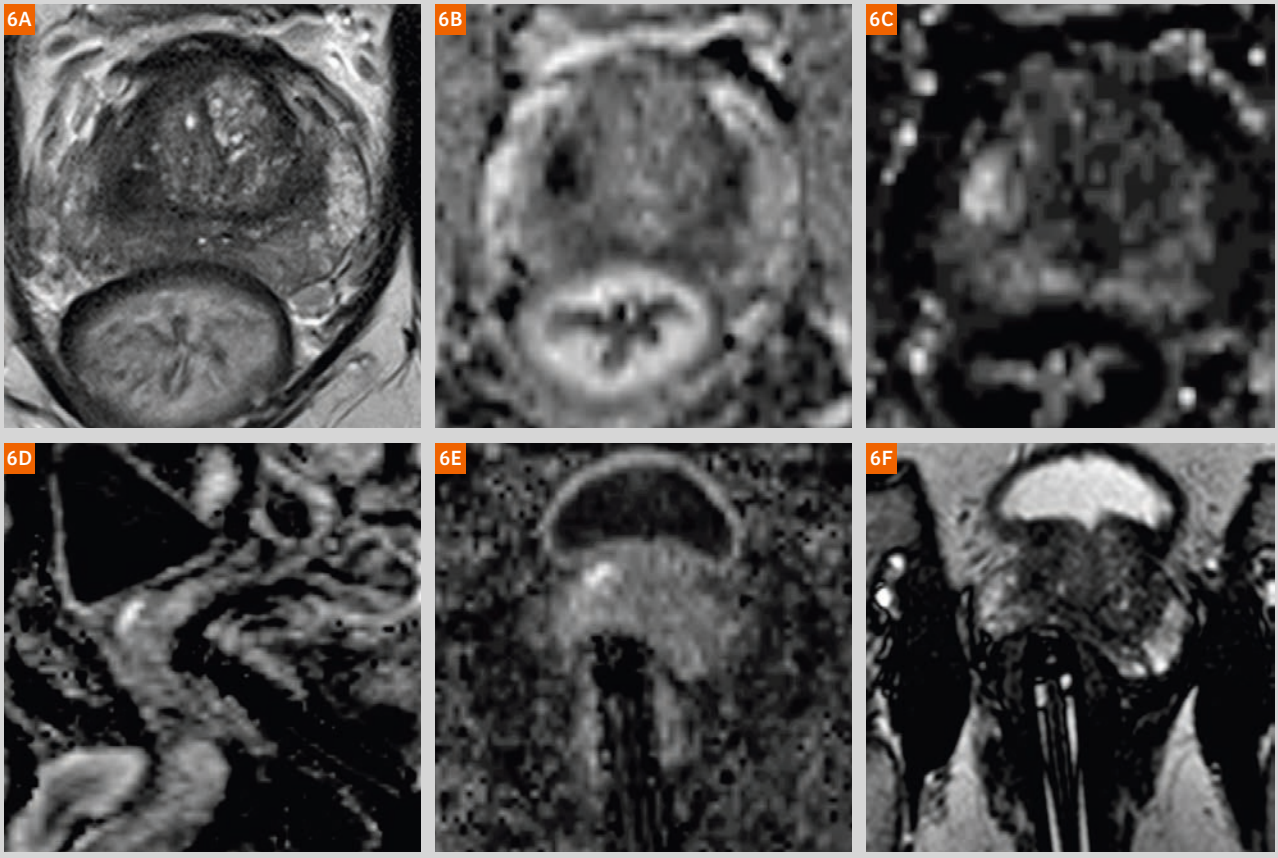

Figure 6: 63-year-old patient with PSA level 5.3.

Diagnostic mpMRI showed an 8 mm tumor suspicious lesion in the transitional zone of the right basal gland.

During the MR-guided biopsy procedure the lesion was hard to localize on TrueFISP and TSE T2 images, but possible to target confidently with the use of diffusion-weighted images.

Histology revealed prostate cancer Gleason grade 3+4.

6A) Diagnostic mpMRI, transversal TSE T2w.
6B) Diagnostic mpMRI, transversal ADC map (RESOLVE diffusion).
6C) Diagnostic mpMRI, transversal calculated b3000 images (RESOLVE diffusion).
6D) Calculated b1500 images (RESOLVE diffusion) sagittaly along the axis of the biopsy needle guide pointing at the target.
6E) Calculated b1500 images (RESOLVE diffusion) transversally along the axis of the biopsy needle guide pointing at the target.
6F) TrueFISP transversally along the axis of the biopsy needle guide pointing at the target.

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