Comparison of adiabatic and non-adiabatic inversion for lipid suppression in ^{1}H-MR spectroscopy

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Abstract: Overlapping signal contributions originating from different metabolites with similar molecular structure is a common problem of in vivo 1H-MR spectroscopy with magnetic field strengths of ≤3 T. One prominent example is the "contamination" of the resonances of the metabolite lactate with fat signals in 1H-MR muscle spectra. The goal of this work was to implement a MRS sequence with inversion recovery based lipid suppression and to test this approach in phantom and in vivo muscle measurements.

Zusammenfassung: Bei der in vivo Protonenspektroskopie an klinischen Scannern mit niedriger bis moderater Feldstärke (≤3 T) stellt die Überlagerung spektraler Signale verschiedener Metaboliten mit ähnlicher Molekularstruktur ein häufig vorkommendes Problem dar. Ein bekanntes Beispiel ist die „Kontamination" der Resonanzen des Energiestoffwechselproduktes Laktat durch Fettsignale in 1H-MR Muskelspektren. Ziel dieses Beitrages war es, eine auf Inversion-Recovery basierende Methode zur Fettunterdrückung zu implementieren und diese anhand von Phantom- und in vivo Messungen im menschlichen Muskel zu testen.

Introduction

Overlapping signal contributions originating from different metabolites with similar molecular structure is a common problem of *in vivo* ^{1}H-MR spectroscopy with low and moderate field strength scanners ($\leq 3\,T$). Taking advantage of the different longitudinal relaxation properties of overlapping metabolites, such as, e.g., of lipids and lactate in ^{1}H-MR muscle spectra, an appropriate selective suppression can be achieved by using an adiabatic lipid nulling approach[1]. Besides demonstrating an implementation of this method on a clinical whole-body MR scanner, this work also compares the efficiencies of lipid nulling performed with adiabatic and non-adiabatic inversion pulses.

Material and Methods

All spectroscopic experiments were performed using a conventional PRESS ^{1}H-MRS sequence (Siemens IDEA, VE11-B) with a preceding non-spatially selective lipid nulling block based on the work of Hövener et al.[1] (Fig. 1).

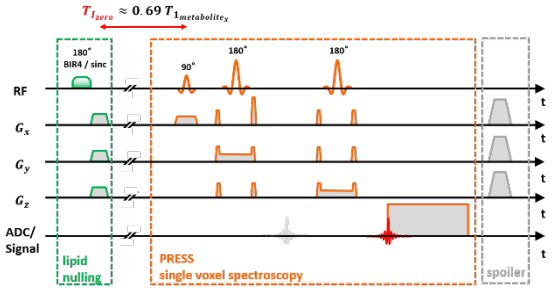

Fig. 1: PRESS sequence with a preceding non-spatially selective lipid nulling block. The suppression block can be played out with either BIR4 or sinc-shaped pulses.

Two different inversion pulses, an adiabatic BIR4 pulse[2] and a non-adiabatic sinc-pulse, were implemented in order to evaluate the inversion efficiency in the presence of inhomogeneous B_1 field distributions. To evaluate the performance, series of spectra were acquired with different inversion times (TI: $10\ to\ 1200\ ms$) in an aqueous fat solution (Lipovenös® MCT 20%) as well as in the right calf muscle of a healthy male subject (voxel size: 35.2 ml; TR/TE = 3000/145 ms). All measurements were conducted with a clinical whole-body 3 T MR scanner (Prisma Fit VE11B, Siemens Healthineers AG) by using a flexible, double-tuned surface coil (^{1}H/ ^{31}P, $\emptyset: 11\ cm$, RAPID-Biomedical). Metabolic intensities were quantified by using the jMRUI 5.2 package (http://www.jmrui.eu).

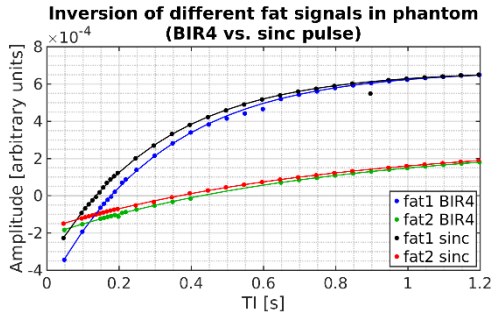

Fig. 2: Inversion-recovery time courses of different lipid signals in aqueous fat solution, obtained with an adiabatic BIR4 (blue, green) and a non-adiabatic sinc-pulse (black, red).

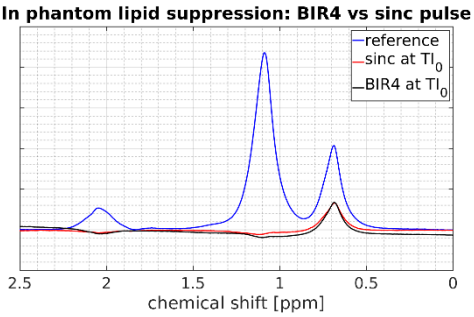

Fig. 4: Comparison between aqueous fat solution spectra obtained with the lipid-nulling method (BIR4: black, sinc: red) and a conventional PRESS spectrum (blue).

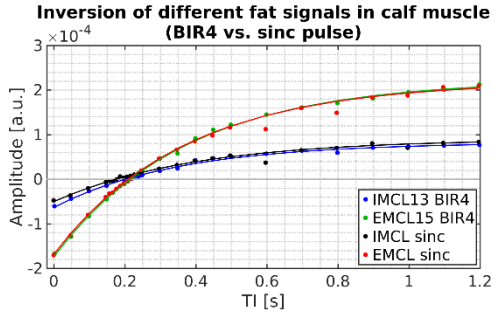

Fig. 3: Inversion-recovery time courses of different lipid signals in the human calf muscle, obtained with an adiabatic BIR4 (blue, green) and a non-adiabatic sinc- pulse (black, red).

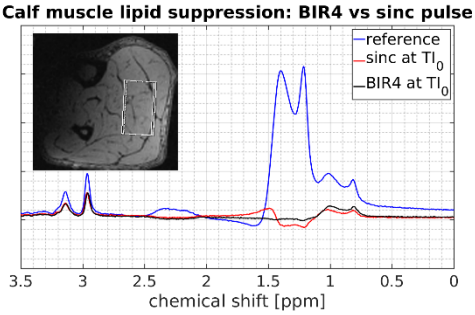

Fig. 1: Comparison between human calf muscle spectra obtained with the lipid-nulling method (BIR4: black, sinc: red) and a conventional PRESS spectrum (blue).

Results

Fig. 2 and Fig. 3 demonstrate the intensity evolutions of two different lipid compounds (phantom: fat1 at 1.1 ppm and fat2 at 0.7 ppm; *in vivo*: EMCL at 1.4 ppm and IMCL at 1.2 ppm), which were measured with the phantom and in the calf muscle with varying TI times and by applying adiabatic or non-adiabatic inversion pulses. Depending on the applied inversion pulse, the fat1 and fat2 signal-TI-curves of the phantom reveal different zero-crossings (TI_0), but similar T_1 time constants (fat1: $T_{1,BIR4}$ / $T_{1,sinc}$ = 0.317 / 0.310 s, fat2: $T_{1,BIR4}$ / $T_{1,sinc}$ = 0.76 / 0.77 s). However, as seen from phantom spectra acquired at TI_0 (Fig. 4), there is no substantial difference in the lipid nulling efficiency between the adiabatic or non-adiabatic inversion pulse. *In vivo*, however, appropriate lipid suppression was achieved with the adiabatic inversion pulse, whereas the spectrum acquired with an inversion time close to TI_0 with the sinc-inversion pulse revealed significant residuals of the lipid signals (Fig. 5). This may originate from the improved robustness of the adiabatic pulse against B_1 field inhomogeneities.

Discussion and Conclusion

In this work, we applied two different inversion pulses (adiabatic and non-adiabatic) to suppress lipid signals in phantom and *in vivo*. Whereas both inversion pulses performed similarly in the phantom measurements regarding suppression efficiency, the *in vivo* measurement in the calf muscle shows clear improvement when using the adiabatic pulse. These preliminary results should be carefully verified in further measurements including, for example, measurements in other human muscles and by examining a proper number of subjects.

References

[1]Hövener J.B. et al..Whole-Brain N-Acetylaspartate MR Spectroscopic Quantification: Performance Comparison of Metabolite versus Lipid Nulling. AJNR Am J Neuroradiol 2008; 29:1441-45.

[2]Garwood M., Ke Y., Symmetric Pulses to Induce Arbitrary Flip Angles with Compensation for RF Inhomogeneity and Resonance Offsets. Journal of Magnetic Resonance 94 1991, 511-525.