Prostate MRI using an external-phased array wearable pelvic coil at 3T: comparison with an endorectal coil and standard pelvic phased array coil

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Aims and objectives

Multiparametric magnetic resonance imaging (mpMRI) of the prostate now plays a central role in the management of prostate cancer. Its use in the local staging of prostate cancer is well established [1,2], and mpMRI can also provide information about tumor aggressiveness [3-5], allows lesion localization for targeted biopsy [6,7] and can be used as part of an active surveillance program [8]. Additionally, there is developing evidence that mpMRI can play a role in the initial workup of patients presenting with suspicion of prostate cancer based on the elevation of serum prostate specific antigen (PSA) or findings on digital rectal examination [9].

As prostate mpMRI increases in importance, so does the need to optimize image acquisition. Currently, mpMRI examinations are performed at 1.5T or 3T using a pelvic phased array coil (PPA) with or without the addition of an endorectal coil (ERC) to increase the signal to noise ratio (SNR). The precise imaging technique used varies across institutions. In the Prostate Imaging - Reporting and Data System version 2 (PI-RADS v2) published in 2015, the authors note that credible imaging results have been obtained without an ERC at 1.5T and 3T, but the combination of a PPA and ERC increases the SNR at any field strength and with some 1.5T systems the use of an ERC is indispensable [10].

After factoring in issues of time, cost and patient acceptibility, there is currently no consensus regarding the optimum imaging technique. A number of studies have been performed comparing the image quality obtained using different field strengths and coil configurations. A recent prostate mpMRI study comparing the image quality obtained at 3T using a PPA and a PPA/ERC combination found that T2 weighted (T2w) images were of comparable quality and that diffusion weighted images (DWI) obtained with an ERC demonstrated superior image quality for one of two readers [11]. The same study found a higher SNR for DWI using a PPA over a PPA/ERC combination, and no significant difference in SNR between the two for T2w. Another study comparing the diagnostic utility of ERC and non-ERC mpMRI at 3T found ERC examinations to be superior at detecting cancer foci [12].

Since prostate mpMRI involves the acquisition of signal from a small volume of tissue, positioning the receive coil as near as possible to the gland may be advantageous. A new wearable pelvic coil aims to optimize non-ERC mpMRI by positioning the coil elements as close as possible to the perineum and therefore the prostate gland. By physically wrapping around and conforming to the pelvis, the coil aims to maximise the signal obtained from the prostate gland. The purpose of this study is to compare the qualitative and quantitative image quality of T2w and diffusion weighted images acquired using a wearable pelvic coil, a standard pelvic phased array coil and an endorectal coil.
Methods and materials

Approval was obtained from the institutional ethical review board, and the study was compliant with the Health Insurance Portability and Accountability Act. Written informed consent was obtained from all participating patients.

Patients

20 men presenting to our prostate cancer MRI clinic as part of a diagnostic workup were prospectively consented to be scanned using an external phased array wearable pelvic coil (WPC) in addition to the standard diagnostic sequences obtained using an endorectal coil (ERC) and standard pelvic phased array coil (PPA) at 3T. All patients were presenting for the assessment of known or suspected prostate cancer. Two patients were excluded, one of whom did not tolerate ERC insertion and the other having undergone prior prostatectomy. 18 patients were included in the study. The age range was 49-72 (mean 63) and the prostate specific antigen (PSA) range was 2.0-10.1 (mean 10.0). A PSA level was unavailable for one patient, having been measured at an outside institution.

MRI Technique

All imaging was performed on the same 3T MR system (Discovery MR750w, GE Healthcare, Waukesha WI, USA). The wearable pelvic coil (PROCURE Prostate/Pelvic Coil, ScanMed, Omaha NE, USA) was applied to the patient, and axial T2w fast spin echo images and diffusion weighted images were acquired using scan parameters given in Table 1. The WPC was then removed, and the endorectal coil (Medrad eCoil, Bayer Medical Care, Indianola PA, USA) was inserted in usual fashion and the balloon inflated with 50-60 mL of air. The 32 channel pelvic phased array coil (GEM flex torso coil, GE Healthcare, Waukesha WI, USA) was positioned over the anterior lower abdomen and pelvis. Glucagon 1mg IM was administered immediately following ERC insertion. Axial, coronal and sagittal localizers were performed to assess ERC position and adjustments were made if necessary. A standard diagnostic PI-RADS v2 prostate MRI protocol was then performed [10,13]. As part of this protocol, axial T2w fast spin echo images were acquired using the ERC and PPA in unison. Two separate diffusion weighted sequences were performed, one using the PPA coil only, and the other using the ERC only. The remainder of the sequences acquired as part of the standard diagnostic MRI were not used for the purposes of the study.

Qualitative Image Analysis
All images were reviewed on a diagnostic Picture Archiving and Communication System (PACS) workstation (Centricity PACS RA1000; GE Healthcare, Barrington IL, USA). Qualitative image analysis was performed in consensus by two readers (ROD and RMD) with experience in prostate MRI. Wearable pelvic coil and endorectal coil T2w images were rated using six criteria (Table 2), some of which have been employed in previous studies assessing prostate MR image quality [14,15]. The T2w image criteria used were: definition of the posterior prostate gland border (1 to 5), the definition of zonal anatomy i.e. the ability to distinguish the peripheral zone and transitional zone (ZA; 1 to 5), visualization of the neurovascular bundle (NVB; 1 to 4), visualization of the seminal vesicles (SV; 1 to 5), the severity of artifacts (SA; 1 to 4) and overall image quality (IQ; 1 to 5).

The three sets of DWI images were scored using five criteria (Table 2), and some of these criteria were employed in a previous study assessing prostate DWI image quality [11]. The criteria used were margin demarcation defined by the ability to trace the prostate margin clearly (GD; 1 to 5), zonal anatomy defined by the ability to distinguish the peripheral zone and transitional zone clearly (ZA; 1 to 5), geometric distortion defined by distortion of the image due to field inhomogeneity using the T2w images as a reference (GD; 1 to 5), the severity of artifacts (SA; 1 to 4) and overall image quality (IQ; 1 to 5). In the case of both T2w and DWI, the nature of any artifacts was recorded.

Quantitative Image Analysis

For the estimation of signal to noise ratio (SNR) in the T2w and b1400 diffusion weighted images, elliptical regions of interest (ROI) were placed over the peripheral zone of the prostate, transitional zone of the prostate and obturator internus muscle, avoiding any artifacts or focal lesions. The mean signal intensity was measured in the peripheral zone ROI and in the transitional zone ROI, and these two values were averaged to give a value for mean prostate gland signal. The standard deviation of the signal in the obturator internus muscle ROI was recorded to provide an estimation of image noise, and the SNR was calculated by dividing the mean prostate gland signal by the image noise [11,16,17].

Statistical Analysis

All ordinal and continuous data are summarized as a mean ± standard deviation. The Wilcoxon matched-pairs signed rank test was used to test each variable for statistical significance. A p value of <0.05 was considered to indicate a statistically significant difference. Statistical analysis was performed using the GraphPad Prism software package (Version 7.0c, La Jolla, CA, USA).
Table 1: Scan parameters (WPC - wearable pelvic coil; PPA - standard pelvic phased array coil; ERC - endorectal coil)

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Table 2: Image scoring system

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Results

Qualitative T2w image analysis

The results of the qualitative T2w image analysis are given in Table 3. Artifact severity was greater in T2w images acquired with the endorectal coil when compared with the wearable pelvic coil (ERC 2.01 ± 0.42 vs. WPC 1.39 ± 0.70, p=0.003). Motion artifact in the phase encode direction emanating from the interface of the endorectal coil and rectal wall was seen on 17 of 18 ERC T2w sequences (Figure 1). There was no statistically significant difference in overall image quality, posterior border definition, zonal anatomy distinction, neurovascular bundle visualization or seminal vesicle visualization.

Qualitative diffusion weighted image analysis

The ability to clearly distinguish the peripheral zone and transitional zone on DWI was greater on images acquired with the endorectal coil when compared with the wearable pelvic coil (ERC 4.28 ± 0.91 vs. WPC 3.72 ± 1.02, p < 0.001; Table 4). ERC DWI images were also superior in clearly distinguishing the peripheral zone and transitional zone when compared with the standard pelvic phased array coil (ERC 4.28 ± 0.91 vs. PPA 3.50 ± 0.92, p = 0.018). There was no significant difference in the ability of the WPC and the PPA to distinguish zonal anatomy. There was no significant difference in gland margin demarcation, geometric distortion, artifact severity and overall image quality between the WPC, PPA and ERC.

Signal to noise ratio

The T2w signal to noise ratio was significantly higher in endorectal coil images than wearable pelvic coil images (ERC 38.32 ± 15.19 vs. WPC 16.57 ± 5.13, p <0.001; Table 5). Similarly, there were significantly higher signal to noise ratios comparing the endorectal coil DWI with the wearable pelvic coil DWI (ERC 81.49 ± 32.42 vs. WPC 19.83 ± 6.30, p <0.001; Table 6), and also comparing the endorectal coil DWI with the standard pelvic phased array coil DWI (ERC 81.49 ± 32.42 vs. PPA 22.88 ± 13.62, p <0.001). There was no significant difference comparing the DWI signal to noise ratio for the wearable pelvic coil and the standard pelvic phased array coil.
Table 3: T2w image scores (WPC - wearable pelvic coil; ERC - endorectal coil)

<table>
<thead>
<tr>
<th></th>
<th>WPC</th>
<th>ERC</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior Border</td>
<td>4.44 ± 0.92</td>
<td>4.61 ± 0.70</td>
<td>0.563</td>
</tr>
<tr>
<td>Zonal Anatomy</td>
<td>4.72 ± 0.57</td>
<td>4.78 ± 0.43</td>
<td>&gt;0.999</td>
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<tr>
<td>Neurovascular Bundle</td>
<td>3.61 ± 0.78</td>
<td>4.39 ± 0.98</td>
<td>0.375</td>
</tr>
<tr>
<td>Seminal Vesicles</td>
<td>4.40 ± 0.78</td>
<td>4.56 ± 0.61</td>
<td>0.500</td>
</tr>
<tr>
<td>Artifact Severity</td>
<td>1.39 ± 0.70</td>
<td>2.01 ± 0.42</td>
<td>0.003</td>
</tr>
<tr>
<td>Overall Image Quality</td>
<td>3.83 ± 0.86</td>
<td>3.94 ± 0.42</td>
<td>0.796</td>
</tr>
</tbody>
</table>

Table 4: DWI image scores (p1 = WPC vs. PPA; p2 = WPC vs. ERC; p3 = PPA vs. ERC)

<table>
<thead>
<tr>
<th></th>
<th>WPC</th>
<th>PPA</th>
<th>ERC</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gland Margin Demarcation</td>
<td>4.39 ± 0.61</td>
<td>4.28 ± 0.89</td>
<td>4.67 ± 0.59</td>
<td>0.781</td>
<td>0.188</td>
<td>0.016</td>
</tr>
<tr>
<td>Zonal Anatomy</td>
<td>3.72 ± 1.02</td>
<td>3.50 ± 0.92</td>
<td>4.28 ± 0.91</td>
<td>0.219</td>
<td>&lt;0.018</td>
<td>&lt;0.001</td>
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<tr>
<td>Geometric Distortion</td>
<td>1.67 ± 0.91</td>
<td>1.72 ± 0.67</td>
<td>1.83 ± 0.62</td>
<td>&gt;0.999</td>
<td>0.637</td>
<td>0.689</td>
</tr>
<tr>
<td>Artifact Severity</td>
<td>1.78 ± 0.88</td>
<td>2.00 ± 0.84</td>
<td>2.22 ± 0.65</td>
<td>0.463</td>
<td>0.097</td>
<td>0.289</td>
</tr>
<tr>
<td>Overall Image Quality</td>
<td>3.61 ± 0.61</td>
<td>3.61 ± 0.61</td>
<td>3.83 ± 0.51</td>
<td>&gt;0.999</td>
<td>0.344</td>
<td>0.289</td>
</tr>
</tbody>
</table>

Table 5: T2w signal to noise ratio

<table>
<thead>
<tr>
<th></th>
<th>WPC</th>
<th>PPA</th>
<th>ERC</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal to Noise Ratio</td>
<td>16.57 ± 5.13</td>
<td>38.32 ± 15.19</td>
<td></td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 6: DWI signal to noise ratio (p1 = WPC vs. PPA; p2 = WPC vs. ERC; p3 = PPA vs. ERC)

<table>
<thead>
<tr>
<th></th>
<th>WPC</th>
<th>PPA</th>
<th>ERC</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal to Noise Ratio</td>
<td>19.83 ± 6.30</td>
<td>22.88 ± 13.62</td>
<td>81.49 ± 32.42</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Fig. 1: T2w images from the same patient acquired with ERC (A) and WPC (B). Note the motion artifact on the ERC images emanating from the interface of the ERC and rectal wall (arrow).
Fig. 2: DWI images from the same patient acquired using a wearable pelvic coil (A), standard pelvic phased array coil (B) and endorectal coil (C and D). Note the clearer delineation of the peripheral zone and transitional zone on endorectal coil images. There is high signal in the peripheral zone secondary to ERC related artifact (arrow).

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Conclusion

Wearable pelvic coil imaging provides comparable image quality to an endorectal coil, potentially reducing the need for an endorectal coil. Wearable pelvic coil imaging showed reduced T2w artefact severity and inferior DWI zonal anatomy distinction when compared with an endorectal coil. Imaging with a wearable pelvic coil produces a lower signal to noise ratio than an endorectal coil.
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