Proton MRS Acquisition Scheme with Long Echo Time and without Water Suppression Simplifying IMCL Evaluation

J. Ren[1,2], A. D. Sherry[1,3], and C. R. Malloy[1,4]

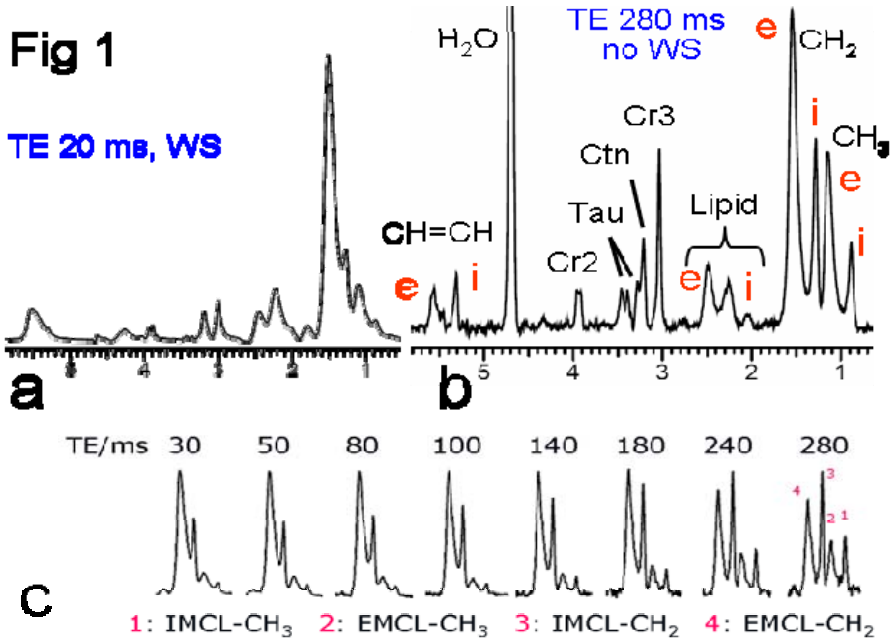
[1]Advanced Imaging Research Center, University of Texas Southwestern Medical Center, Dallas, Texas, United States, [2]Department of Radiology, University of Texas Southwestern Medical Center, [3]Department of Chemistry, University of Texas at Dallas, Richardson, Texas, United States, [4]VA North Texas Health Care System

Introduction

^{1}H MRS enables resolution of intra- from extra-myocellular lipids (IMCL and EMCL) in skeletal muscle [1,2]. It is believed that elevated IMCL may predispose to insulin resistance and diabetes and for this reason MRS is now widely used in nutritional research. However, in a conventional muscle ^{1}H MR spectrum acquired with the popular single-voxel localization sequence at short TE (< 60 ms), EMCL often dominates the fat signals. The severe overlap between EMCL (e) and IMCL (i) requires fitting procedures to separate these two components, even for spectra collected on ultra-high field scanner at 7 Tesla [3]. This post-processing, unfortunately, is cumbersome because 1) the chemical shift region of interest (from 0.8 to 1.8 ppm) is crowded by multiple lipid resonances, and 2) the lineshape of EMCL resonances are asymmetric, with a "tail" over-shadowing the neighboring smaller upfield IMCL resonances. This asymmetry, caused by the orientation-dependence of strands of extracellular lipids dispersed among muscle fiber bundles, is mathematically more difficult to deal with than the familiar Gaussian or Lorantzian lineshape. In spite of improved sensitivity and dispersion at high fields, these limitations hamper the application of ^{1}H MRS as a clinical research tool for evaluation of fat metabolism in muscle. The goal of the current study was to evaluate a long echo time sequence with the goal of improving chemical shift resolution.

Methods

Twenty healthy volunteers aged 22-57 years participated in the study following the guidelines of the local IRB with informed written consent. The MRS data were collected using STEAM-based sequence on a Philips 7T MRI scanner (Achieva, Best, The Netherlands), with leg positioned parallel in Bo field and the left calf placed on the surface of a customized 2-channel T/R coil that fits the shape of the calf. For the voxel localization, axial, coronal, and sagittal T2-weighted turbo spin echo images were acquired of the left calf muscle. Typical parameters were: TR 1.5 s, echo TE 75 ms, turbo factor 16, FOV 180x180 mm. For ^{1}H spectral acquisition, STEAM- or PRESS-based sequence was used to collect data from single-voxels located in soleus and/or gastrocnemius muscles. Typical parameters were: TR 2 s, short TE 20 ms with water-suppression (WS), and long TE 140 or 280 ms without WS, voxel dimension APxRLxHF 12x15x25 (4.5 ml, or larger if the anatomy permits) for soleus and 11x12x23 (3.0 ml, or larger if the anatomy permits) for gastrocnemius, spectral bandwidth (BW) 4 kHz, number of points (NP) 4,096 and zero-filled to 8,192 prior to Fourier transform, Number of scan (NA) 16 (scan time 32 sec) to 128 (scan time4.3 min), phase-cycling 16.



Results and Discussion

Figs 1a and 1b compare typical ^{1}H spectra acquired from soleus muscle with conventional method (water-suppression, with short TE of 20 ms, NA 16 scans), and with the long echo-time scheme (no water suppression, long TE of 280 ms, NA 128 scans), under otherwise identical conditions such as shimming, voxel location and size, etc. At long echo times, spectral resolution was enhanced, not only in the important fat region (0.8 - 1.8 ppm), but also "metabolic finger-print" region (3 – 4 ppm), and "un-saturated fat marker" region (~5 - 6 ppm). Fig. 1c shows the ^{1}H spectra collected from soleus muscle of a different subject at a constant TR of 2 s, but at varying TEs, from 30 to 280 ms, for the fat region from 0.8 to 1.8 ppm. This is to illustrate that the enhanced spectral resolution at lengthened TE is mainly a result of two facts: (1) an faster decaying of EMCL than IMCL, and (2) an increasing lipid CH_3/CH_2 intensity ratio. The additional benefits of long echo time scheme include (1) elimination of preparation time for optimizing WS, (2) lower SAR level, (3) water signal as an internal standard for metabolite quantification, and (4) clean spectral base line due to insensitivity to imperfect pulse, and side-band and other artifacts. The trade-off for long echo time spectra is the increase in number of scan (from 16 to 128) to compensate sensitivity loss, but a scan time of 4.3 min is acceptable.

Conclusion We demonstrated that an easy-to-read muscle ^{1}H spectra can be acquired using a long echo time scheme at 7T, to meet the clinical challenge for a simple, accurate, fast and effective evaluation IMCL content and fat composition. This scheme would be a valuable tool for investigating high-profile diseases such as insulin resistance and diabetes.

References 1. Schich F et al Mag Reson Med 1993, 29:158-67. 2. Boesch C et al NMR Biomed 2006, 19:968-88. Khuu et al Magn Reson Med 2008, 59.