Non-Invasive Quantification of Fatty Infiltration of Lumbar Para-Spinal Muscles: Comparison of Different Acquisition and Correction Techniques

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Introduction

Single-voxel MR spectroscopic fat-signal quantification found increased fat-signal fractions (*FSF*) in lumbar para-spinal muscles of patients with chronic lower-back pain when compared to those in asymptomatic volunteers, while a qualitative visual grading failed to differentiate the two groups [1]. In contrast to single-voxel spectroscopic quantification, newly developed methods promise large-volume image-based quantitative estimation of fat-signal fractions—but various acquisition and correction algorithms are currently under evaluation.

Purpose

To estimate and compare quantitative *FSF* of symptomatic patients with lower-back pain based on (i) single-voxel spectroscopy, on (ii) 3D dual-gradient-echo based fat-water-signal separation, and on (iii) 3D multiple-gradient-echo based fat-water-signal separation with and without T2* correction, as well as with T2* correction plus correction for multiple fat spectral lines.

Materials and Methods

Patient data and data acquisition In this IRB approved prospective study 56 patients (32 women; 52±15 years) suffering from lower-back pain underwent clinically indicated MRI on a 1.5-Tesla scanner (HDxt, General Electric, Waukesha, WI). The exam included acquisition of left and right-side single-voxel point-resolved spectra (TR/TE 4000/27.0 ms, 2048 acquisition points, NEX 2, number of scans 16, voxel volume 1.5 x 1.5 x 4.0 cm, spectral width 2500 Hz), 3D dual-gradient echo imaging (*3D DE*, "LAVA-FLEX") (TR 6.2 ms, TE1/TE2 2.1, 4.2 ms, flip angle 12°, FOV 40 x 32 cm, in-plane acquired data points 320 × 224, slice thickness 4.0 mm, receive bandwidth ± 125 kHz, NEX 2, number of slices 40, acquisition time 33 s), and 3D multiple-gradient-echo imaging (*3D ME*, "IDEALQUANT") (TR 20.1 ms, 8 echoes, TE: 1.6, 3.2, 4.8, 8.1, 10.3, 12.5, 14.8, 17.0 ms, flip angle 5°, FOV 40 x 40 cm, in-plane acquired data points 300 × 224, section thickness 4.0 mm, receive bandwidth ±143 kHz, number of slices 20, parallel-imaging acceleration factor 2, acquisition time 60 s) at the level of vertebral bodies L4 and L5.

Data processing and evaluation *FSF* were calculated as (fat signal / (water signal + fat signal)) in all cases. For $FSF_{SPECTRO}$, the total integrated signal intensity in spectral regions between 0.5 and 2.0 ppm, and between 4.0 and 5.4 ppm was assigned to fat and water, respectively, after coil-combination, to-*Gaussian* line-broadening of 1.5 Hz, zero-filling, *Fourier*-transformation, and phase- and baseline correction of the data with the proprietary SAGE software tool (Spectroscopy Analysis of GE, General Electric, Waukesha, WI). Image-based water and fat signals were estimated in volumes of interest that were placed at locations that matched the spectroscopy single voxels, neglecting chemical-shift related displacement of the actually excited water and fat volumes [2]. Both *3D DE* and *3D ME* sequences featured vendor-provided image reconstruction of separate fat- and water-signal only image series. Custom software was used to calculate image series displaying fat-signal fractions from these (FSF_{DE*} and FSF_{ME*}). In addition, the *3D ME* recon also yielded T2* corrected fat and water image series, which were also used to generate maps of fat-signal fractions (FSF_{ME}). Finally, the *3D ME* recon directly estimated fat-signal-fraction image maps (FSF_{ME_ML}) corrected for T2* and presence of multiple spectral lines in the fat spectrum. Variables are described as mean ± standard deviation. The data was descriptively reviewed and statistically tested for normality with the Kolmogorov-Smirnov test. Correlation between MRI and spectroscopic measurements was assessed using Pearson's correlation analysis. Student's t-test for related samples was used to test for significant differences between MRI and spectroscopy, whereas the method of Bland and Altman was used to determine the mean differences (bias) with corresponding limits of agreement. P-values <0.05 were considered statistically significant.

Results

Mean $FSF_{SPECTRO}$ was 19.6±11.4 (range, 5.4-63.5, n=102); mean FSF_{DE*} was 21.2% (SD ± 14.1%; range 3.4% – 65.2%); mean FSF_{ME*} was 20.1% (SD ± 11.9%; range 4.3% - 73.4%); mean FSF_{ME} was 17.4% (SD ± 11.9%; range 4.0% - 72.1%) and mean FSF_{ME_ML} was 14.9% (SD ± 13%; range 1.2% - 63.3%). Significant linear correlations were observed between all image-derived fat indices and $FSF_{SPECTRO}$ (all $p<0.001$) with the correlation coefficient of FSF_{DE*} ($r = 0.92$) being slightly lower than those of FSF_{ME*} and FSF_{ME} (both, $r = 0.96$). FSF_{ME*} estimates were similar to spectroscopic estimates with no significant difference ($p=0.11$) and a mean bias of +0.5% with narrow limits of agreement (-6.0% to +7.2%). FSF_{DE*} was significantly higher than $FSF_{SPECTRO}$ ($p<0.01$) with a mean measurement bias of +1.6% and wide limits of agreement ranging from -8.6% to +11.9%. FSF_{ME*} , FSF_{ME} estimates, on the other hand, were both lower than $FSF_{SPECTRO}$ (both, $p<.001$) with a mean measurement bias of -2.2% , -4.7% and smaller limits of agreement ranging from -9.3% to +4.9% , -13.11% to +3.8% respectively.

Conclusions

Large-volume image-based and spectroscopic estimations of fat-signal fractions correlated reasonably well, with the spectroscopic results being best approximated by 3D multi-echo acquisition with neither T2*- nor multiple-spectral-line corrected fat- and water-signal separating reconstruction. Correction methods optimized for quantitative liver-fat content estimations may require adaptation for fat quantification in skeletal muscles.

[1] B. Mengiardi et al., Radiology 2006; 240: 786-792.
[2] W.R. Lazar et al, Proceedings of the ISMRM, #936, 2010