Multiparametric 3-Tesla MRI using a phased-array coil for preoperative local staging of prostate cancer: utility of the 3D T2-weighted sequence

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Aims and objectives

Prostate cancer remains a major health concern among the male population. Local staging of prostate cancer plays an important role in planning treatment and predicting prognosis. Magnetic resonance imaging (MRI) is increasingly being used and recommended for prostate cancer (PCa) staging. Knowledge of the presence and localization of extracapsular extension (ECE) of prostate cancer is an essential requirement for choosing the optimal therapeutic strategy for the individual patient and select patients eligible for nerve sparing procedures for radical prostatectomy (RP). Surgical margin status is an important prognostic factor for biochemical recurrence following RP and the only factor to be influenced by surgical method and nerve sparing strategies.

Endorectal coil MRI has been widely accepted as the best imaging modality in the preoperative local staging of prostate cancer due to higher spatial and contrast resolution, improving image quality [1-8]. However, endorectal coil system requires more time, involves higher costs, and can causes greater discomfort in the patient; even further, it cannot be performed in patients with prior anorectal surgery, inflammatory bowel disease, and high anal sphincter tone. In recent years, higher magnetic field system such as 3.0 Tesla (3-T) MRI system has become widely used in the routine clinical setting. The increased signal-to-noise ratio (SNR) of 3.0-T MRI can improve the spatial or temporal resolution of phased-array coil MRI. Three studies have reported that 3.0-T phased-array MRI showed the similar diagnostic performance of local staging prostate cancer relative to 1.5 Tesla (1.5-T) endorectal MRI [9-11].

Prostate MRI is routinely performed with a 3-4 mm slice thickness of a 2D T2-weighted imaging (T2WI) with in the axial, coronal, and sagittal planes through the prostate to maximize delineation of the presence and location of tumor foci and for assessment of local tumor staging. MRI acquisition with a higher spatial resolution would thus be desirable to improve accuracy of local staging. A 3D T2-weighted sequence is now available on most recent MRI equipments and has been used with a pelvic-array coil to acquire 1 mm thick 3D T2-weighted image data sets for prostate imaging with relatively time-consuming [12,13]. A possible way to reduce imaging time would be to perform a single 3D acquisition and retrospectively reconstruct the data in multiple separate planes.

Therefore it can be hypothesized that 3D high resolution 3-T MRI with phased-array coil may constitute a valid alternative technique to 3-T endorectal MRI in the preoperative local staging accuracy of prostate cancer. The purpose of this study is to evaluate the diagnostic accuracy of multiparametric, 3-T MRI using phased-array coil for the
preoperative detection and extraprostatic extension of prostate cancer and to clarify the utility of 3D high spatial resolution T2WI by comparison with 2D conventional T2WI.
Methods and materials

Patients

Between December 2009 and December 2013, 216 consecutive patients presenting with a clinically localized prostate cancer (clinical stage #T3) prospectively scheduled for radical prostatectomy (RP) underwent a 3.0-Tesla (3-T) MRI examination in our hospital. Our prospective study was approved by our institute's ethics committee, and written informed consent was obtained.

Twenty-nine patients were excluded for having received androgen deprivation therapy before surgery (n=14) or radiation therapy instead of surgery (n=3). The remaining 199 patients formed the study group (Table 1). The mean patient age was 66 years (range 49-77). The median serum prostate specific antigen (PSA) level was 7.3 (range 3.33-24.2). The median number of days between biopsy and MRI, and MRI and RP were 81 (range=43-258) and 23 (range=1-97), respectively.

MRI protocol

MRI was performed at least 6 weeks after biopsies to minimize biopsy artefacts related to hemorrhage. All patients underwent MR images obtained with 3-T magnet (Achieva QuasarDual; Philips Medical Systems, Best, The Netherlands) with phased-array coil (six-channel cardiac coil). An endorectal coil was not used. Peristalsis was suppressed with intramuscular administration of 20 mg of scopolamine butylbromide (Buscopan; Boehringer Ingelheim, Yamagata, Japan) or 1 mg of glucagon (Glucagon-G Novo; Eisai Co. Ltd., Tokyo, Japan). Multiparametric MR imaging including T2WI, diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI) and dynamic contrast-enhanced imaging (DCEI) were scanned.

Two different (2D and 3D) turbo spin echo (TSE) T2WI, covering the entire prostate gland and seminal vesicle were acquired in axial plain. 2D T2WI were performed with the following parameters: repetition time (TR), 4000 msec; echo time (TE), 130 msec; flip angle (FA), 90 °; slice thickness, 3 mm; imaging matrix, 256x256; field of view (FOV), 200; number of signals averaged (NSA), 3; parallel imaging factor, 2; voxel size, 0.78x0.78x3.0 mm; scan duration time, 3 min 40 s. 3D T2WI were performed with the following parameters: TR, 1500 msec; TE, 141 msec; FA, 90 °; slice thickness, 1.1 mm; imaging matrix, 320x320; FOV, 220; NSA, 3; parallel imaging factor, 2; voxel size,
0.69×0.69×1.1 mm; scan duration time, 6 min. Additional coronal TSE T2WI was acquired with voxel size, 0.78×0.78×3.0 mm and scan duration time, 3 min 40 s.

DWI was obtained along three orthogonal directions using spin-echo type single-shot echo planar imaging with the following parameters: TR, 4000 msec; TE, 65 msec; FA, 90 °; voxel size, 3.13×4.05×3 mm; imaging matrix, 128×102; FOV, 450; NSA, 3; parallel imaging factor, 3. From December 2009 to September 2012, b-values were 0, 1000, 2000 s/mm² and the scan acquisition time was 3 min 20 s. From October 2012 to December 2013, b-values were 0, 50, 100, 200, 500, 1000, 2000, 3000 s/mm² and the scan acquisition time was 4 min 30 s. Although FOV differs, T2WI and DWI were obtained at the same slice location and direction.

DCEI was performed with nonfat-suppressed 3D-fast field echo (FFE) sequence with following parameters: TR, 3.8 msec; TE, 2.2 msec; voxel size, 3.13×3.13×4 mm ; FOV, 300 (From December 2009 to August 2012) and TR, 2.4 msec; TE, 0.88 msec; voxel size, 3.13×3.13×4 mm ; FOV, 400 (From September 2009 to December 2013). Contrast agent (Meglimine gadoterate, Magnescope, Guerbet, Tokyo, Japan), a concentration of 0.1 mmol/kg of body weight, was injected at a rate of 2.0 mL/s using power injection pump (Spectris Solaris EP, Nihon Medrad K.K., Osaka, Japan). After contrast agent injection, a 20-mL saline flush at the same injection rate followed immediately.

MRI interpretation

One experienced board-certificated genitourinary radiologist with 11 years of prostate MRI experience, who had no knowledge of either the histopathologic findings or the clinical data, retrospectively analyzed the images using two interpretation protocols. Protocol A is a combination of axial and coronal 2D T2WI, DWI, and DCEI. Protocol B is a combination of axial 3D T2WI and reconstructed multiple separate planes, DWI, and DCEI. Each dataset was reviewed with a minimum interval of 1 month to avoid any decision threshold bias due to reading-order effects. They evaluated preoperative tumor staging in terms of the presence or absence of tumor, extracapsular extension (ECE), and seminal vesicle invasion (SVI) with a five-point rating scale: 5, definitely present; 4, probably present; 3, possibly present; 2, probably absent; 1, definitely absent.

The presence of ECE was evaluated on the basis of specific features described in the literature as being highly indicative of extra-prostatic disease [1-15]. Criteria for ECE included (1) capsular irregularity, (2) bulging of the capsule, (3) capsular retraction, (4)
obliteration of the recto-prostatic angle, (5) extracapsular tumour, (6) enhancement of an extracapsular tumour, (7) asymmetry or direct involvement of the neuro-vascular bundles, and (8) asymmetric enhancement of neurovascular bundles. Additionally, the following criteria were defined for seminal vesicle invasion (SVI): (1) focal low signal intensity mass within the lumen, (2) focal wall thickening, (3) asymmetric enhancement within the lumen.

**Statistics**

The comparison between MRI and histopathology was performed on a per patient basis. Diagnostic accuracy for assessing tumor detection, the detection of ECE and SVI was compared between two protocols (2D versus 3D T2WI).

To estimate each protocol's ability to detect ECE and SVI of prostate cancer, receiver operating characteristic (ROC) analysis was used. An ROC contrast estimation was used to compare the diagnostic capability of protocols A and B on a per-patient basis. To test if the area under the ROC curves (AUC) were different the correlation of the testing protocols was accounted for in the analysis. Tests for differences in sensitivity, specificity, and accuracy between two protocols were conducted with the McNemar test. To calculate the sensitivity and specificity of each protocol, scores of 4 and 5 were considered positive. A p value less than 0.05 was considered to indicate a statistically significant difference for all analyses. Statistical analysis was performed using SAS software version 9.3 (SAS Institute, Cary, NC).
Results

Of the 199 individuals enrolled in the study, Pathologic examination of the surgical specimens revealed that 143 (71.9%) patients had disease confined to the prostate (pT2) and 56 patients (28.1%) had locally advanced disease (pT3). The stages were listed as follows: pT2a (n=97); pT2b (n=7); pT2c (n=39); pT3a (n= 47); pT3b (n= 9). ECE and SVI were observed in 52 patients (26.1%) and 9 (4.5%), respectively.

14 patients (7%), whose no tumor could be identified on both protocols, are excluded from the analyses. There was no case whose tumor could be detected only by either protocol. Among 185 patients, histology showed ECE and SVI in 52 (28%) and 9 (5%) cases, respectively.

The sensitivity, specificity, accuracy, and Az for ECE were 32.7% (17/52), 94.7%, (126/133) 77.3% (143/185), and 0.73 for protocol A and 63.5% (33/52), 90.2% (120/133), 82.7% (153/185), and 0.82 for protocol B, respectively. The sensitivity, accuracy and Az of protocol B were significantly better than protocol A (p=0.00018, p=0.0044, p=0.0002).

The sensitivity, specificity, accuracy, and Az for SVI were 66.7% (6/9), 98% (172/176), 96.2% (178/185), and 0.86 for both protocols.

Figure Legends

Case 1 Stage T3a (extracapsular extension) carcinoma of the prostate in 66-year-old man with a PSA level of 6.75 ng/ml.

Fig1. Axial conventional 3 mm-thick 2D T2-weighted FSE 3-Tesla MR image (0.78×0.78×3 mm) with phased-array shows low signal-intensity area at the right peripheral zone. The grade of protocol A was 3 for extracapsular extension.

Fig 2. Corresponding axial 1.1 mm-thick 3D T2-weighted FSE 3-Tesla MR image (0.69×0.69×1.1 mm) with phased-array shows low signal-intense extracapsular mass at the right peripheral zone, defining extracapsular extension (the grade of the protocol B was 5).
Fig 3. Histopathological finding (HE) of resected specimen shows tumor with capsular penetration.

Case 2 Stage T3b (seminal vesicle invasion) carcinoma of the prostate in 71-year-old man with a PSA level of 5.38 ng/ml.

Fig 4. Axial conventional 3 mm-thick 2D T2-weighted FSE 3-Tesla MR image (0.78×0.78×3 mm) with phased-array shows low signal-intensity area at the left seminal vesicle, suggesting seminal vesicle invasion. The grade of protocol A was 5 for seminal vesicle invasion.

Fig 5. Corresponding axial 1.1 mm-thick 3D T2-weighted FSE 3-Tesla MR image (0.69×0.69×1.1 mm) with phased-array shows low signal-intensity area at the left seminal vesicle, suggesting seminal vesicle invasion. The grade of protocol B was 5 for seminal vesicle invasion.

Fig 6. Axial DWI shows abnormal signal intensity of the left seminal vesicle, reflecting restricted diffusion.

Fig 7. Axial dynamic contrast enhanced imaging shows the localized enhancement of the left seminal vesicle.

Fig 8. Histopathological finding (HE) of resected specimen shows tumor with seminal vesicle invasion.
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**Fig. 8:** Histopathological finding (HE) of resected specimen shows tumor with seminal vesicle invasion.

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Conclusion

Our work shows that multiparametric, phased-array 3-T MRI using 3D high resolution T2WI was reasonably accurate in terms of prostate cancer detection and local staging accuracy. Statistically validated comparative prospective studies alone will be able to evaluate whether the technique can be considered an alternative to the MRI staging techniques using endorectal coils.
References


