

Automated-Shim Approach to Facilitate ^1H -MRS in Mouse Hearts *In Vivo*

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Introduction: ^1H -MRS of the heart *in vivo* is hampered by technical challenges such as low metabolite concentrations, cardiac and respiratory motion, and magnetic field inhomogeneity. However, good field homogeneity is essential to aid water suppression and to achieve the spectral resolution required to resolve the closely packed metabolite signals. Homogenizing the B_0 -field may be achieved by localized shimming, which is typically performed manually and, therefore, is a time-consuming procedure, prone to sub-optimal results. We sought to implement an automated cardiac-specific shim approach in mice at 9.4T to aid the routine metabolic phenotype characterization of normal and genetically modified mouse hearts at ultra-high magnetic fields.

Materials & Methods: Auto-shim and single-voxel ^1H -MRS were implemented on a 9.4T Varian VNMRS DirectDrive MR system (Varian Inc., USA). Fieldmaps (starting from zero-shims) were acquired in 5 mice ($28.9 \pm 1.9\text{g}$) using a segmented, double-gated 3D gradient echo sequence, repeated at two echo times ($\text{TE/TR}=1/3\text{ms}$, $\Delta\text{TE}=1\text{ms}$, $\text{FOV}=30\times30\times16\text{mm}$, matrix size $64\times64\times32$, 12mm slice thickness in axial orientation), reconstructed off-line and phase-unwrapped as reported previously (1). A $2\mu\text{l}$ voxel was placed in the septum of the heart using a PRESS sequence ($\text{TE/TR}=8/2000\text{ms}$, 4 dummy scans (DS), 16 signal averages (NT), ECG and respiratory gating (2)). A $4\times4\times4\text{mm}$ cubed voxel was either shimmed manually (*M-shim*) at the same location using the same PRESS sequence, or was defined on the fieldmaps, masked and shimmed automatically (*C-shim*). As a third option, the B_0 -field was automatically homogenized over a 4mm diameter sphere (*S-shim*) located at the centre of the $2\mu\text{l}$ voxel using the same fieldmaps/algorithm as for the C-shim. The line-widths of unfiltered spectra, repeated three times for each shim approach, were measured at 50% and 0.55% of the maximum peak height using the VnmrJ scanner software. Following the S-shim, water suppressed metabolite spectra of the $2\mu\text{l}$ voxel were acquired (DS=4, NT=256).

Results: Figure 1 shows the individual line-widths at (a) 50% (FWHM) and (b) 0.55% of maximum peak height (mean \pm SD; open bars – S-shim; grey bars – C-shim; black bars – M-shim). The mean FWHM were $25.0 \pm 8.8\text{Hz}$ for the S-shim, $31 \pm 17\text{Hz}$ for the C-shim and $31 \pm 16\text{Hz}$ for the M-shim, respectively. At 0.55% of the maximum peak height the achieved line-widths were: S-shim – $178 \pm 81\text{Hz}$; C-shim $210 \pm 80\text{Hz}$; M-shim $179 \pm 101\text{Hz}$. The times required for the various shim approaches were: S-shim – $171 \pm 10\text{s}$; C-shim $179 \pm 12\text{s}$; M-shim $206 \pm 66\text{s}$. Following the S-shim metabolite spectra were successfully acquired in all 5 mice. An example from a wild type mouse heart is shown in Figure 2. Only a mild line broadening of 10 Hz was applied.

Figure 1:

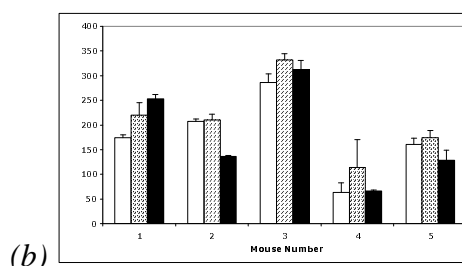
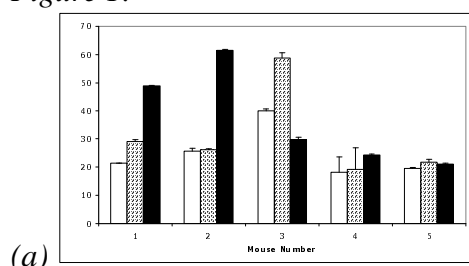
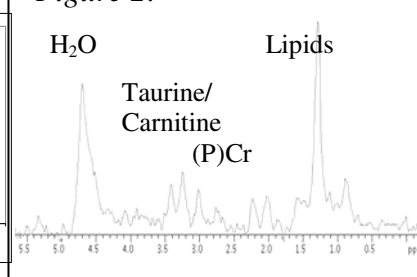


Figure 2:



Discussion & Conclusion: An automated shim-approach was successfully implemented in mouse hearts at 9.4T that routinely achieved comparable or better line-widths at 50% and at 0.55% of the maximum water amplitude than the manual shim within shorter times (scan + post-processing times combined). Importantly, it showed superior reproducibility than the manual shim and did not require extensive user experience, which will make this technology more broadly available. Work is in progress to apply this technique in a metabolic phenotype study to characterize robustness and repeatability of the auto-shim.

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Reference:

1. Clare S, Evans J, Jezzard P. Magn Reson Med 2006;55(1):210-214.
2. Schneider JE, Tyler DJ, et al. Magn Reson Med 2004;52(5):1029-1035.