Real-time motion and shim correction by volumetric EPI navigators improves 3D LASER localized spiral MRSI of the brain at 3T

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Target Audience:
Scientists interested in sequence development (MRS, motion correction, imaging acceleration) and potential clinical application.

Purpose:
High-field MR spectroscopic imaging (MRSI) is limited by localization artifacts (i.e., imperfect selection profiles, chemical shift errors, B_1 inhomogeneities), motion-related artifacts (i.e., position changes, phase artifacts, B_0 changes, lipid artifacts), and long measurement times (i.e., causing reduced spatial coverage and low spatial resolution).
Low-power localized adiabatic selective refocusing (LASER) provides accurate selection even at high fields [1]. In addition, spiral encoding accelerates MRSI acquisition and thereby enables 3D-coverage with high spatial resolution [2]. Real-time position- and B_0-updating using volumetric navigators (vNav) suppresses motion-related artifacts [3].
In this study we evaluate the benefits of combining a spiral 3D-LASER-MRSI sequence with real-time motion correction to allow fast and robust metabolic imaging of the brain at 3T.

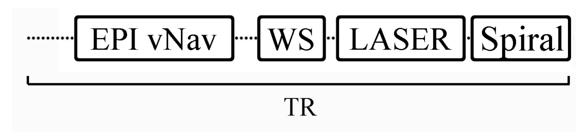

Fig. 1: Sequence schema: the volumetric EPI navigator was added prior to water suppression (WS), LASER localization, and final spiral readout.

Methods:
Phantom and volunteer measurements were performed on a 3T TIM Trio Scanner (Siemens, Erlangen, Germany) using a 32-channel head coil. For phantom measurements a cylindrical multi-compartment phantom containing tubes filled with acetate, ethanol, and isopropyl surrounded by water was used (Fig. 2). IRB approval and written, informed consent were obtained.
A dual-contrast, multi-shot 3D-EPI navigator was inserted prior to water suppression of a LASER localized 3D-MRSI sequence that uses Gradient Offset Independent Adiabatic (GOIA) pulses (i.e. 3.5ms and bandwidth 20kHz) for accurate localization. The vNav calculates both shim and head pose once per TR and applies any relevant corrections within the same TR. Readout was performed by a stack of constant density spirals with acceleration in x,y-plane and standard phase encoding in z-direction (Fig 1). The *in vivo* MRSI sequence parameters were: TR/TE 1500/30ms; 0.5cc isotropic voxels; matrix 25×25×12 interpolated to 32×32×16; Hamming filter; FOV 200×200×96mm; VOI 100×88×44mm; bandwidth 1.25kHz; 2 temporal and 6 angular interleaves; 2 averages; TA ~7min.
Standardized movement patterns (i.e. rotations/translations +20-60° and +4-6cm) were tracked and corrected during the MRSI acquisition. Localization accuracy and spectral quality were evaluated qualitatively and quantitatively (i.e. linewidth, SNR).

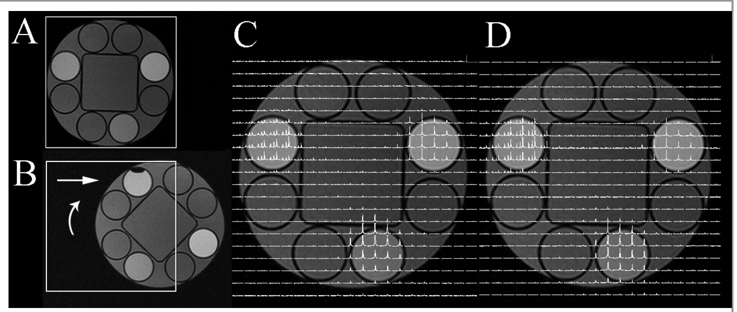

Fig. 2: The localization phantom was moved relative to the MRSI VOI (white quadratic box) during the scan from position (A) by both translations+rotation to position (B). Stack of spectra for a single slice selected from 3D-MRSI comparing (C) MRSI without movement and (D) MRSI with movement corrected by MoCo show excellent correlation.

Results:
In the static case spiral 3D-LASER-MRSI provided accurate localization and high spectral quality in phantoms and volunteers (NAA SNR 88±24, FWHM 8±2 Hz)(Fig. 2,3). Strong motion during the scans significantly biased localization and decreased spectral quality (Fig 3E). Even for extreme motion, real-time MoCo restored the overall data quality (Fig. 2, 3). Similar data quality as in the static volunteer measurements was obtained even for extreme motion (>5cm translation, >30° rotation)(SNR 59±18, FWHM 9±2 Hz). Estimations show that differences of ~20-50% in SNR can be attributed to differences in receive sensitivity that were not corrected.

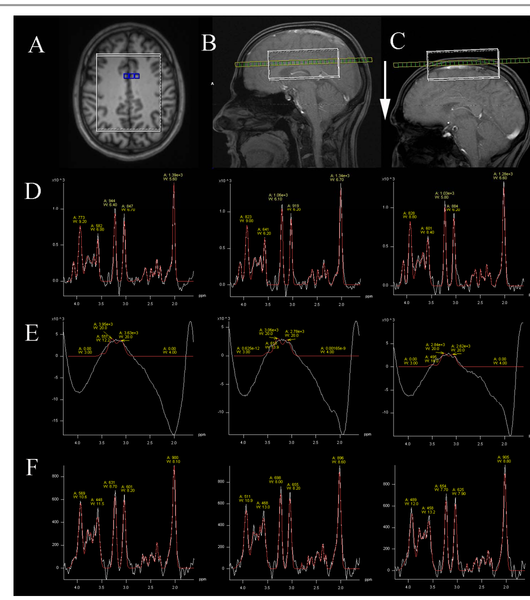

Fig. 3: Three adjacent *in vivo* sample spectra (position indicated by blue boxes) in (A) are compared. The head was moved (~5cm translation, ~30° rotation) from position (B) to position (C) during the scan.
Sample spectra are displayed for the (D) static case compared to motion during the scans: (E) without MoCo and (F) with MoCo. Comparable spectral quality was obtained for (D) and when (F) MoCo was performed during a motion affected MRSI scan.

Discussion/Conclusions:
The efficient combination of spiral 3D-LASER-MRSI with real-time motion and shim updating significantly improved the localization accuracy and spectral quality obtained in both phantoms and volunteers, even if extreme motion was apparent during scans. Additional coil sensitivity correction could further improve results. Spiral 3D-LASER-MRSI with real-time motion and shim correction using volumetric EPI navigators allows fast and robust metabolic imaging of the brain at 3T for clinical routine applications.

References:
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[2] Andronesi et al. Radiology 2012 Feb;262(2):647-61
[3] Hess et al. NMR Biomed 2012 Feb;25(2):347-58