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Diffusion-weighted imaging in the assessment of prostate cancer: Comparison of zoomed imaging and conventional technique

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ABSTRACT

Purpose: To compare reduced field-of-view (zoomed) diffusion-weighted imaging (DWI) and conventional DWI in the evaluation of prostate cancer with respect to lesion detection, image quality and alignment accuracy.

Material and methods: The study was carried out in accordance with the Declaration of Helsinki and was approved by the institutional review board. Image data of 29 histology-proven prostate cancer lesions in 15 patients were evaluated. All patients underwent both conventional DWI and zoomed DWI at 3 T. Zoomed DWI and conventional DWI sequences were analysed qualitatively and quantitatively. Subjective image quality, visual distortion and presence of artefacts were rated on a 5-point Likert scale (1 = excellent) by two readers in consensus. Lesion conspicuity, sensitivity and specificity in lesion detection were evaluated and compared for both DWI sequences using ROC curves and area under the curve (AUC). To analyze the geographic distortion in DWI the alignment accuracy of prostate and lesions was measured in three spatial dimensions referring to the T2-weighted anatomical images as reference. In a region of interest (ROI) evaluation, ADC values were measured in prostate tissue and malignant lesions. Comparison of qualitative and quantitative parameters was performed using Wilcoxon test with subsequent Bonferroni correction.

Results: Subjective image quality was rated significantly higher in zoomed DWI compared to conventional DWI (2.1 ± 0.9 vs. 2.7 ± 0.9; $p = 0.0375$). Visual distortion and artefacts were reduced in zoomed DWI without reaching statistical significance (1.8 ± 0.7 vs. 2.4 ± 1.0 and 2.1 ± 1.0 vs. 2.5 ± 1.0). Sensitivity and specificity of zoomed and conventional DWI were not significantly different. Zoomed DWI had a slightly higher AUC compared to conventional DWI without significant difference (0.82 versus 0.78; $p = 0.0576$). Lesion conspicuity did not significantly differ between zoomed DWI and conventional DWI (1.8 ± 0.8 vs. 1.9 ± 1.0; $p = 0.8523$). The alignment accuracy of zoomed DWI was significantly higher regarding both the prostate gland and lesions (deviation of outer contours of lesions in sagittal plane: 3 ± 4 mm vs. 5 ± 3 mm; $p = 0.0008$). ADC tended to be higher in zoomed DWI without statistical significance (ADCmean in peripheral zone: $1.7 \pm 0.2 \times 10^{-3}$ mm^2/s vs. $1.5 \pm 0.4 \times 10^{-3}$ mm^2/s; ADCmean in lesion: $1.0 \pm 0.71 \times 10^{-3}$ mm^2/s vs. $0.8 \pm 0.2 \times 10^{-3}$ mm^2/s).

Conclusions: Zoomed technique offers improved image quality for diffusion-weighted imaging of the prostate with reduced image distortion both for the whole gland as well as for cancer lesions and at least comparable diagnostic performance. The zoomed technique could be useful for multiparametric tissue characterization but also for biopsy and radiation therapy planning.

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1. Introduction

Prostate cancer is the third most common cause of death in men in Europe [1]. Multiparametric MRI is nowadays an accepted

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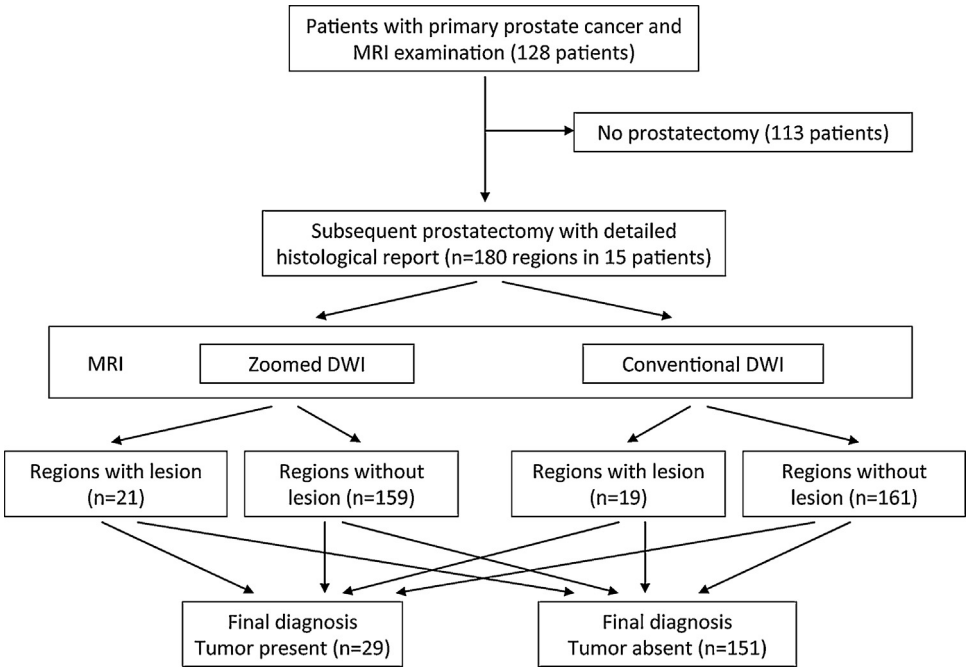

Fig. 1. Chart with flow of patients. MRI: magnetic resonance imaging. n: number. DWI: diffusion-weighted imaging.

diagnostic tool for detection of prostate cancer especially after negative ultrasound-guided biopsies and for the evaluation of local extent of disease [2,3]. While T2-weighted sequences provide exact anatomic information, additional functional techniques like diffusion-weighted imaging (DWI) allow for a more sophisticated tumour characterization by measurement of cell density [4], which is typically elevated in tumour areas [5], thus restricting diffusion in tumour lesions. Furthermore, the extent of diffusion restriction in cancer lesions has been shown to correlate with tumour aggressiveness (Gleason Score) [3]. In large meta-analyses, DWI reached a sensitivity of 0.69 and specificity of 0.89 in the diagnostic evaluation of prostate cancer, which was significantly more precise than T2-weighted imaging alone, providing a sensitivity of 0.60–0.62 and specificity of 0.76–0.77. The combination of T2-weighted imaging and DWI yielded a sensitivity of 0.70–0.76 and a specificity of 0.82 [6,7].

In most routine protocols, DWI is performed using single-shot echoplanar imaging (EPI); however, this technique is prone to distortion and susceptibility artefacts due to field inhomogeneity which may limit the diagnostic evaluation of the prostate in pelvic MRI, especially at 3 T, because the prostate is located near the adjacent air-filled rectum. The higher field strength, on the other hand, has the advantage of providing higher signal-to-noise ratio so that the examination can generally be performed without the use of an endorectal coil [8–10]. Another drawback of conventional EPI sequences is the limited spatial resolution which hampers the detection of small lesions due to partial volume effects [11]. These drawbacks may be overcome by sequences with 2D selective excitation pulses, which allow a focused excitation of a reduced field of view (FoV) in phase-encoding direction [12,13]. These selective excitation pulses are realized in an acceptable time by parallel transmission (pTx) with two separated radiofrequency (RF) transmitter channels [11,12].

The applicability of zoomed DWI applications of the prostate has been demonstrated both for diffusion-weighted imaging and diffusion-tensor imaging (DTI) [11,12,14]. Rosenkrantz et al. showed a significantly higher clarity of anatomical structures and reduced wrap artefacts, ghosting and distortion in the ADC maps and high b-value images [12]. Thierfelder et al. report a higher overall image quality and anatomic differentiability compared to conventional EPI images with a significant reduction of artefacts and higher correlation with the T2-weighted images concerning the size of the prostate [11]. Reischauer et al. proved the feasibility of DTI of the prostate using a reduced FoV technique with potential improvement in detection of focal tumours [14]. The DTI technique, however, is time-consuming (acquisition time in the study by Reischauer et al. was >13 min) if performed in adequate spatial resolution and is therefore, currently, not yet applied in clinical routine prostate protocols. To our knowledge, the diagnostic potential of the zoomed DWI technique with special focus on lesion detection and geometric image distortion effects in histology proven prostate cancer lesions has not been investigated so far.

Therefore, the aim of our study was the evaluation of the reduced field of view (zoomed) DWI technique in comparison to conventional DWI concerning lesion detection, image quality, ADC values and alignment accuracy in patients with histology proven prostate cancer lesions.

2. Material and methods

2.1. Patients

The study which was carried out in accordance with the Declaration of Helsinki was approved by the institutional review board. All patients gave their written informed consent to the examination and to the scientific evaluation of their data. 128 consecutive patients with primary diagnosis of prostate cancer prospectively underwent clinically indicated routine MRI of the prostate in our institution between June 2013 and May 2014. Only patients with subsequent radical prostatectomy and detailed description of tumour localisation in the histological report were included in the evaluation in order to ensure adequate reference standard. The histopathological evaluation was performed blinded to the MRI examination and assigned the localisation of prostate lesions to twelve different regions (left peripheral, left central, right peripheral, right central in base, mid and apex).

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