Comparative Clinical Evaluation of 3.0T MRS with Phased-Array or Endorectal Coils in Prostate Cancer Patients.

Running title: Endorectal coil for 3.0T MRS.

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Abstract

Background: There are no magnetic resonance spectroscopy (MRS) data comparing endorectal coils and phased-array coils in prostate cancer patients on a 3.0T MRI system at the same position using the same sequence parameter.

Objectives: The purpose of this study was to semiquantitatively compare MRS in biopsy-proven prostate cancer patients with phased-array or endorectal coils.

Materials and Methods: Five patients with low-risk prostate cancer underwent MRS with endorectal coils and phased-array coils using a combination of point-resolved spectroscopy (PRESS) volume localization and 3D chemical shift imaging (CSI). Signal intensity lines between 0 ppm and 10 ppm (L0) and positive portion between 1.5 ppm and 2.4 ppm and 3.5 ppm and 4.0 ppm (L), water peak height (H0), citrate peak height (h), H0/L0 and h/L, and the full width at half maximum (FWHM) of the water peak were measured and compared between the two coils.

Results

Both L0 and L were either marginally or statistically significantly shorter for the endorectal coils than for the phased-array coils (L0: $p = 0.063$, L: $p < 0.05$). The H0 / L0 of the endorectal coils was also significantly higher ($p < 0.05$), and the H / L was slightly higher than that of the phased array coils ($p = 0.344$). The mean FWHM of the water peak with the endorectal coil was shorter than that with the phased-array coil ($p < 0.05$).

Conclusion: Endorectal coils provided higher SNR on a 3.0T MRI system than phased-array coils in prostate cancer patients.

Key words

Proton Magnetic Resonance Spectroscopy, Prostatic Neoplasm, Magnetic Resonance Imaging

Introduction

Magnetic resonance spectroscopy (MRS) has emerged as a powerful tool in the field of medical imaging, offering non-invasive insights into metabolic changes within tissues [**1-3**]. In prostate cancer, MRS improves diagnostic accuracy, detects metabolic alterations, and helps characterize and monitor treatment responses. The ability to evaluate tumors non-invasively makes MRS an attractive option for patients and clinicians alike. Despite these benefits, there remain several limitations and challenges in MRS application. For instance, while the use of an endorectal coil enhances the signal-to-noise ratio (SNR) and spatial resolution, its effectiveness in a 3.0T MRI system has not been thoroughly evaluated in clinical cases by comparing it with and without the endorectal coil [**4**]. Previous studies have shown mixed results, with some indicating improved image quality and diagnostic performance with endorectal coil, while others highlight potential drawbacks such as increased artifacts and patient discomfort [**5,6**]. Furthermore, the integration of endorectal coil in clinical practice often faces resistance due to these drawbacks and the added complexity. Moreover, there is a pressing need for more robust comparative studies that can provide definitive evidence regarding the benefits and limitations of using endorectal coils in 3.0T MRI systems. This gap in the literature underlines the importance of our study, which aims to semiquantitatively compare MRS in biopsy-proven prostate cancer patients with and without the use of endorectal coils. By addressing these issues, our research seeks to clarify the actual clinical value of endorectal coils and potentially influence future guidelines and practices in prostate cancer imaging. The purpose of this study was to semiquantitatively compare MRS in biopsy-proven prostate cancer patients using phased-array body coils and endorectal coils.

Methods

Patient

The study included five patients with biopsy-confirmed, low-risk prostate cancer (cT1c-T2a N0 M0, Gleason score 3+3, serum prostate-specific antigen level: 4.5-9.1 ng/mL). Since this is a feasibility study, only 5 patients were enrolled in the study. All patients underwent systemic biopsy of the prostate and at least 14 specimens were obtained. Patients receiving hormone therapy, radiation therapy, or high-intensity focused ultrasound were excluded. This MRI protocol was approved by the institutional review board of TECC (Ref. RO001132), and all procedures were conducted in accordance with the 2013 revision of the Declaration of Helsinki. The patient signed informed consent for the use of the collected MRI data for publication. The patient signed informed consent for the publication of their data.

MRI protocol

Although 3.0T MRI systems generally have a higher SNR than 1.5T MRI systems for prostate MRS, the need for endorectal coils is not well understood and has never been compared and evaluated in the same patient. MRI was performed with both 18-channel phased-array body coil and endorectal coil (Medrad eCoil, Bayer HealthCare, Whippany, NJ, USA) using a commercial 3.0T

MRI system (MAGNETOM Skyra, Siemens, Munich, Germany). After T2-weighted 2D fast spin echo imaging (repetition time [TR] 3050 ms, echo time [TE] 84 ms, flip angle [FA] 133, slice thickness 3 mm, field of view [FOV] 200 mm x 200 mm) and diffusion-weighted imaging (b-values: 0, 1000 s/mm^2), MRS was performed. The matrix size in CSI MRS was 64 x 64 x 16. The endorectal coil was left in place and the MRS from the endorectal coil and that from the phased-array body coil were acquired with the same sequence parameters.

MRS

MRS of the prostate was performed using a combination of point-resolved spectroscopy (PRESS) volume localization and 3D chemical shift imaging (CSI). The PRESS volume was set to encompass the entire prostate while avoiding the coil interface and the influence of surrounding tissue such as seminal vesicles and fat. Outer volume saturation bands (20-30mm thick) were placed to shape the volume of interest (VOI) to better conform to the shape of the prostate and eliminate unwanted extra-prostatic tissue signal. The CSI MRS parameters were as follows: TR 750 ms, TE 145 ms, voxel size 4 x 4 x 4 mm, number of averages 4.

Measured data

The length of the signal intensity line between 0 ppm and 10 ppm (L0) and the height (H0) of the water peak (4.7 ppm) were measured using an endorectal coil or a phased-array coil (**Figure 1a**).

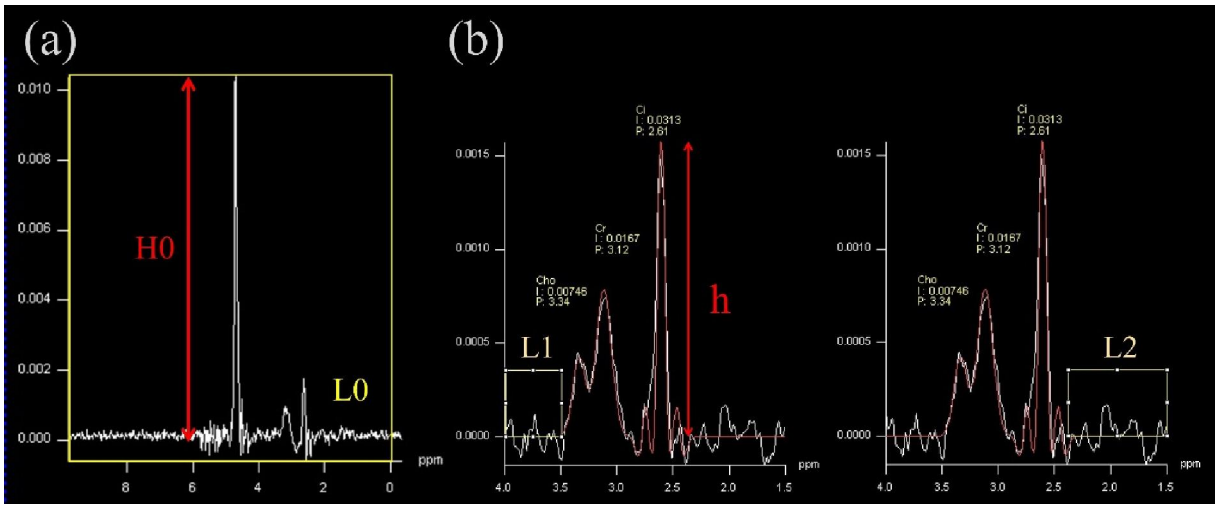

Figure 1. Magnetic resonance spectroscopy data acquisition and analysis.
(**a**) Water peak and noise between 0 ppm and 10ppm. The length of the signal intensity line between 0 ppm and 10 ppm (L0) and the height (H0) of the water peak (4.7 ppm) were measured using an endorectal coil or a phased-array coil. (**b**) Citrate peak and noise between 1.5 ppm and 4.0 ppm. The total length (L) of the positive values of the signal intensity lines from 1.5 ppm to 2.4 ppm (L1) and 3.5 ppm to 4.0 ppm (L2) and the height (h) of the citrate peak (2.6 ppm) were measured using an endorectal coil and a phased-array coil.

The total length (L) of the positive values of the signal intensity lines from 1.5 ppm to 2.4 ppm (L1) and 3.5 ppm to 4.0 ppm (L2) and the height (h) of the citrate peak (2.6 ppm) were measured using

an endorectal coil and a phased-array coil (**Figure 1b**). The voxel location was set at a position where no cancer was found on biopsy and where the citrate peak was higher than the choline peak. The dynamic range of the intensity was set to the maximum and minimum values of the signal intensity line. L0, H0, H0/L0, L (=L1 + L2), h and h/L were compared between the endorectal coil and the phased-array body coil. We also calculated the full width at half maximum (FWHM) of the water peak and compared it between the endorectal coil and the phased-array body coil.

Statistical analysis

All data are expressed as mean +/- standard deviation (SD) and 95% confidence interval (CI). The length of the signal intensity line, the height of the water or citrate peak, the ratio of peak height to signal intensity line length, and the FWHM of the water peak were compared between the two groups. Statistical analysis was performed between the two groups using the Wilcoxon signed-rank test, and a p-value of less than 0.05 was considered statistically significant.

Results

Summarized results of the comparison of endorectal and phased-array body coils are shown in **Table 1**.

Table 1. Comparison of Endorectal and Phased-Array Body Coils.

Parameter	Endorectal Coil	Phased-Array Body Coil	p-value
L0 (Signal intensity line length 0-10 ppm)	1391.2 ± 473.1 (95% CI: 976.5-1864.3)	4171.8 ± 1722.1 (95% CI: 2662.3-5893.9)	0.063
H0 (Water peak height)	13.1 ± 6.6 (95% CI: 7.3-19.7)	13.9 ± 5.1 (95% CI: 9.4-19.0)	0.125
H0 / L0	$9.42 \times 10^{-3} \pm 3.75 \times 10^{-3}$ (95% CI: 6.1-13.2 x 10^{-3})	$3.90 \times 10^{-3} \pm 2.27 \times 10^{-3}$ (95% CI: 1.9-6.2 x 10^{-3})	< 0.05
L (Total signal intensity line length 1.5-2.4 ppm & 3.5-4.0 ppm)	1105.2 ± 283.7 (95% CI: 856.6-1388.9)	2550 ± 1058.0 (95% CI: 1622.6-3608.0)	< 0.05
h (Citrate peak height)	233.4 ± 75.1 (95% CI: 167.6-308.5)	257.4 ± 40.0 (95% CI: 222.3-297.4)	0.313
h / L	0.229 ± 0.0941 (95% CI: 0.146-0.323)	0.125 ± 0.084 (95% CI: 0.051-0.209)	0.344
FWHM of water peak	0.075 ± 0.016 (95% CI: 0.061-0.090) ppm	0.117 ± 0.058 (95% CI: 0.066-0.168) ppm	< 0.05

FWHM: full width at half maximum.

The length of the signal intensity line between 0 ppm and 10 ppm (L0) was 1391.2 +/- 473.1 (95% CI 976.5-1864.3) for the endorectal coil and 4171.8 +/- 1722.1 (95% CI 2662.3-5893.9) for the phased-array body coil (p = 0.063) (**Figure 2a**).

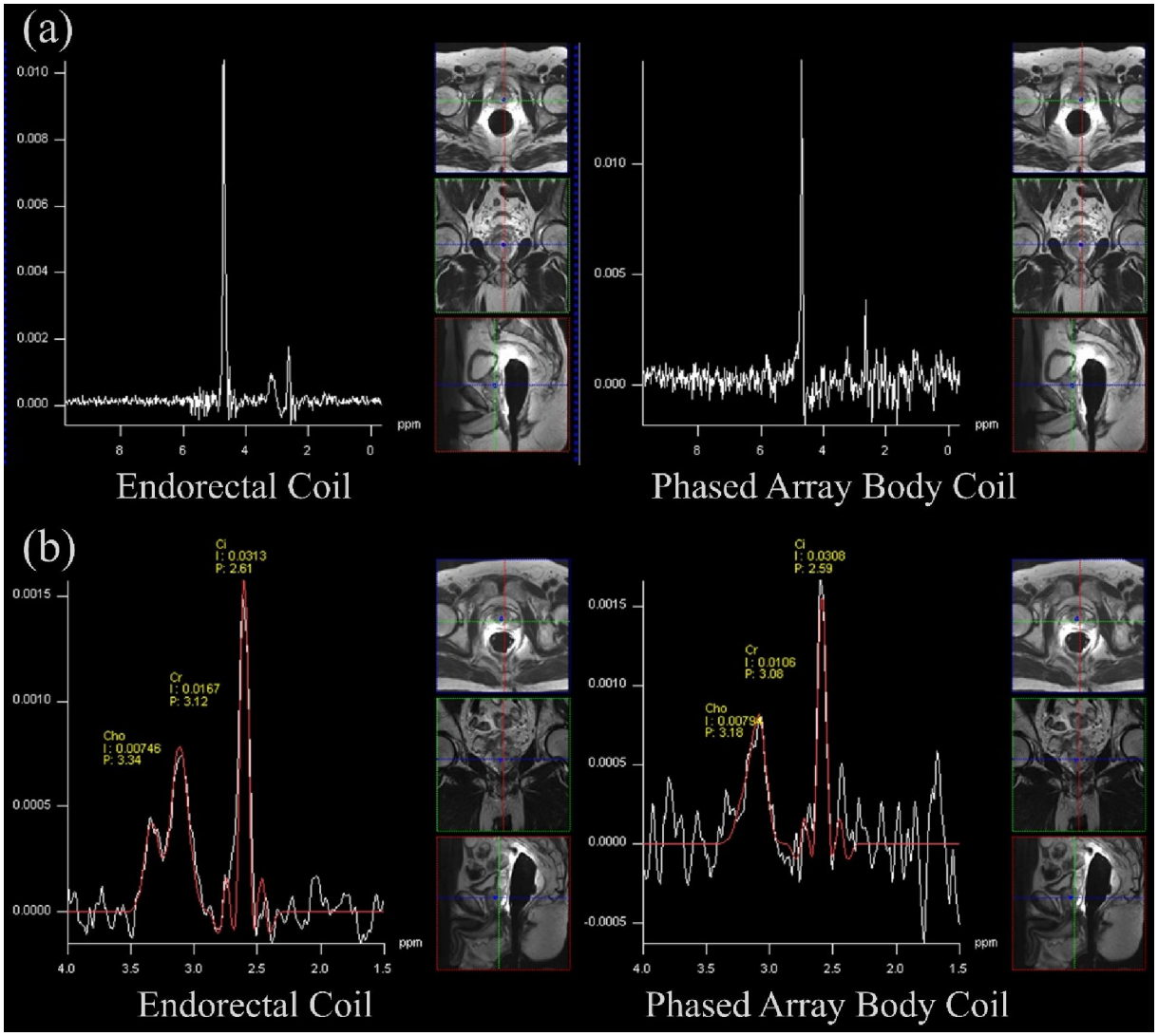

Figure 2. Signal intensity lines of the endorectal coil and the phased-array coil in the same patient at the same position using the same sequence parameter.
(**a**) Between 0 ppm and 10 ppm, the baseline of signal intensity was less disturbed in the endorectal coil than in the phased-array coil, and the length of the line was shorter. (**b**) Between 1.5 ppm and 4.0 ppm, the positive part of the baseline between 1.5 ppm and 2.4 ppm and 3.5 ppm and 4.0 ppm was less disturbed in the endorectal coil than in the phased-array coil, and the line length was shorter.

The height (H0) of the water peak (4.7 ppm) was 13.1 +/- 6.6 (95% CI 7.3-19.7) for the endorectal coil and 13.9 +/- 5.1 (95% CI 9.4-19.0) for the phased-array body coil (p = 0.125). H0 / L0 was 9.42 x 10^{-3} +/- 3.75 x 10^{-3} (95% CI 6.1-13.2 x 10^{-3}) for the endorectal coil and 3.90 x 10^{-3} +/- 2.27 x 10^{-3} (95% CI 1.9-6.2 x 10^{-3}) for the phased-array body coil ($p < 0.05$).

The total length (L) of the signal intensity lines between 1.5 ppm and 2.4 ppm (L1) and

between 3.5 ppm and 4.0 ppm (L2) was 1105.2 +/- 283.7 (95% CI 856.6-1388.9) for the endorectal coil and 2550 +/- 1058.0 (95% CI 1622.6-3608.0) for the phased-array body coil ($p < 0.05$) (**Figure 2b**). The height of the citrate peak (2.6 ppm) (h) was 233.4 +/- 75.1 (95% CI 167.6-308.5) for the endorectal coil and 257.4 +/- 40.0 (95% CI 222.3-297.4) for the phased-array body coil ($p = 0.313$). H / L was 0.229 +/- 0.0941 (95% CI 0.146-0.323) for the endorectal coil and 0.125 +/- 0.084 (95% CI 0.051-0.209) for the phased-array body coil ($p = 0.344$). The mean FWHM of the water peak with the endorectal coil was 0.075 +/- 0.016 (95% CI 0.061-0.090) ppm, while that with the phased array coil was 0.117 +/- 0.058 ppm (95% CI 0.066-0.168 ppm) ($p < 0.05$).

Discussion

This feasibility study compared prostate MRS using endorectal and phased-array coils in five patients with low-risk prostate cancer. The primary finding was a statistically significant difference in the ratio of water peak height to total signal intensity line length (H0/L0), with the endorectal coil showing a higher ratio. This suggests a potentially different signal profile between the two coil types. In addition, the total length of signal intensity lines in certain chemical shift regions (L) was significantly greater with the phased-array coil. Critically, the endorectal coil yielded a significantly smaller FWHM of the water peak, indicating superior spectral resolution. While differences were observed in other measured parameters (L0, H0, citrate peak height (h), and h/L), these did not reach statistical significance. In essence, the study suggests that the endorectal coil provides improved spectral resolution, potentially allowing for more accurate metabolite quantification than phased-array body coils. However, the small sample size (n=5) requires cautious interpretation and highlights the need for larger studies to validate these preliminary findings.

To our knowledge, this is the first report of a semiquantitative comparison of MRS performed in the same patient using endorectal and phased-array body coils with the same sequence parameters. It has been reported that magnetic field strength and coils had a significant effect on SNR in a phantom study, but SNR was evaluated by (choline + creatine)/citrate ratio, which could not evaluate out-of-peak noise [4]. On the other hand, this study not only evaluated the specific peaks of citrate and water, but also compared the applicability of endorectal and phased-array body coils in MRS in a semiquantitative manner by measuring the noise outside the specific peaks. To evaluate the SNR between 1.5 ppm and 4.0 ppm, only positive values of the signal intensity line were evaluated because the post-processing software automatically adjusts the citrate peak to positive values.

This study has several strengths. First, The SNRs of the endorectal and phased-array coils were compared over a wide range of 0-10 ppm, including the water peak. Since the water peak is much higher than the citrate and choline peaks, we believe that using the water peak as a reference peak will more accurately quantify the out-of-peak noise. Second, there are no clinical data comparing endorectal coils and phased array coils in prostate cancer patients on a 3.0T MRI system [4,7]. The results of this study will provide important insight into the use of endorectal coils for

MRS in a 3.0T MRI system.

There are several limitations to the study. First, the number of patients in the study is only five. The benefit of endorectal coils has already been demonstrated at 1.5T field strength [8], and if the same proof of principle is demonstrated at 3.0T, there is no need to increase the number of patients. Second, this is a semiquantitative, not quantitative, comparison of endorectal and phased-array coils in terms of SNR for MRS on a 3.0T MRI system. At present, there is no established standard method for quantitative evaluation of SNR in MRS. Further studies are needed to demonstrate the benefit of endorectal coils in prostate MRS on 3.0T systems.

Endorectal coils in prostate MRS offer superior peak resolution due to increased SNR, which may lead to improved cancer detection. However, they also have drawbacks. Patient discomfort during insertion and inflation is a primary concern, potentially causing anxiety and motion artifacts. The procedure requires additional technologist time and increases costs. Therefore, the decision to use an endorectal coil should be individualized. In patients with high suspicion for prostate cancer or those on active surveillance, the benefits of using endorectal coils may outweigh the disadvantages. Patient tolerance is critical; alternative strategies should be considered for those who are uncomfortable with the procedure. The availability of advanced external coil technology, which may provide comparable image quality, also influences the decision. While research into improved external coils and imaging techniques continues, endorectal coils remain a valuable tool when used judiciously and tailored to the specific needs and circumstances of the patient. Ultimately, the choice should be made in consultation with the healthcare provider, taking into account the clinical indication, patient preference and available resources.

Conclusions

In conclusion, MRS using a 3.0T MRI system has shown semiquantitatively that the endorectal coil provides a higher SNR than the phased-array coil in prostate cancer patients. Further studies are needed to evaluate the benefits of endorectal coils in prostate MRS at 3.0T, specifically assessing improvements in image quality (SNR, artifact reduction), metabolite quantification accuracy, and small tumor detection, while also considering patient tolerance and cost-effectiveness compared to standard phased-array coil techniques.

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