**Evaluating the effect of rectal distension on prostate multiparametric MRI image quality**

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**Highlights:**

* Rectal distension had a significant negative effect on the quality of DWI
* There was a correlation between rectal distension and T2W motion artefact
* Rectal distension had no significant effect on T2 sharpness and DCE image quality
* Targeted biopsy PPV was higher for mild versus moderate/severe rectal distension
* Bowel preparation prior to prostate MRI is advised to improve image quality

**Abstract**

Purpose

To evaluate the effect of rectal distension on the quality of anatomical and functional prostate multiparametric (mp) MRI.

Materials and Methods

Multiparametric (mp) 3T-MRI images of 173 patients were independently evaluated by two radiologists in this retrospective study. Planimetry rectal volumes were derived and a subjective assessment of rectal distension was made using a 5-point Likert scale (1 = no stool/gas, 5 = large amount of stool/gas). Image quality of diffusion-weighted imaging (DWI) was evaluated using a 5-point Likert scale. DWI was further scored for distortion and artefact. T2W images were evaluated for image sharpness and the presence of motion artefact. The stability of the dynamic contrast-enhancement acquisition was assessed by recording the number of corrupt data points during the wash-out phase.

Results

There was a strong correlation between subjective scoring of rectal loading and objectively measured rectal volume (r = 0.82), p<0.001. A significant correlation was shown between increased rectal distension and both reduced DW image quality (r = -0.628, p<0.001), and increased DW image distortion (r=0.814, p<0.001). There was also a significant trend for rectal distension to increase artefact at DWI (r = 0.154, p = 0.042). Increased rectal distension led to increased motion artefact on T2 (p = 0.0096), but did not have a significant effect on T2-sharpness (p = 0.0638). There was no relationship between rectal distension and DCE image quality (p = 0.693). 63 patients underwent lesion-targeted biopsy post MRI, there was a trend to higher positive predictive values in patients with minor rectal distension (34/38, 89.5%) compared to those with moderate/marked distension (18/25, 72%), p = 0.09.

Conclusion

Rectal distension has a significant negative effect on the quality of both T2W and DW images. Consideration should therefore be given to bowel preparation prior to prostate mpMRI to optimise image quality.

**Keywords:** Rectal distension, multiparametric MRI, prostate, image quality, susceptibility artefact

**Introduction**

Multiparametric magnetic resonance imaging (mpMRI) incorporating T2W, DWI and DCE sequences has now become established in the work-up of prostate cancer [1].   
  
Increasingly, mpMRI is being performed on 3T scanners to provide a superior signal-to-noise ratio, allowing the use of a surface body coil instead of an endorectal coil (ERC), which is better tolerated by patients, and reduces the time and cost of the examination [2]. Although an ERC is known to induce motion via rectal spasm [3], it may also serve as a mechanical barrier to movement of the rectum and prostate, similar to the effects of endorectal balloon placement for prostatic radiotherapy [4]. Previous studies assessing the effect of rectal loading are lacking, aside from positional differences in relation to radiotherapy planning. Rectal distension has been shown to correlate to increased rectal movement [5], thus in the absence of an endorectal coil, T2W, DWI and DCE images may be degraded by motion artefact. Additionally, the absence of an ERC allows for rectal loading and distension with air/faeces and may induce susceptibility artefact, particularly on diffusion weighted images (DWI), similar to that described with neuroimaging and liver MRI [6], which may be further magnified at 3T [6-8].

As MRI is used for lesion detection, staging, and biopsy-targeting, the importance of good quality imaging without significant artefact and distortion is essential. The lack of evidence to inform patient preparation prior to MRI has been highlighted in the recently updated Prostate Imaging-Reporting and Data System (PI-RADS) guidelines, which are aimed at standardizing MRI acquisition and interpretation [9]. One reason for this deficit in the literature may relate to the formerly widespread use of endorectal coils, with subsequent expulsion of rectal contents. Current practice reflects a shift to 3T MRI with no endorectal coil, making rectal loading a potential issue, and artefact may even be exacerbated by the higher field strength employed.  
  
To date, no study has directly evaluated the correlation between rectal distension and the degree of artefact at mpMRI, with only one study assessing the effects on image quality of intervention with a cleansing enema [10]. The purpose of this study was therefore to determine the effect of rectal distension on the quality of T2W, DWI and DCE sequences of prostate mpMRI.

**Methods***Study population*

This single-institution retrospective study was approved as part of a prostate MRI service evaluation, with the need for informed consent for data analysis waived by the local ethics committee (study registration CUH/5126). The study included 173 patients undergoing prostate 3T-MRI for any indication during a 12 month window, which ended in February 2016. Exclusion criteria included presence of pelvic metalwork and any previous treatment for prostate cancer.  
  
*Magnetic Resonance Imaging*Patients underwent MRI at 3T (MR750, GE Healthcare) using a 32 channel phased array cardiac coil. Sequences included axial T1 weighted FSE (fast spin echo) pelvic images and high resolution T2 weighted fast recovery FSE images of the prostate in the axial, sagittal, and coronal planes. T1 weighted parameters: TR/TE 561/11ms, FOV 24 × 24 cm, resolution 1.1 x 1.0mm. T2 weighted parameters: TR/TE 4273/102ms, FOV 22 x 22 cm, resolution 0.8 x 0.7mm, 1.5 signal averages. Axial diffusion-weighted imaging (DWI) was performed using a dual spin-echo planar pulse sequence: TR/TE 3775/70ms, FOV 28 × 28 cm, resolution 2.2 x 2.2mm, with 6 signal averages; b-values of 150, 750, 1400 and 2000 s/mm2, with automated ADC maps. Axial 3D dynamic contrast-enhanced (DCE) images were acquired using a fast-spoiled gradient echo sequence (TR/TE 4.088/1.788ms; FOV 24 x 24 cm) with a temporal resolution of 7s. After 28s a bolus of Gadobutrol (Gadovist, Schering AG) was injected via a power injector at 3 mL/s (dose 0.1 mmol/kg) followed by a 25 mL saline flush at 3 ml/s. The axial T2-w, DWI and DCE sequences were spatially matched, with a 3 mm thickness and 0-mm gap.

*Image analysis*Images were reviewed for image quality by two radiologists, blind to the clinical details, with 7 years (**XX**) and 2 years experience (**XX**) in prostate MRI reporting. Planimetry rectal volumes were derived using maximal axial and sagittal dimensions (anal canal to peritoneal reflection), and a subjective assessment of rectal distension was made using a 5-point Likert scale: 1 = no stool/gas, 2 = minimal, 3 = small amount, 4 = moderate, 5 = large amount of stool/gas (**Figure 1, 2**). T2-weighted imaging was qualitatively assessed for image sharpness (based on the sharpness of the neurovascular bundle, seminal vesicles, and prostatic capsule compared to periprostatic fat) and motion artefact (ghosting or movement). DW image quality was scored on the highest b-value imaging (b=2000 s/mm2) using a 5-point scale: poor = 1, suboptimal = 2, adequate = 3, above average = 4, excellent = 5. DWI was also assessed for artefact and distortion using 4-point scales; artefact: none = 1, mild, not/ mildly impacting diagnosis = 2, artefact moderately impacting diagnosis = 3, marked artefact/non-diagnostic = 4; distortion: none = 1, <5mm mismatch to T2WI = 2, ≥5 mm mismatch to T2WI *or* mild warping = 3, significant warping = 4 [11]; **Figures 3,4**. DCE images were assessed based on the number of corrupt data points, using a region-of-interest of ≥0.2cm3 in normal appearing peripheral zone, and recording the number of corrupted data points from the contrast curve (defined as any >10%, between-point, signal intensity changes during the wash-out phase) [10].  
  
*Statistics*Wilcoxon signed ranked tests were performed to assess differences between binary criteria (T2 motion and sharpness) and the ordinal image quality scales. Fisher’s exact test was used to compare targeted biopsy outcomes between groups of patients with differing rectal distension. Spearman’s correlation was performed to assess the relationship between ordinal variables. A p-value <0.05 was defined as statistically significant. Weighted Cohen’s Kappa was performed to assess inter-rater agreement using the following rules of thumb (0–0.20 = slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–1 almost perfect agreement) [12]. The statistical analysis was performed using R (version 3.1.1, The R Foundation for Statistical Computing, Vienna, Austria).

**Results**

A total of 173 patients were included with a median age of 65 years (mean 63.8, range 59 - 69) and a median PSA of 6.57 (mean 6.78, range 4.17 - 10.02).   
  
Indications for MRI were a raised PSA in biopsy-naïve patients (n = 67), active surveillance (69), previous negative systematic biopsy with continuing suspicion of cancer (27), staging (6) and other, including suspicion of abscess (4). Subsequent benign biopsy was not an exclusion criterion. The majority of patients had no cancer diagnosis (n = 72), the remaining 101 patients were diagnosed with Gleason grade 3+3 cancer (n = 59), 3+4 (23), 3+5 (2), 4+3 (9), 4+4 (2) and Gleason score 9-10 disease (n = 6).

The inter-rater agreement for subjective scoring of rectal loading expressed using Cohen's kappa coefficient was 0.819 indicating excellent agreement between the two readers. The subjective rectal loading scores are shown in **Table 1**. Rectal loading was additionally measured in the antero-posterior (AP), axial right-left (RL), and cranio-caudally (CC) planes, producing a volume measurement. AP averaged 39.7 mm (interquartile range 30 – 48 mm), RL 34.3 mm (26 – 42) and CC 91.0 mm (82 – 98), with an average volume measurement of 73.5 cm3 (inter-quartile range of 32.9 - 102.0 cm3). There was a strong correlation between subjective scoring of rectal loading and objectively measured AP diameter (r = 0.882) and rectal volume (r = 0.82), p<0.001; **Figure 5**.

The mean score for DW image quality (out of 5) was 3.39 (± 0.98), with an inverse correlation shown between DW image quality and rectal loading subjective scores (r = -0.628, p<0.001) and objective volume measurements (r = -0.552, p<0.001). The presence of distortion artefact on DWI (out of 4) was scored as 2.31 (± 0.92) on average, with a strong correlation between increased DW distortion and increasing rectal loading based on both subjective scores (r = 0.814, p<0.001) and objective volume measurements (r = 0.987, p<0.001; **Figure 6**. The pairwise relationships between these ordinal variables are shown in **Figure 7.** Average DWI artefact (out of 4) was 1.62 (± 0.57), with a significant but less marked trend for increased rectal loading scores to show increased artefact at DWI (r = 0.154, p=0.042).

Correlation statistics were not performed for T2 categories due to binary categorization. T2 motion was present in 66/173 cases (38.2%), with Wilcoxon signed ranked tests showing a significant effect of rectal loading on presence of T2 motion (p = 0.0096). T2 sharpness was  
rated as acceptable in 56/176 studies (32.4%), there was no statistical association with rectal loading (p=0.0638); **Table 2**.  
  
The average number of corrupted data points in the DCE wash-out phase was 3.05 (median 3, IQR 1 - 4). There was no relationship between rectal loading and the number of corrupt data points (p = 0.693); **Figure 8**.

The cancer detection rate relative to rectal distension score is shown in **Table 3**. Biopsy was performed in 134/173 (77.5%) of patients; there was a trend to perform less in patients with rectal scores 1-3 (no stool/gas to small amount) with 79/107 (73.8%) undergoing biopsy compared to scores 4-5 (moderate to large amount stool/gas) with 55/66 (83.3%). Based on the original MRI read being positive or negative, the result matched subsequent biopsy in 114/134 cases (85.1%), wherein a positive MRI call was congruent to biopsy-proven cancer, or a negative MRI call showed no cancer or small volume Gleason 3+3 disease. The MRI was in agreement with biopsy in 69/79 (87.3%) of patients with rectal scores 1-3, compared to 45/55 (81.8%) with score 4-5. Positive predictive value was assessed in the 63 patients undergoing lesion-targeted biopsy post MRI and compared with Fisher’s exact test. Overall 52/63 (82.5%) targeted biopsies showed cancer, comparing the two groups with rectal scores 1-3 versus those with scores 4-5 the cancer detection was 34/38 (89.5%) and 18/25 (72%), respectively; odds ratio=0.309, p=0.096.

**Discussion**

The results of our study show that increasing rectal distension has a significant negative effect on the quality of both T2W and DW images. DWI was the most affected sequence, with increasing rectal loading correlating to increased artefact and distortion, with reduced image quality demonstrated. For T2W imaging, increased rectal loading induced increased T2W motion but had no statistical effect on sharpness. In contrast, DCE was the only unaffected sequence with no relationship shown between rectal distension and number of corrupt data points.

The echo planar readouts used within diffusion weighted imaging are very sensitive to the uniformity of the magnetic field. MRI scanners have high magnetic field uniformity, however, the field becomes distorted when a body is placed into the magnetic field. Modern clinical scanners attempt to correct for magnetic field uniformity around the patient by actively shimming, which is performed on a per-patient basis. Although this improves the general quality of the MR images, localized magnetic field in-homogeneity will remain, particularly in areas around air-tissue interfaces such as the internal tissues in the proximity of bowel gas. The resultant distortions that appear on DW images are a result of accumulated phase errors as the echo planar read-out samples and reads multiple lines of *k*-space. T2-weighted fast spin echo images are less degraded because a refocusing radiofrequency pulse is used between each line of *k*-space which gets sampled. That said, fast spin echo readouts are still sensitive to motion artefact as the slower sampling of *k*-space means they are more likely to experience patient or bowel motion, which explains the positive correlation between rectal distension and T2W motion artefact [6-8]**.** This result may be confounded as the number of corrupt data points may be sensitive to general patient motion during the acquisition and not just localized bowel movement as associated with bowel distension.

There are a limited number of previous studies looking at the issue of rectal distension and prostate MRI quality. Lim et al [10]showed no improvement in the quality of DWI, T2W or DCE prostate images in a retrospective study of 28 patients receiving a cleansing enema prior to imaging. Despite showing a significant correlation of stool volume to motion artefact on T2 and the presence of less stool in the enema group, there was no significant difference to a control group with no enema. Of note however, only a minority of patients (16%) in the non-enema group had moderate or large amounts of stool, compared to 38.2% in our cohort. A further confounding factor may be the introduction of air post-enema, as the induced susceptibility artefact may have counteracted the effect of reduced stool distension. Another difference to our study was the choice of b-value for DWI, with a maximum b value of 1000 s/mm2 whereas we used a high b value of 2000 s/mm2 which is more prone to artefact [13]. In terms of DWI distortion we additionally assessed for geometric distortion, which is an important component of susceptibility artefact [7, 8, 14], and may explain the higher distortion scores seen in our study. Previous work by Padhani et al [5]demonstrated a significant correlation between the degree of rectal distension and rectal wall and (secondarily) prostate motion. Although these results are supportive of our findings, the aim of their study was to quantify motion in the context of radiotherapy planning and as such image quality was not recorded, nor motion artefact assessed.

PI-RADS-version 2 incorporates T2W, DWI, ADC and DCE sequences, with DWI being the dominant sequence for assessment of the peripheral zone (PZ) [1]. Satisfactory quality of diffusion-weighted imaging is therefore fundamental for several reasons. The highest proportion of prostate carcinomas arise within the PZ, particularly in a posterior location, where warping adjacent to the rectum more typically occurs. Although T2W images were less affected by motion artefact, good quality T2W images are essential for assessment of BPH nodules in TZ and for staging purposes in the assessment of the prostatic capsule, fat planes and seminal vesicles. Image quality likely affects radiologists’ interpretation and confidence when reporting. Although not all patients underwent biopsy, we can infer some findings from the biopsy outcomes between patients with mild rectal loading (scores 1-3) and those with more significant distension (scores 4-5). There was a tendency to biopsy a higher percentage of patients with increasing rectal distension, which may reflect a reduced reader confidence in MRI quality. Although not significant due to smaller numbers, the PPV of MRI compared to targeted biopsy for the mild rectal loading group (89.5%) was higher than the group with moderate/marked rectal distension (72%). Additionally the MRI call of being negative or positive was more congruent to final biopsy pathology in the former compared to the latter group.   
  
Our study has some limitations, including its retrospective nature. Rectal volumes were estimated using planimetry measurements and not calculated by more accurate measures incorporating 3D-reconstruction volumetry. However, previous studies for calculating prostate volumes have shown no significant difference between 3D measurements and those derived from a prolate ellipsoid formula [15]. The main purpose of the study was to evaluate image quality; cancer detection results were secondarily assessed, but may have been biased by the heterogeneous indications for MRI and the fact that not all patients underwent biopsy, further work is therefore required to determine whether rectal distension has a clinical impact. A strength of our study is the relatively large sample size, and also the strong inter-observer agreement.

Our results suggest that bowel preparation may help improve image quality. It should also be noted that for radiotherapy planning multiple strategies for rectal emptying have been employed, but there remains no robust evidence to recommend one strategy over another [16, 17]. Therefore, other, non-patient related solutions could be considered, including using different DWI techniques [11, 18], switching to prone imaging [9], correcting the inhomogeneous magnetic field during its acquisition [19], or applying post-processing techniques to correct for distortion [20]. Although use of a cleansing enema did not significantly affect image quality, simple advice for patients to evacuate their bowels prior to an MRI appointment may be beneficial [9], however, to establish this, further prospective work would be necessary.

**Conclusion**

Rectal distension has a significant negative effect on the quality of both T2W and DWI images. Consideration should therefore be given to bowel preparation prior to prostate mpMRI to optimise image quality.

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**Figure Legends  
  
C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 1.tifFigure 1: Mild rectal loading, no distortion or artefact.**  
61 year old, PSA 8.1 ng/ml, MRI performed pre-biopsy. A: Subjective scores of mild rectal loading, overall rectal volume 23.2 cm3. B: No motion on T2-weighted axial imaging. C, D: Diffusion-weighted imaging scored as no distortion or artefact.  
  
**C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 2.tifFigure 2. Marked rectal loading with moderate artefact.**  
53 year old, Active Surveillance for Gleason 3+3 disease, PSA 3.82 ng/ml. Subjective scores of large volume rectal loading, overall rectal volume 179.3 cm3 (A, B). B: No motion on T2-weighted imaging. C: Diffusion-weighted imaging shows mild warping and artefact score 3, moderately impacting diagnosis (wrap artefact; arrows).  
  
**C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 3.tifFigure 3: Marked rectal loading with moderate warping.**  
67 year old, PSA 4.18 ng/ml, MRI performed pre-biopsy. Subjective scores of marked rectal loading; overall rectal volume 195.8 cm3 (D). Moderate warping of prostate outline and orientation is noted on DWI (A) and ADC maps (C), compared to T2 (B). E, F: white outline of ADC map superimposed on red prostate outline on T2 image and vice versa, to depict the warping effect.  
  
**C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 4.tifFigure 4: Marked rectal loading with significant warping.**  
66 year old, PSA 5.63 ng/ml, MRI performed pre-biopsy. A: Subjective scores of marked rectal loading. B: T2 imaging scored as loss of sharpness and presence of motion artefact. C: DWI shows significant warping (score 4).

**C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 5.tifFigure 5.** The relationship between the subjective rectal loading score and objectively measured AP diameter (A) and rectal volume (B) indicated a strong and significant correlation (r = 0.882 and r = 0.82, respectively), p<0.001.

**C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 6.tif  
Figure 6.** The relationship between distortion artefact on DWI and objective rectal loading measurements, demonstrating a strong correlation (r = 0.987, p<0.001).

**C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 7.tifFigure 7.** Ordinal comparisons of rectal loading versus DW image quality. The frequency of occurrences is represented for each pairwise comparison (A) a highly significant inverse correlation was noted between rectal loading and DW image quality (r = -0.628, p<0.001) (B) shows a positive correlation between rectal loading and higher DW distortion (r=0.814, p<0.001)  
  
**C:\Users\Tristan\Desktop\Rectal Loading\For EJR Resub_15.2.17\Figure 8.tif**  
**Figure 8.** The relationship between rectal loading and the number of corrupt data points noted during the DCE acquisition was not statistically significant (r=0.05, p=0.693)

**Tables**

**Table 1: Subjective rectal loading scores**

|  |  |  |  |
| --- | --- | --- | --- |
| **Score** | **Reader 1 (n = 173)** | **Reader 2 (n = 173)** |  |
| 1 (no stool/gas)  2 (minimal)  3 (small amount)  4 (moderate)  5 (large) | 18 (10.4%)  49 (28.3%)  40 (23.1%)  39 (22.6%)  27 (15.6%) | 17 (9.8%)  41 (23.7%)  46 (26.6%)  46 (26.6%)  23 (13.3%) |  |
|  |  |  |  |

\*Kappa for overall agreement = 0.819

**Table 2: Image quality and rectal loading**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Correlation (r)** | **p-value** |
| T2 motion | N/A | 0.009\* |
| T2 sharpness | N/A | 0.06 |
| DWI quality | -0.628 | <0.001\* |
| DWI distortion  DWI artefacts | 0.814  0.154 | <0.001\*  0.042\* |
| DCE corrupt data points | 0.05 | 0.693 |
|  |  |  |

\* = significant (p <0.05. DWI = diffusion-weighted imaging; DCE = dynamic contrast-enhanced

**Table 3: Cancer detection rates by rectal loading score**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Pathology** | **Total** (n=173) | **Score 1** (n=18) | **Score 2** (n=49) | **Score 3** (n=40) | **Score 4** (n=39) | **Score 5** (n=27) |
| No biopsy | 39 (22.5%) | 5 (27.8%) | 14 (28.6%) | 9 (22.5%) | 8 (20.5%) | 3 (11.1%) |
| No cancer | 33 (19.1%) | 3 (16.7%) | 9 (18.4%) | 8 (20%) | 7 (17.9%) | 6 (22.2%) |
| 6 | 59 (34.1%) | 4 (22%) | 17 (34.7%) | 12 (30%) | 11 (28%) | 15 (55.6%) |
| 7 | 32 (18.5%) | 4 (22%) | 6 (12.2%) | 10 (25%) | 10 (25.6%) | 2 (7.4%) |
| 8 | 4 (2.3%) | 2 (11%) | 1 (2%) | 1 (2.5%) | 0 (0%) | 0 (0%) |
| 9, 10 | 6 (3.5%) | 0 (0%) | 2 (4.1%) | 0 (0%) | 3 (%) | 1 (3.7%) |