Identification and prevention of common artefacts in ^{1}H-MR spectra of intramyocellular lipids (IMCL)

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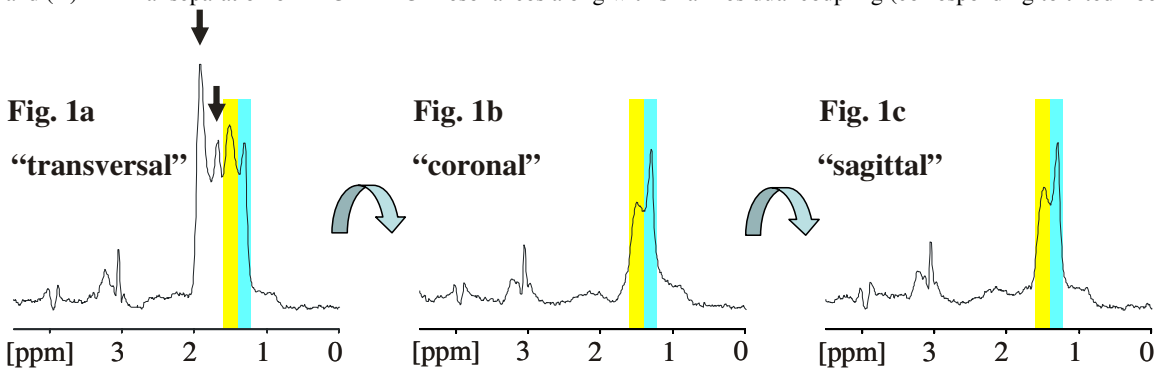
Introduction: Resonances of intramyocellular lipids (IMCL) are separated from chemically comparable extramyocellular (EMCL) lipids signals by up to 0.28 ppm in a ^{1}H-MR spectrum, based on susceptibility differences between plate-like EMCL structures and spherical IMCL droplets ([1] and references therein). The separation depends on the angle between the muscle fibers/fasciae and the main magnetic field. Since IMCL levels are known to be related to insulin sensitivity and to muscle function, an increasing number of different muscles is examined. Fat signals in adipose tissues have a proton density that is several orders of magnitude larger than for the IMCL signal, therefore, even an otherwise negligible contamination from outside the selected voxel may result in deleterious artefacts in the IMCL/EMCL region. Muscle groups in the proximal extremities or the trunk (e.g. spinal musculature) are particularly prone to such contamination since the large coil arrays used in these regions can pick up signals from parts of the body that are not sufficiently suppressed/selected. It was the aim of this study (a) to identify and demonstrate such artefacts, (b) to show the general relevance of this observation in multiple MR systems, and (c) to find ways to overcome this problem.

Methods: IMCL were determined by ^{1}H-MRS using single voxel (11×12×18mm^3) PRESS sequences on two different MR systems (a) at 1.5 Tesla (GE SIGNA, TR 3 s, TE 30 ms) and (b) 3 Tesla (SIEMENS TIM-TRIO, TR 3 s, TE 30 ms) in healthy volunteers. In order to test the occurrence of the artifacts, the voxels were placed in both MR systems in different muscle groups of the thigh and spinal musculature. Additionally, a 2D-MRSI sequence with PRESS volume pre-selection (transverse orientation, TR 1.6 s, TE 35 ms) has been used as previously described [2] to measure muscle fiber orientation based on residual dipolar splitting of the creatine CH_2-group at 3.93 ppm and its relation with the position of the EMCL signal.

Results: The positions of "real" IMCL and EMCL methylene signals are indicated in Figures 1-4 in blue and yellow, respectively. Figures 1 and 2 have been acquired at 3 Tesla, Figures 3 and 4 at 1.5 Tesla, illustrating the fact that artifacts generated by fat depots outside the selected voxel can be found independently of the field strength or the vendor. Figure 1 shows the identification and successful removal (Figs 1b and 1c) of the artifacts (arrows in Fig.1) by a permutation of the gradients/RF-pulses in the PRESS sequence. Figures 2, 3 and 4 illustrate various kinds of in- and out-of-phase artifacts (black arrows). As shown in the example of Fig.1, artifacts in Figs 2, 3 4 could also be removed successfully by permutations of gradients and RF-pulses (spectra not shown). 2D-MRSI data shows generally two types of spectra (A) maximal separation of IMCL/EMCL methylene resonances along with large residual dipolar coupling (corresponding to a parallel orientation of the muscle fibers with the magnetic field), and (B) minimal separation of IMCL/EMCL resonances along with small residual coupling (corresponding to tilted fiber orientations), respectively.



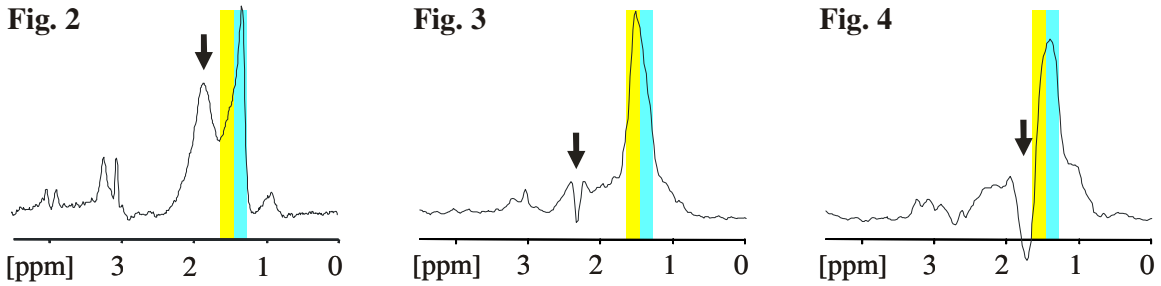


Fig.1 a-c: PRESS spectra acquired from the identical voxel in the vastus muscle. A permutation of the gradients/RF-pulses in b+c removes the artifacts that are indicated in Fig.1a (black arrows).

Fig.2: illustrates that artifacts can mimic in-phase "real" EMCL signals, The artifact at about 1.9 ppm can be removed by permutation of the PRESS sequence while the much smaller, true EMCL signal (shoulder at the IMCL signal indicated in yellow) remains during permutation of the PRESS sequence.

Fig.3+4: shows out-of-phase artifacts at 1.5 Tesla (suboptimal separation of EMCL/IMCL is due to an unfavorable orientation of muscle axis in these cases).

Discussion: Large coil arrays are very helpful if the position of the voxel has to be optimized in complex anatomical structures such as the spinal musculature. However, since lipid signals from adipose tissue are several orders of magnitude larger than IMCL signals from within the selected voxel, even highly selective PRESS sequences may produce artifacts from outer volume signals. Three strategies may help to overcome this problem: (1) whenever appropriate, coils with a limited sensitive volume should be used or coil-arrays should be disabled during spectroscopy except the one closest to the voxel (caveat: arrays may be selectable in groups of multiple coils only); (2) a permutation of the PRESS sequence must result in the same spectrum if no artifacts are picked up; and (3) EMCL signals resonating above 1.6 ppm (corresponding to a parallel orientation of the muscle fibers/fasciae with the magnetic field, where it has been shown that the separation of IMCL and EMCL is maximal [1]) require additional caution.

Conclusions: The measurement of IMCL signals in muscles close to the trunk, in particular with large coils or coil arrays, requires careful inspection of the spectra and identification of possible artifacts by a permutation of the PRESS sequence.

References: [1] Boesch C et al. NMR Biomed 2006;**19**:968-988 [2] Vermathen P et al Magn Reson Med 2003;**49**:424-432.

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