Musculoskeletal Fat Quantification by Using High-Resolution Metabolite Cycling Magnetic Resonance Spectroscopic Imaging at 3 T

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Introduction

The increase of musculoskeletal fat content has been linked to several diseases such as type 2 diabetes mellitus[1], cerebral palsy[2], and Duchenne muscular dystrophy[3]. Dixon MRI technique[4] is usually used to quantify fat fraction (FF). However, Dixon method cannot differentiate between intramyocellular lipid (IMCL) and extramyocellular lipid (EMCL). In certain situation, IMCL becomes the lipid of particular interest since the increase of its level found to be a marker for insulin sensitivity[5]. Conventional MRSI overcomes these by providing spectra over any ROI size, but it requires a long acquisition time. In this work, we demonstrate a high-resolution density–weighted concentric ring trajectory (DW-CRT) metabolite cycling MRSI acquisition, which provides high SNR results of simultaneous fat and water only spectra within clinically acceptable time at 3T.

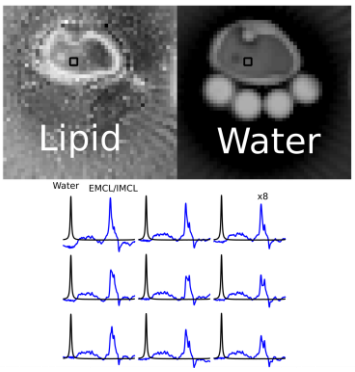

Figure 1. Representative water (black) and fat (blue) spectra from the FID DW-CRT metabolite cycling MRSI.

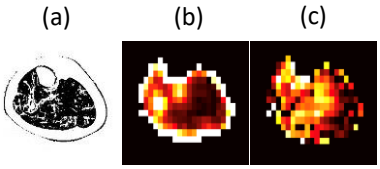

Figure 2. (a): a Dixon-MRI image shows the global fat distribution, (b): EMCL, and (c) IMCL distribution maps

Methods

In-vivo lower leg scans were acquired from healthy volunteers using the integrated body coil of Siemens Prisma 3-Tesla MR system (Siemens, Germany). The FID MRSI acquisition parameters were: FOV = 240 mm × 240 mm, matrix size = 48×48, slice thickness = 10 mm, acquisition delay = 4 ms, repetition time = 1 s. DW-CRT was prescribed using a Hanning-window and the following parameters: points-per-ring = 64, temporal samples = 512, resolution = 5×5×10 mm^3, number of rings = 24, spatial interleaves = 4, time acquire = 96 s and spectral bandwidth = 1250 Hz[6]. For metabolite-cycling, an 80 Hz transition bandwidth (-0.95 < Mz/M0 < 0.95) and 820 Hz inversion bandwidth (-1 < Mz/M0 < -0.95), 70 to -750 Hz) downfield/upfield from the carrier frequency (carrier frequency offset=+60 Hz and -60 Hz for downfield and upfield). The number of averages was 1, corresponding to a total acquisition duration of 3:16 minutes. For comparison, Dixon was performed with a proton density turbo spin-echo sequence, total acquisition time = 7:10 minutes, echo time = 11 ms, repetition time = 5 s, echo train length = 15, 2 averages, FOV = 200 mm × 200 mm, and resolution = 0.6×0.6×10 mm^3. For MRSI, prior to LCModel fitting[7], combined upfield/downfield FIDs were used to remove residual eddy current effects.

Results and Discussion

Representative water-only and fat-only spectra from the FID DW-CRT MRSI illustrated in Figure 1. Figure 2 shows the global fat only Dixon image and the EMCL and IMCL distribution maps derived from the FID DW-CRT MRSI. Since separate spatial distribution maps of IMCL and EMCL lipids is generated, the FF from this sequence can be also calculated for global fat, EMCL-only, or IMCL-only in a similar mathematical way used by Dixon. These results show that our proposed fast high-resolution metabolite cycling MRSI sequence can be a basic clinical tool to quantify ECML, ICML, or global fat in muscles or even for the Intra-Hepatocellular Lipids (IHL) to diagnose fatty liver.

References

1. Goodpaster et al, The American journal of clinical nutrition, 2000;71; 885-892. 2. Johnson et al, The Journal of pediatrics, 2009;154;715-720. 3. Wren et al, American Journal of Roentgenology, 2008;190;W8-W12. 4. Dixon, Radiology, 1984;153;189-194. 5. Krssak et al, Diabetologia, 1999;42;113-116. 6. Steel et al, Scientific Reports, 2018;8;7792. 7. Provencher, Magnetic resonance in medicine, 1993;30;672-679.

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