SHIMMING FOR QUANTITATIVE SUSCEPTIBILITY MAGNETIC RESONANCE IMAGING

Quantitative Susceptibility Mapping (QSM) has emerged as a powerful imaging modality with significant clinical relevance. It provides valuable insights into the magnetic properties of tissues, enabling improved diagnosis and monitoring of various neurological disorders, including neurodegenerative diseases, traumatic brain injuries, and cerebrovascular conditions. By quantifying tissue susceptibility, QSM offers a unique window into the underlying pathology and can potentially aid in treatment planning and disease progression assessment.

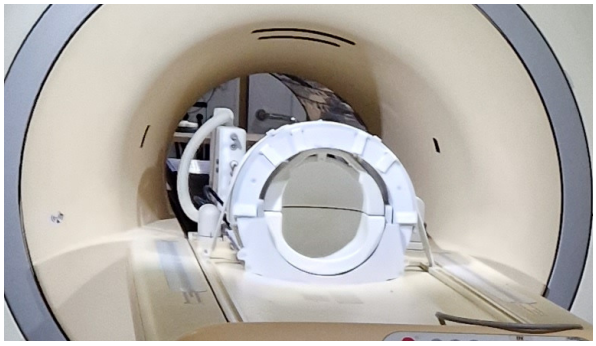
However, the accuracy and reliability of QSM are highly dependent on the precise homogeneity of the MRI scanner's background magnetic field. B0 shimming, the process of optimizing the magnetic field homogeneity, therefore plays a crucial role in ensuring high-quality QSM data. Traditional shimming methods using spherical harmonic shim coils especially at high field MRI may not be sufficient to address the field homogeneity in challenging anatomical regions such as close to the air cavities, leading to artifacts and compromised data quality.

"The remarkable QSM development efforts since 2008, as evidenced by an exponential growth in the number of QSM papers, have propelled QSM technology from basic research to adaptation and investigation for clinical applications" [1]

In this white paper, we present a case study aimed at improving the accuracy and reliability of QSM by leveraging advanced shimming capabilities.

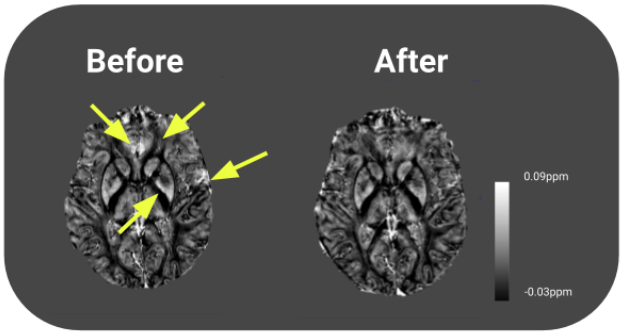
Innovative Technology

The *Elara* local shim system for brain imaging [2] is a **modular local** shim array designed specifically for optimizing magnetic B0 field homogeneity in brain imaging. Compared to the scanner shims, local shim coils provide a higher degree of spatial specificity in magnetic field adjustments. By placing these coils in close proximity to the region of interest, they can generate localized magnetic field corrections. This targeted approach allows for more precise and efficient shimming. Additionally, local shim coils offer increased flexibility in adapting to different anatomical structures.



Elara shim array mounted on the head RF coil

The system comes with all necessary amplifiers and peripherals, ensuring a seamless integration process with existing MRI systems. To achieve optimal magnetic field performance, the Elara local shim system utilizes advanced shim algorithms. These algorithms are specifically designed to address the challenges associated with cavities as well as small and ill-conditioned regions in brain imaging. By optimizing the magnetic field homogeneity, the Elara Head Shimming Array ensures accurate and reliable QSM data.



QSM maps showcasing the reduction in artificially dark and bright spots

Case Study

A case study [3] was conducted using a 7T Siemens Magnetom MRI system equipped with an 8Tx/32Rx NOVA head RF coil [4]. The objective of the study was to reduce artifacts resulting from local B0 inhomogeneity gradients that were too steep to be adequately accounted for during pre-processing of the gradient echo phase data.

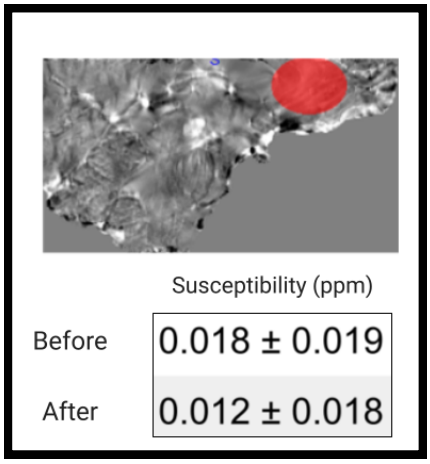
A 16-channel *Elara* local shim system was employed to optimize the magnetic field homogeneity. B0 field mapping was performed to assess the magnetic field inhomogeneity, and global shimming was conducted over the entire volume. QSM acquisition was then performed using 3D multi-echo gradient echo sequences, and susceptibility maps were calculated using the STAR-QSM algorithm with background field removal via V-SHARP.

The outcome of this case study demonstrated a significant reduction of artificially dark/bright spots in the QSM maps. The incorporation of the Elara Head Shimming Array effectively reduced artifacts resulting from magnetic field inhomogeneity. This improvement ensures more accurate and reliable interpretation of the susceptibility maps.

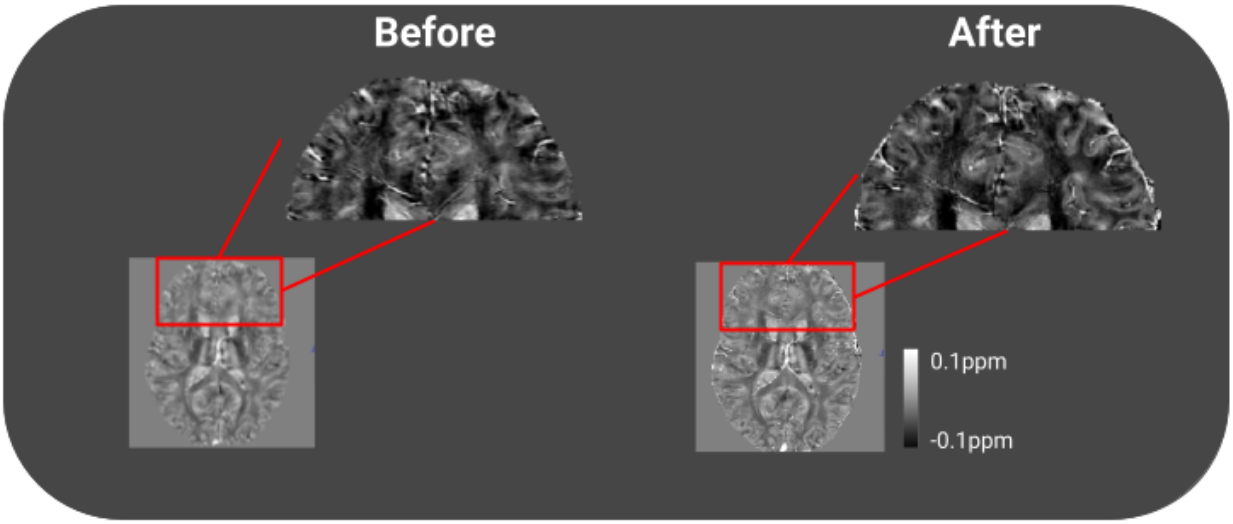
Furthermore, an improved tissue delineation was observed. The optimized magnetic field homogeneity facilitated clearer and more distinct tissue delineation in the QSM images.

This improved visualization enhances the ability to identify and characterize regions of interest, providing valuable information.

Furthermore, the calculated susceptibility values in challenging shim regions (such as the frontal lobe close to the air cavity) were artificially high as a result of the residual inhomogeneities in the magnetic field. With the addition of the local shim array, the inaccuracies in the quantification can be reduced.



Artificially high susceptibility value in the highlighted region before the use of the local shim array



Less blurry images and more tissue dilineation as a result of improved shimming with the local shim array

Conclusion

Shimming plays a critical role in optimizing the magnetic field homogeneity, which is particularly important for acquiring accurate QSM maps. The integration of the Elara Head Shimming Array offers a cutting-edge solution to address the specific challenges associated with shimming for QSM, especially at high field MRI. The case study results presented here underscore the effectiveness of the Elara system in reducing artifacts, improving tissue delineation, and producing clearer QSM images. By ensuring accurate and reliable measurement of tissue susceptibility, the Elara Head Shimming Array enhances the utility of QSM.

[1] Wang, Yi, et al. "Clinical quantitative susceptibility mapping (QSM): biometal imaging and its emerging roles in patient care." Journal of magnetic resonance imaging 46.4 (2017): 951-971.

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

[3] Straub S, et al, "Improvements from local B0 shimming for QSM at 7 Tesla", Proc. Intl. Soc. Mag. Reson. Med. 29 (2021)

The local shim systems offered by MR Shim are customizable to any MRI setup or anatomical region, and are capable of dynamic and real-time updates.
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