Comparison of signal-to-noise ratio at 3T MRI of the prostate: the influence of endorectal coil and body habitus

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Introduction

Prostate gland cancer is the second most common cause of death from cancer among men. Because it is such a heterogeneous disease (most men with the disease ultimately die from other causes) an individualized risk analysis is essential for optimal clinical management [1].

Background

Multiparametric MR imaging (mpMRI), currently the most accurate imaging technique for prostate cancer detection and staging, utilizes an endorectal coil (ERC) as the standard of care to improve image quality [2,3].

While some practitioners have transitioned to imaging protocols without endorectal coil due to patient discomfort, invasiveness , cost and the increasing prevalence of 3T systems, there is insufficient data to support that one approach is superior or equivalent to the other. Most of the reported studies comparing non-ERC versus ERC MR imaging protocols are either:

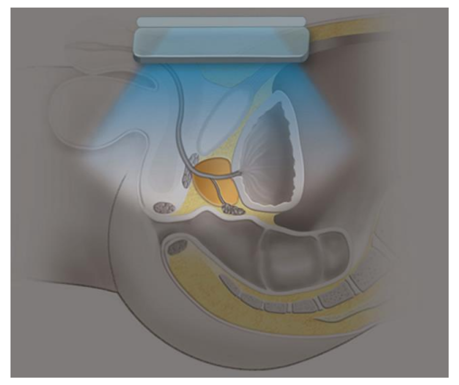
1. Retrospective [4-8]
2. Did not use a paired-patient design (i.e. compared different strategies in different cohorts instead of directly comparing two distinct diagnostic approaches in the same patient) [4-8]
3. Included only men with biopsy-proven cancer who underwent radical prostatectomy [4-7, 9-11]
4. Did not include diffusion-weighted imaging (8, 9, 7-10)(DWI), assessed the diagnostic performance for local staging but not cancer detection (5-7, 9, 10)
5. Were limited to the subjectively perceived image quality
6. Used ERC imaging at 1.5T field strength as the benchmark (4, 6-8)
7. Did not use comparable imaging parameters or hardware across protocols (8, 10, 11).

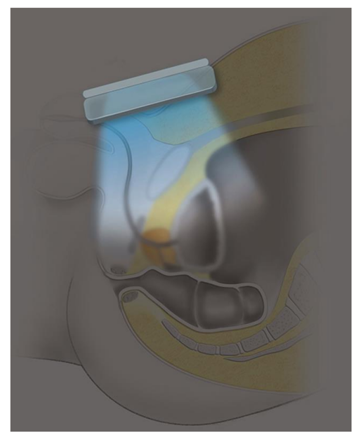
Thus, we propose an objective step-wise determination of signal-to-noise ratio (SNR) gains attributable to the endorectal coil in a 58 patient cohort. In conjunction with clinical diagnostic performance of the same patient cohort, this data can guide the optimization of non-endorectal coil MR imaging protocols in patients with suspected prostate cancer.

Objectives

The objective of our study was to:

1. Determine and compare the SNR for the evaluation of the prostate between two different non-ERC strategies and ERC MRI.
2. Detect a potential association between body habitus and SNR values (see figures below).





Images obtained from patients with larger body habitus may suffer signal loss that is correctable with ERC placement.

Methods and Results:

Image Acquisition

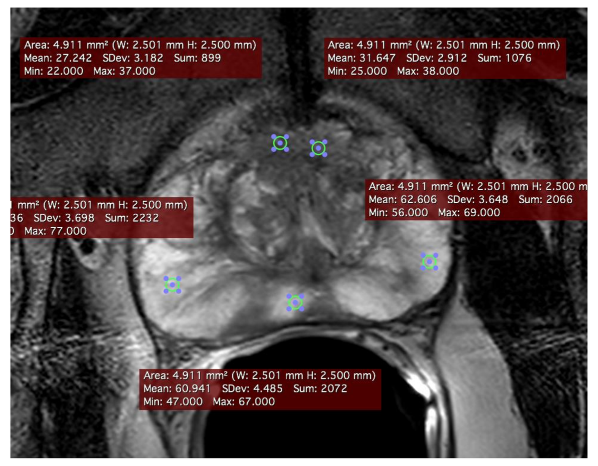
A cohort of 58 patients was randomized into 1 of 2 arms: a standard non-ERC protocol (T2 and DWI b=0, 1000, 2000) and enhanced non-ERC protocol with twice as many signal averages. Patients subsequently underwent the standard mpMRI protocol with T2, DWI and DCE images using the ERC. Since DCE data were exclusively available for the ERC clinical protocol, these were not considered in this investigation. All other acquisition parameters were similar across non-ERC and ERC protocols.

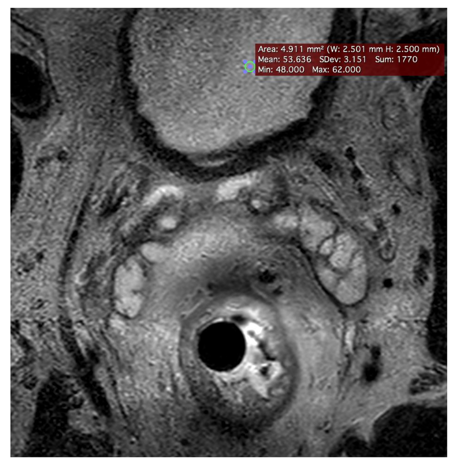
All MRI studies were performed in one of two 3T MRI scanners (Ingenia and Achieva, Philips Medical Systems) with an endorectal (eCoil, Medrad) and a phased-array SENSE 6-channel cardiac (Achieva) or dSTREAM Torso XL (Ingenia) surface coil (Philips Medical Systems).

Body habitus was estimated by five parameters: BMI, waist circumference, pubic circumference, and anterior AP distance and posterior AP distance using prostate as a middle mark (these values were estimated from the images).

ROI analysis

2.5 mm diameter regions of interest (ROIs) were drawn to avoid areas of lower signal density that may indicate lesions. Two ROIs in the anterior zone and three ROIs the peripheral zone at the mid prostate level were used to calculate average signals and noises in those respective areas. Due to the absence of air in each slice, noise in homogeneous urine was substituted as a benchmark for noise (see images below).





The most widely used formulae for SNR measurement:

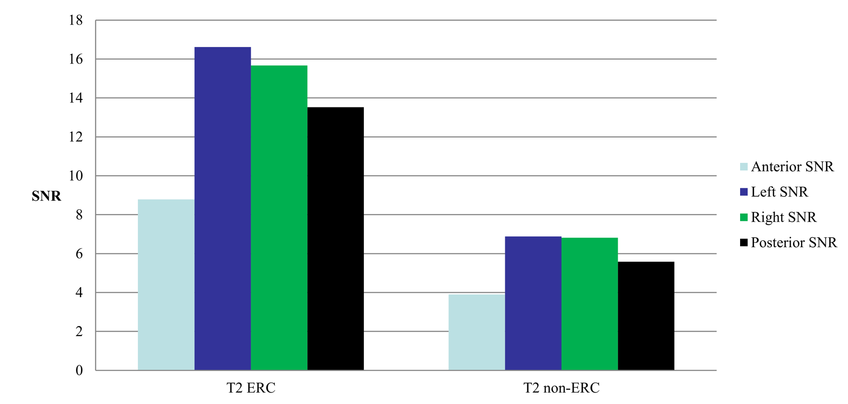
$$SNR = 0.655\frac{\mu_{SI}}{\sigma_b}$$

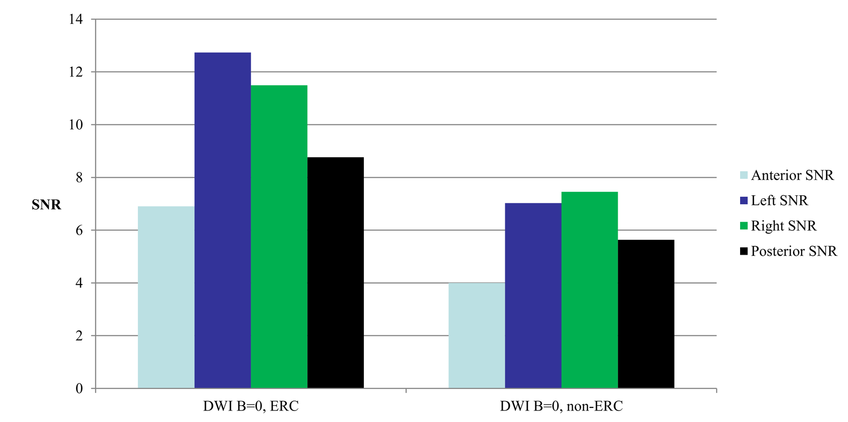
was used, where μ_{SI} represents the mean signal intensity for each 50 pixel ROI and σ_b represents the standard deviation in a homogeneous background (urine). The 0.655 factor is used to correct for the artificial decrease in noise variation (which is positive and negative) in magnitude plots.

Although more accurate measures of SNR exist, this method is acceptable for assessing the statistical significance between imaging protocols irrespective of quantity or degree of improvement [12]. In addition, measurements were bound by limitations in the prospective study.

Results

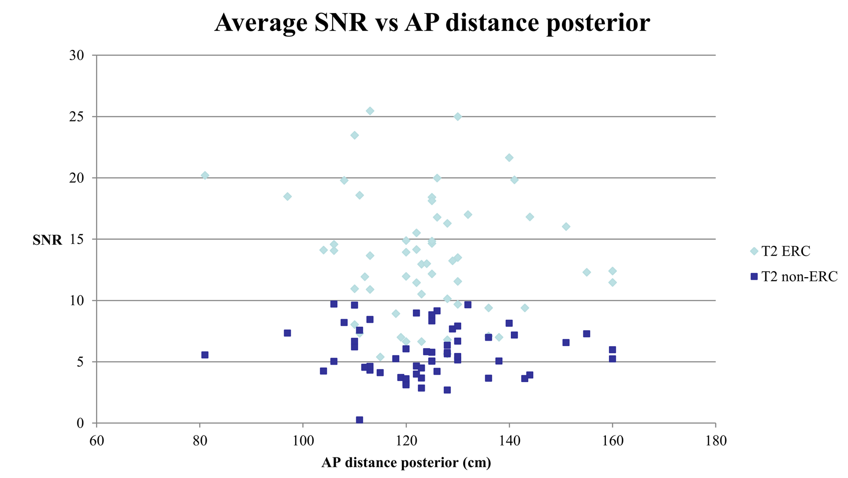
The mean SNRs were calculated for each set of ROIs and averaged over the entire patient cohort (see chart below). Each of the peripheral zone ROIs are presented separately.

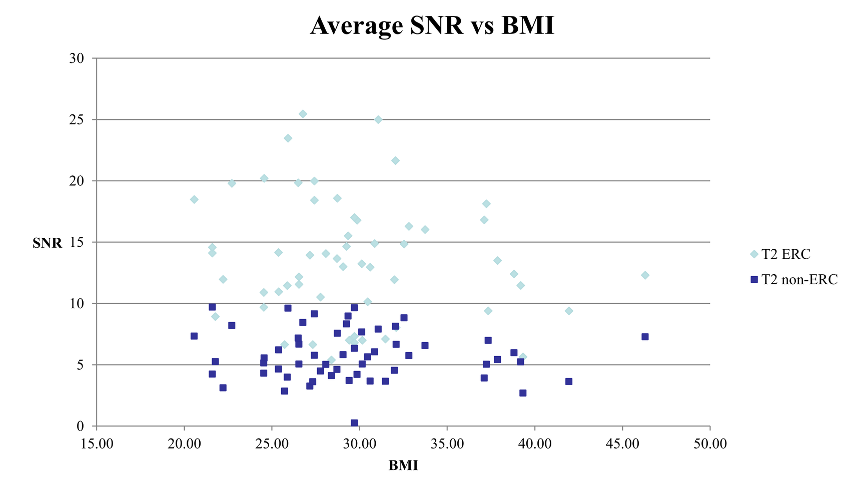


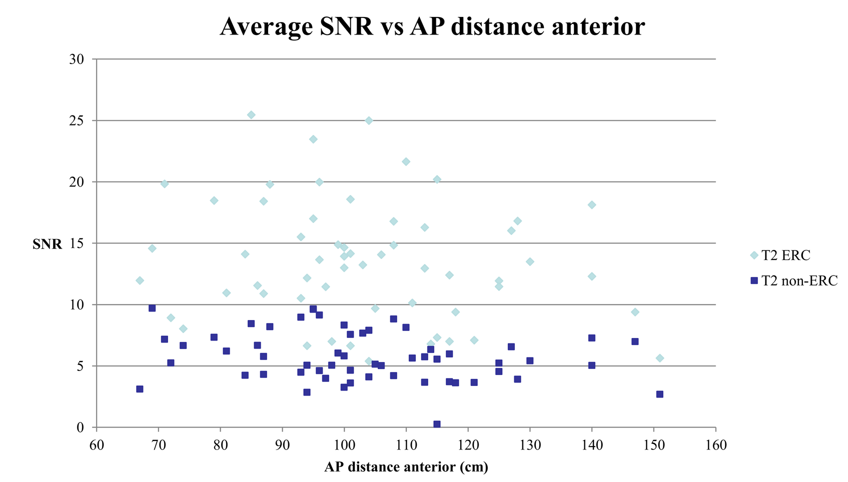


Body Habitus Results

The average SNR composed of all five ROIs in each image were plotted against the body habitus information for the respective patient. In the interest of space and nature of the results, only data for BMI and AP distances comparisons are presented here.







Conclusion

The mean SNR measurements for T2W images with ERC were uniformly twice as large in all ROIs as mean SNR measurements for T2W images without ERC. Similarly, we were able to demonstrate a 1.7x increase in SNR on diffusion weighted images with ERC at b = 0. In addition ANOVA tests verified our hypothesis that the endorectal coil significantly ($p < 0.05$) improves SNR over either non-ERC methods, and no significant differences in SNR were detected between the non-ERC images and "enhanced" ERC images for both T2W and DWI at b = 0.

Comparisons between SNR and body habitus information, specifically BMI, waist circumference, and anterior-posterior distance from anterior-to-prostate and prostate-to-rectal wall in showed no significant difference in both T2W and DWI, b = 0 images between either set of protocols. This did not support our hypothesis that an increased distance between the surface coil and the prostate due to the larger size of the patient would result in an appreciable decrease in signal intensity, and subsequently a decreased SNR as the patient body habitus increased.

The significant increase in SNR in the ERC images, as opposed to the non-ERC images, agree with literature that support the continued use of endorectal coil until better imaging protocols, pulse sequences and/or field strengths become available. Overall, these results can further guide recommendations for multiparametric MR imaging of the prostate with or without endorectal coil, though more data is required to guide coil placement in obese vs thin individuals.

References

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