Simultaneous Muscle Water T2 and Fat Fraction Mapping using Transverse Relaxometry with Stimulated Echo Compensation

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Target audience: To clinicians and researchers involved in neuromuscular disorders studies.

Introduction

Skeletal muscle inflammation/necrosis and fatty infiltrations are strong indicators of disease activity and progression in many neuromuscular disorders. They can respectively be assessed by muscle T2 relaxometry[1] and water/fat separation techniques[2]. These two evaluations are usually performed separately with dedicated NMR sequences. Estimates of muscle T2 are often derived from standard Multi-Slice Multi-Echo (MSME) acquisitions and mono-exponential fitting of the temporal signal decay. However, MSME signal rarely displays a pure spin-echo decay as it is a mix of refocused echoes (T2 weighted) and stimulated echoes (T1 and B1+ weighted). Recently, Lebel and Wilman have proposed to process MSME signal using the Extended Phase Graph (EPG) algorithm to take into account stimulated echo for accurate transverse relaxometry[3]. Nevertheless, in fatty infiltrated muscles, because of the long T2 of fat as compared with T2 of normal muscle tissue, a single-component fit of non-fat-suppressed MSME signal results in "muscle" T2 determination that primarily reflects the degree of fat infiltration and hides inflammation processes. Rooney et al. already derived water T2 values on fatty infiltrated muscles from a fat suppressed MSME sequence using the EPG algorithm[4]. But since the EPG approach can be extended to quantify multicomponent T2 (e.g. in the brain[5]), we propose to apply a fat/water multi-component EPG fitting to simultaneously quantify the muscle water T2 and fat fraction from standard MSME acquisitions.

Materials & Methods

Twenty four patients with different degrees of fatty infiltration, five patients with diagnosed myositis and five healthy volunteers were scanned on a 3T whole-body scanner (Tim Trio, Siemens Healthcare). MSME sequence was acquired on the thighs with the following parameters: TR=3000 ms, nominal flip angles=90°/180°, a train of 17 echoes (TEs from 9.5 to 161ms, ES = 9.5ms), FOV = 224x448 mm^2, pixel size = 1.4x1.4mm^2, 11 slices (TH = 10mm, slice gap = 25mm), T_{acq} = 3min41s. We designed an EPG model parameterized by the triplet (water T2, fat fraction, B1+), with fixed T1 values for fat (T1 = 365ms) and water (T1 = 1400ms)[6]. First, fat T2 was estimated for each patient in the subcutaneous fat with a single-component EPG model. This value was then fixed and a bi-component EPG model was fit on the muscle tissues to simultaneously quantify water T2, fat fraction and effective B1+. For comparison and validation, a water/fat separation acquisition was also performed using a 3D gradient echo sequence with 3 echo times (TE1/TE2/TE3/TR = 2.75/3.95/7.55/10ms, spatial resolution = 1x1x5mm^3, T_{acq} = 1min36s). Quantitative fat fraction maps were reconstructed using the gold standard 3-pts Dixon approach[7].

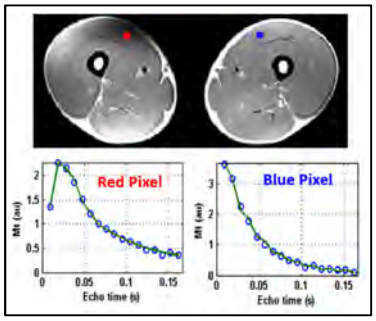

Figure 1: First echo of MSME sequence acquired on a healthy volunteer. B1+ inhomogeneities lead to different NMR signal decay patterns (blue circles) that can be adjusted by EPG-fitting (green lines).

Results

Figure 1 shows a typical image of the MSME 1st echo acquired on a healthy volunteer. B1 inhomogeneities are clearly visible within the thighs, and can lead to different NMR signal decay patterns. Nevertheless, even in the presence of large stimulated echo effects (red pixel), the EPG algorithm achieves an accurate fitting of the experimental data points with less than 4% residuals. Figures 2-a and b respectively display water T2 and fat fraction maps, derived from an MSME sequence on a patient exhibiting fatty infiltrations. Unlike the "global" T2, derived from a mono-component EPG analysis, the water T2 estimated with the 2-component model does not correlate with the fat fraction in the entire cohort (figure 2-d). As depicted by figure 2-c and the Bland Altman graph on figure 2-e, the fat fraction derived from the proposed method correlates well with the fat fraction derived from the 3-pts Dixon method. In the five myositis patients, water T2 maps exhibit significantly higher values than those of healthy volunteers (figure 3-a-b), as expected in case of inflammation of muscle tissues. Water T2 values estimated on healthy volunteers (31.6±2.5ms) are in good agreement with reference values found in the literature at 3T[8,9].

Discussion & Conclusion

In this study, we demonstrated that EPG- fitting was able to simultaneously estimate muscle water T2 and fat fraction from standard MSME acquisitions. This was successfully tested on healthy volunteers and patients suffering from several neuromuscular disorders. This novel approach has two major advantages over the IDEAL-CPMG method[10] which also derives water T2 and fat fraction from a single MR experiment. First, it has been demonstrated that EPG fitting is relatively insensitive to B1+ variations[3]; this would allow to derive these parameters with good confidence intervals even in body parts prone to B1+ inhomogeneities (e.g. the forearm). Second, unlike IDEAL-CPMG, the MSME sequence is easily available on clinical scanners delivered by the main manufacturers, and would consequently be more suitable in multi-center trials to accurately monitor neuromuscular diseases, and responses to treatments. Although promising, the method could even be optimized; for example, refocusing flip angle could be reduced to decrease SAR. It would allow acquiring more echoes to improve fitting confidence intervals, or increasing the number of slices to reach better spatial resolution.

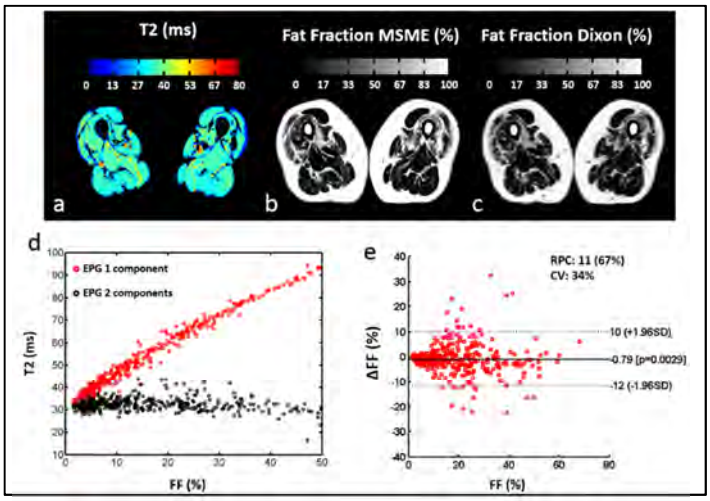

Figure 2: Water T2 map (a), fat fraction map (b) derived from MSME sequence and corresponding fat fraction map derived from the 3pts-Dixon method (c) on patient exhibiting fatty infiltrations. (d) Correlation between fat fraction and T2 extracted with single (red) and bi-components (black) EPG models on the entire cohort. (e) Correlation between fat fractions derived from MSME sequence with EPG fitting and with 3-pts Dixon method on the entire cohort.

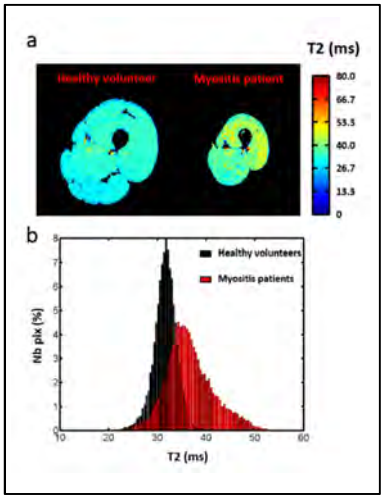

Figure 3: (a) Water T2 maps acquired on a healthy volunteer and on a patient suffering from myositis. (b) T2 distribution histogram obtained on the 5 healthy volunteers (black) and on the 5 myositis patients (red).

References

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