Eur J Med Res (2008) 13: 287-291

MR Imaging of the Prostate at 3.0T with External Phased Array Coil – Preliminary Results

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Abstract
Introduction: Among all imaging modalities, MRI of the prostate has the highest sensitivity to predict extracapsular tumor spread, seems to have added value for the preoperative treatment planning. It is an adjunct tool in patients with high suspicion of prostate cancer and so far negative TRUS-guided biopsies. Due to the higher intrinsic signal, it is expected that 3.0T enables to image the prostate without endorectal coil. Aim of this study was to evaluate the diagnostic accuracy of phased array coil 3.0T MRI in patients with suspicion of prostate cancer.
Material and methods: A high spatial resolution T2-w 3.0T pulse sequence (0.47 x 0.47 x 3mm voxel size) was performed in 26 patients prior to US-guided biopsy.

Qualitative analysis comprised visual signal to noise, tissue contrasts and motion artifacts. MR diagnoses were correlated with histology. Diagnostic indices for the detection of prostate cancer in the peripheral zone were calculated.
Results: Histopathologic examination revealed prostate cancer in 12 and benign prostate disorders in 14 patients. Motion artifacts due to peristalsis were rated moderate. Mean visual signal to noise was high. Contrast between peripheral and central zone of the prostate was excellent. MRI had 4 false negative and 2 false positive diagnoses (sensitivity 66.7 %, specificity 86.7 % diagnostic accuracy 76.9%).
Conclusion: At 3.0T, diagnostic indices for cancer detection seem to be comparable to data reported about endorectal 1.5T MRI. Thus 3.0 T offers new options for MR imaging of the prostate in selected patients who cannot or are not willing to be examined with the endorectal coil.

Introduction

Among all imaging modalities, MRI of the prostate has the highest sensitivity to predict extracapsular tumor spread and seems to have added value for the preoperative treatment planning [1-9]. It should be used as adjunct tool in patients with high suspicion of prostate cancer and so far negative TRUS-guided biopsies [10, 11, 12].

Because high spatial resolution is required, the application of endorectal coils is considered essential at 1.5T.

However endorectal coil MRI has limitations. It is not recommended very soon after radiation therapy, is not feasible after rectum resection. In addition, some patients refuse endorectal MRI because of discomfort.

Nowadays, high field scanners are available. Due to the higher intrinsic signal, it is expected that 3.0T enables to image the prostate without endorectal coil.

The aim of this study was to evaluate the image quality and the diagnostic accuracy of prostate MRI at 3.0T with a phased array coil in patients with clinical suspicion of prostate cancer.

We prospectively analyzed the image quality of an axial T2-weighted TSE sequence with high spatial resolution and correlated the MR imaging diagnoses with twelve core TRUS-guided biopsy.

Material and Methods

Study design

Between October 2004 and May 2005, we performed a prospective study on patients who were referred for MR imaging of the prostate with clinically suspected prostate cancer (elevated PSA level: > 4 ng/ml or abnormal digital rectal examination) prior to twelve core TRUS-guided biopsy. Biopsy was performed in all patients regardless of the MR imaging diagnosis, i.e. also if MRI did not detect prostate cancer. The study design was approved by our institutional review board and all 26 patients provided informed consent.

Patients

We included twenty-six consecutive patients (age range: 56 - 75 years, mean age: 67 years; SD: 5 years).

MR imaging technique

Studies were performed on a clinical 3.0T MR scanner (Intera 3.0T, Philips Medical Systems, Best, The Netherlands; maximal gradient amplitude: 30 mT/m; slew rate: 150 T/m/sec and Archiva 3.0T, maximal

gradient amplitude: 80 mT/m; slew rate: 200 T/m/sec) equipped with a transmit-receive quadrature body coil. Pelvic imaging was performed with a six-channel-phased-array receive-only surface coil. A REST (Regional saturation technique) was placed on the anterior abdominal wall to minimize ghosting artifacts. The MR sequence was based [13] on a high spatial resolution protocol for female patients (7:53 min scan time; 0.47 x 0.47 x 3mm voxel size, TR/TE 3756 ms/70 ms, 30 slices with 3 mm slice thickness). In order to *reduce the radiofrequency energy deposition*, the T2-weighted TSE sequence [13] was combined with parallel imaging (SENSE, SF 3) and variable refocussing angle technique (FAS 130°) [14]. Spatial resolution at 3.0T was 0.66 mm^3 which is comparable to endorectal MRI at 1.5T (0.66 -1.12 mm^3 voxel size) [15, 16].

Image Analysis

Two radiologists (MPW, NM) analyzed the MR images (consensus).

In order to evaluate the image quality, signal to noise, tissue contrasts and artifact level were analyzed.

First, *signal-to-noise* was evaluated with regard to delineation of anatomic details (prostate capsule and seminal vesicles). As described in previous publications [17, 18], we performed a mere *qualitative analysis of signal-to-noise* using a *3 point scale as described in* [17, 18]. We assigned *three points* if visual signal was rated excellent, two points if visual signal to noise was rated moderate and *one point* if signal to noise was rated *poor* resulting in a non-diagnostic study.

Analysis of *tissue contrasts* on the T2-w MR images was performed qualitatively. We evaluated if the central and peripheral zone of the prostate could be differentiated (*3 point scale* with 3 = excellent, 2 moderate, yet diagnostic study, 1 = poor = non-diagnostic study).

The *degree of artifacts* due to ghosting of the abdominal wall and peristalsis was analyzed in consensus (MPW, NM) *using a five point scale as described in* [18].

One point was assigned if no artifacts were present. *Two points* were assigned in case of minor artifacts, *three points* were assigned in case of *moderate* (not diagnostically relevant) artifacts. *Four points* were assigned in case of stronger artifacts (*diagnostically relevant*), *five points* were assigned in case of severe artifacts (*non-diagnostic study*).

To assess the diagnostic accuracy, we correlated the *final MR imaging diagnoses* with histology and calculated the *diagnostic indices* for the detection of prostate cancer.

Only prostate cancer in the peripheral zone was assessed. To diagnose prostate cancer the same criteria were applied that are in use for clinical MR imaging of the prostate at 1.5 T [4, 10, 16, 19, 20]. The results of TRUS-guided biopsy were used as standard of reference.

Statistical Analysis

For statistical analysis, the SPSS software package (SPSS, Inc.) was used to calculate mean values, standard deviations and the diagnostic indices.

Results

Based on TRUS-guided biopsy, twelve (12/26) patients had a diagnosis of prostate cancer (Fig. 1) and fourteen (14/26) patients had benign prostate disorders such as prostatitis and benign prostate hyperplasia (BPH).

3T phased-array MRI of the prostate was technically successful in all 26 patients.

With regard to the *artifact level*, only minimal to moderate artifacts caused by motion of the abdominal

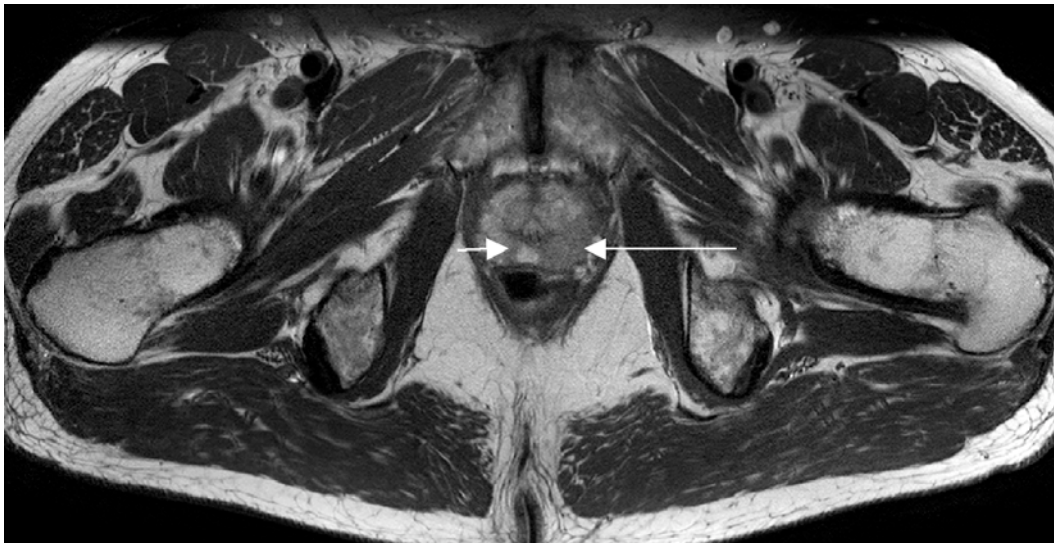

Fig. 1. Fifty-year-old patient with clinical suspicion of prostate cancer in the left prostate (suspicious TRUS, DRE and elevated PSA level (14.9 ng/ml). MRI shows an area of diffuse reduced signal intensity in the left (long arrow) and a focal area of reduced signal intensity in the right peripheral zone (short arrow) highly suggestive for multifocal prostate cancer. TRUS-guided biopsy confirmed the diagnosis of prostate cancer in both locations. Please note the excellent differentiation between the central and the normal peripheral zone and the good discrimination of the hypointense area in the peripheral zone. Visual signal to noise was rated excellent, motion artifacts were absent.

wall or peristalsis were observed (mean 2.23 ± 0.65; range 1-3).

The mean *visual signal to noise* and thus delineation of anatomic details (prostate capsule and seminal vesicles) was rated almost excellent (2.77 ± 0.43; 2-3).

With regard to *tissue contrast*, qualitative analysis provided excellent (mean: 3 points in all ratings) discrimination between the central and normal peripheral zone of the prostate in all 26 patients.

With regard to the *diagnostic indices*, MRI had eight true positive, twelve true negative, two false positive diagnoses in patients with a focal prostatitis and four false negative diagnoses in patients with carcinomas. This resulted in a sensitivity of 66.7% (8/12), a specificity of 86.7% (12/14), a positive predictive value (PPV) of 80% (8/10), a negative predictive value (NPV) of 75% (12/16) and an overall diagnostic accuracy of 76.9% (20/26) for the diagnosis of prostate cancer.

Discussion

Recently, the advantages of high field strength for MR imaging of the female pelvis have been reported [13, 17, 18]. It has been demonstrated that technical aspects such as susceptibility, chemical shift artifacts, altered relaxation times and SAR limits do not affect MR imaging of the female pelvis. Furthermore, a large homogeneous field of view is feasible and motion artifacts can be minimized with the use of n-butyl-scopolamine or fast MR sequences [18].

The higher intrinsic signal at 3.0T allows to increase spatial resolution as compared to 1.5T thus improving tumor staging [13]. At 1.5T, the use of endorectal coils is regarded essential for MR imaging of the prostate in order to achieve high spatial resolution. However, endorectal coils do have some drawbacks and contraindications. Major disadvantages are the reduced patient comfort, increased cost [6, 21] and increased vulnerability to motion artifacts from peristalsis. Signal nonuniformity can be dealt with by employing surface coil intensity correction algorithms [22]. Endorectal coils are contraindicated in patients shortly after surgery or radiation therapy to the pelvis [23], certain patients refuse or cannot be examined with (e.g. patients after rectum resection) the endorectal coil. Furthermore, endorectal prostate MRI always requires an additional scan with a surface coil or the body coil in order to cover a larger FOV for staging purposes. Meanwhile, several publications have dealt with 3T MRI of the prostate [15, 16, 21, 24-26].The initial results have shown that 3.0 T enables high spatial resolution MR imaging of the male pelvis with good delineation of anatomic structures. Due to the high intrinsic signal at 3.0T, phased array coils seem to provide an image quality comparable with that of endorectal 1.5T MR imaging [21]. The authors did not detect a significant difference in the subjective assessment of the posterior border of the prostate, seminal vesicles and neurovascular bundles [21] comparing 3T phased array MRI and 1.5T endorectal MRI. However, this study [21] did not evaluate the prostate cancer detection at 3.0T, therefore data on the diagnostic accuracy were not available.

The aim of this study was to evaluate the image quality and the diagnostic accuracy of prostate MRI at 3.0T with a phased array coil in patients with clinical suspicion of prostate cancer.

We evaluated a modified high spatial resolution T2-weighted TSE sequence that is also in use for MR imaging of the female pelvis in our institution. To assess if this pulse sequence yielded *diagnostic image quality* in the male pelvis , we analyzed the visual signal to noise, motion artifact level of peristalsis and tissue contrasts of anatomic structures.

The results of this study are in accordance with data obtained with MR imaging of the female pelvis [13]. The high spatial resolution TSE sequence was *technically successful* in all 26 male patients. Our data show that 3.0T enables to image the prostate with high image quality using a surface coil. *Visual signal to noise* was rated almost excellent which is the basis for an adequate detectability of anatomical details. The *artifact level* was only minimal to moderate. Despite the use of the FAS technique, *tissue contrasts* remain familiar in the male pelvis which can be regarded as prerequisite for the detection of prostate disorders. To evaluate the *diagnostic potential* of the 3.0T high-spatial resolution sequence without use of an endorectal coil we analyzed the detectability of prostate cancer in the peripheral zone and calculated the diagnostic indices for prostate cancer in the peripheral zone. As our data show, diagnostic indices at 3.0 T were in the range of data reported about endorectal 1.5T MRI. In our study, sensitivity for cancer detection was 66.7 %, specificity was 86.7% as compared to sensitivity values of 51%-89% and specificity values for cancer detection of 67%-87% at 1.5T [27]. 3.0T MRI had two false positive diagnoses in patients with focal prostatitis. It has to be stated that this differential diagnosis is difficult with endorectal 1.5T prostate MRI also, because an area of low signal in the peripheral zone is not highly specific for prostate cancer but may occur with benign disorders also. On the other hand, 3.0T MRI had four false negative diagnoses, the same difficulties are known for 1.5T endorectal MRI.

We want to emphasize that we did not exclusively include patients who could not be examined with endorectal MRI, but consecutive patients with clinical suspicion of prostate cancer. At the time, this study was undertaken, we did not possess an endorectal coil. Because the role of phased array 3.0T prostate MRI was not yet defined, the MR imaging diagnoses did not alter the therapeutic approach. This was explained to the patients prior to the MR examination.

Meanwhile our data have been confirmed by Kim [28] who report a sensitivity of 55 %, a specificity of 88 % and diagnostic accuracy of 70 % for prostate cancer detection at 3.0T with use of T2-w MR images and a surface coil. Toricelli [29] report comparable data for the preoperative staging with external phased array coil 3.0 T MRI of biopsy-confirmed prostate cancer.

In addition, meanwhile the potential of endorectal prostate MRI at 3.0T has been evaluated[25,26]. It has been demonstrated that with the additional use of an endorectal coil spatial resolution at 3.0T may be fur-

ther improved resulting in high accuracy for local staging of prostate cancer [25] also with regard to the detection of minimal capsular invasion. The results of the aforementioned study lead us not to advocate the general use of surface coils alone for MR imaging of the prostate at 3.0T.

Our study has several *limitations*. Because data analysis was performed in consensus, we are not able to provide data for interobserver variability. Our data lack an absolute standard of reference since diagnosis of prostate cancer was not based on *whole-mount prostatectomy specimens* but on TRUS-guided biopsy. Therefore we were not able to provide data on local tumor staging, i.e. we could not appreciate if phased array coil 3.0T MRI enabled tumor staging. Meanwhile this issue has been addressed by Toricelli et al [29] who assume that phased array coil 3T MRI will provide comparable diagnostic information to endorectal 1.5T MRI during preoperative staging despite a slightly worse image quality at 3.0T. Moreover, it is conceivable that with the availability of whole-mount prostatectomy specimens diagnostic indices of prostate MRI might differ due to the possibility of false negative TRUS-guided biopsy. In addition, we did not perform an intraindividual comparison between endorectal 1.5T MRI and 3.0T phased array coil MRI.

Future studies should also address the value of the additional use of MR spectroscopy and of dynamic contrast-enhanced MRI of the prostate.

CONCLUSION

Our data confirm that 3.0 T enables high spatial resolution MRI of the prostate with high image quality without use of an endorectal coil. Diagnostic indices for cancer detection seem to be in the range of data reported at 1.5T. Thus 3.0 T offers new options for MR imaging of the prostate in patients who cannot or are not willing to be examined with the endorectal coil.

Disclosures - Conflicts of interest:
One of the authors also worked for Philips Medical Systems (Best, the Netherlands). Authors who are not employees of or consultants for Philips Medical Systems had control of inclusion of any data and information that might present a conflict of interest for the author who is employee of or consultant for that industry.

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Received: August 11, 2007 / Accepted: May 19, 2008

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