B0 SHIMMING FOR PROSTATE MAGNETIC RESONANCE IMAGING

Prostate cancer remains a significant health concern worldwide, with far-reaching implications for individuals and society as a whole. In fact, **1 in 8 men** will be diagnosed with prostate cancer during their lifetime [1]. Early detection and accurate characterization of prostate tumors are crucial for effective treatment planning and improved patient outcomes.

Multi-parametric Magnetic Resonance Imaging (MRI) has emerged as a valuable tool for prostate cancer assessment, with some European countries now advocating that all men at risk of prostate cancer receive an MRI scan ahead of an invasive biopsy.

While multi-parametric MRI offers several advantages in prostate cancer evaluation, it faces challenges related to field inhomogeneity within the prostate region. Achieving reliable and artifact-free diffusion-weighted imaging (**DWI**) and proton magnetic resonance spectroscopy imaging (1H **MRSI**) in the prostate can be **particularly demanding**. Patients often need to receive anti-peristaltic medications to mitigate the effects of inhomogeneous magnetic fields. However, due to the heterogeneity of the tissue and air surrounding the prostate, even with these interventions, artifacts can still compromise lesion conspicuity and the accuracy of cancer detection.

In this white paper, we present an investigational study [2] aimed at improving DWI and MRSI image quality in the prostate using an advanced shimming technology.

Innovative Technology

To address the artifacts introduced by field inhomogeneities in the prostate, we present a novel solution: ***Dia*** [3] is a semi-flexible local array of shim coils. With its small shim coils in the proximity of the region of interest, the local shim system enables precise and localized magnetic field adjustments within the prostate region.

Since a prostate MRI may save the patients from an unnecessary biopsy, any attempt to improve the MRI data quality could be highly impactful.

The local shim array consists of two modules: a posterior module placed on the MRI bed and an anterior module positioned on the patient. The shim coils are specifically designed to provide strong magnetic field corrections within the prostate region (reaching 3 microtesla (uT) field strength for 1A of current). This exceptional local field control allows for the cancellation of highly localized inhomogeneities. Furthermore, the patented technology incorporated into the system simplifies calibration, making it user-friendly and efficient.

The shim software is specifically designed to provide an optimal workflow including automatic retrieval of the shim volume over the prostate.

Anterior shim modules mounted on a Siemens [4] Flex body coil

Posterior shim modules to be placed under the mattress of the MRI bed

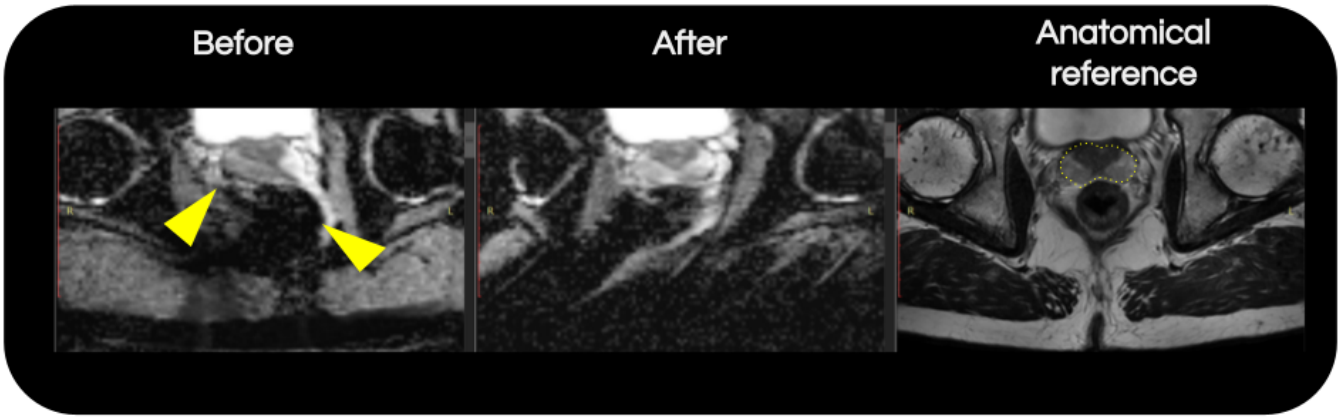
Case Study

To evaluate the effectiveness of shimming using the *Dia* local shim technology, a comprehensive study [2] was conducted using a 3T Siemens Prisma MRI scanner [4] equipped with a Siemens body flex as well as the spine receive array [4]. The primary objective was to improve the reliability and accuracy of prostate DWI and 1H MRSI measurements using the local shim system.

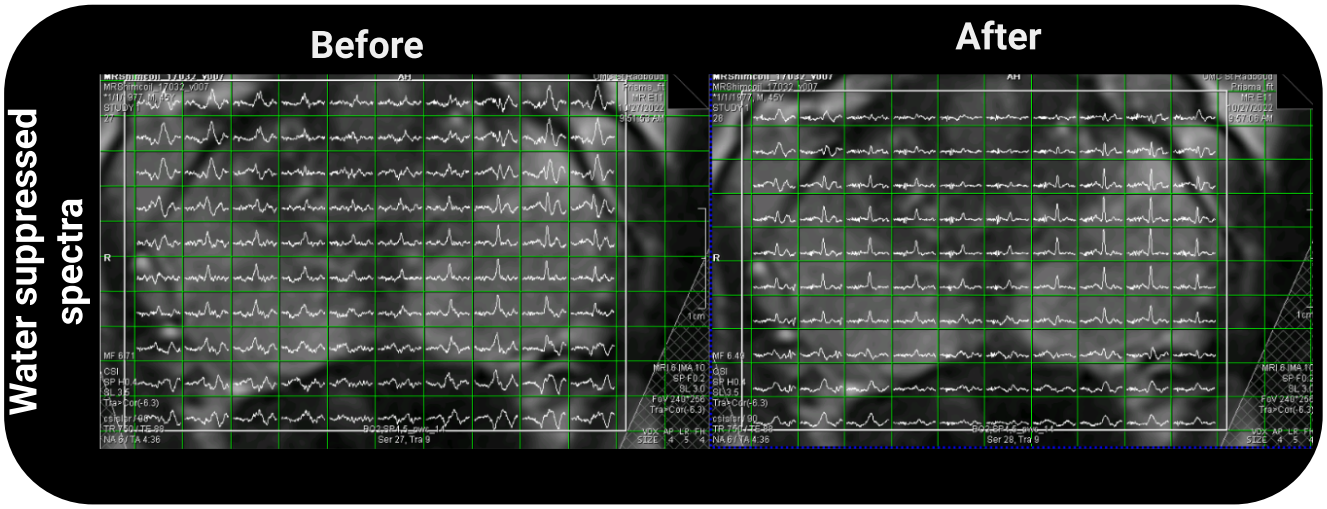
B0 field maps, DWI images and MRSI datasets were acquired once with and once without the use of the local shim system. For DWI, an echo-planar imaging (EPI) sequence with a b-value of 50 s/mm2 was used and the sequence was repeated with b-values 50, 400, and 800 s/mm2, from which an ADC map was generated. For 1H-MRSI data a semi-LASER [5] pulse sequence with lipid and water suppression techniques was used. Anatomical T2-weighted scans were acquired and used as reference.

The results indicated statistically significant improvement (p=0.01) in similarity coefficient (Dice similarity coefficient, DSC) of DWI images to anatomical reference resulting from the use of the local shim system. The increased DSC signifies improved image accuracy and can enhance image interpretation.

For MRSI, the results indicated significant (p=0.018) improvement in citrate line-width, with a 40% reduction in the fluctuation of full-width at half-maximum (FWHM) over the entire prostate (as measured by the standard deviation of the FWHM over the volume). This enhancement indicates improved spectral resolution and more accurate characterization of prostate tissue. Additionally, decreased lipid contamination in 1H MRSI spectra shown in the figure below indicates enhanced metabolite detection.



3T prostate DWI images (left) and anatomical reference (right) showcasing the reduced distortion artifacts after local shimming was used



Water suppressed spectra overlaid on anatomical reference showcasing the reduced lipid contamination and sharper peaks after local shimming was used

Conclusion

Shimming using the local shim technology offers a promising solution to address the challenges associated with field inhomogeneity in prostate DWI and 1H MRSI imaging. The improvements in citrate line-width, DSC, lipid contamination and pile-up artifacts underscore the potential value that enhanced shimming can bring to prostate imaging.

[1] "Key Statistics for Prostate Cancer", American Cancer Society

[2] Tenbergen C, et al., "An add-on local external shim array to improve the main magnetic field homogeneity in the prostate", Proc. Intl. Soc. Mag. Reson. Med. 31 (2023)

[3] CAUTION: Not a medical device. Limited by Federal (or United States) law to investigational use.

[4] All product and company names are the registered trademarks of their original owners. The use of any trade name or trademark is for identification and reference purposes only.

[5] Steinseifer IK et al., Improved volume selective 1H MR spectroscopic imaging of the prostate with gradient offset independent adiabaticity pulses at 3 tesla. In: Magnetic Resonance in Medicine. Vol 74. ; 2015. doi:10.1002/mrm.25476

The local shim systems offered by MR Shim are customizable to any MRI setup and capable of dynamic and real-time shimming
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