Texture Analysis of Muscle 3-Point Dixon Fat-Fraction: Changes Over 1 Year

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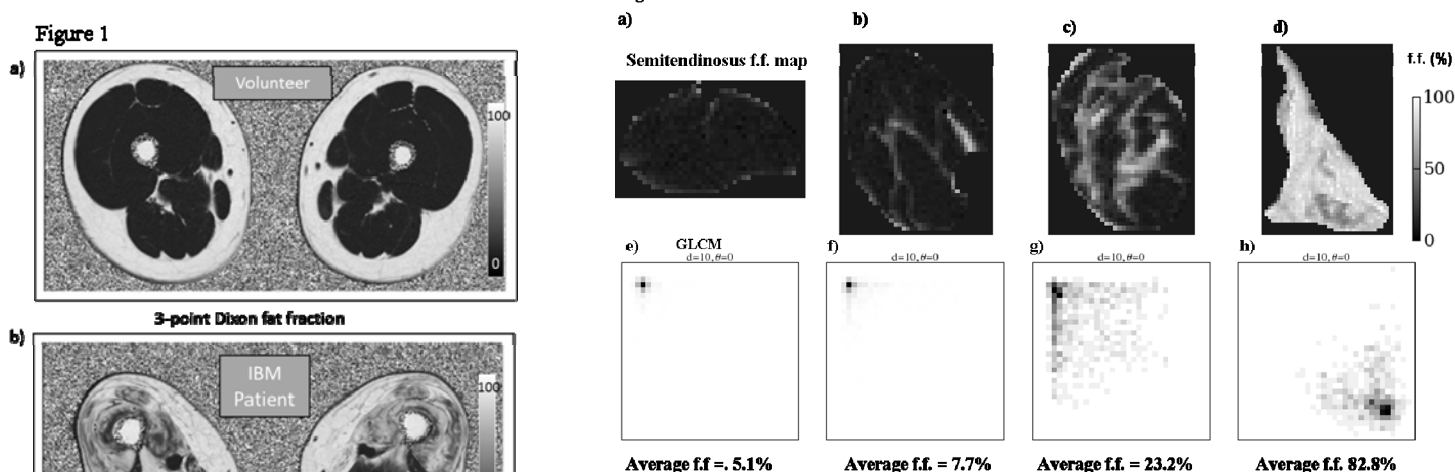
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Introduction There is a need for new sensitive outcome measures for clinical trials in neuromuscular diseases. Progressive fat-infiltration of skeletal muscle is a common pathology in many conditions. While characteristic patterns of T1-weighted change are commonly assessed visually according to qualitative scales [1], MRI quantification of muscle fat-fraction (f.f.) using fat-water chemical shift imaging holds great promise as an objective outcome measure. While mean f.f. in a given muscle region-of-interest (ROI) is commonly chosen to measure cross-sectional disease severity or longitudinal change, more sophisticated descriptors ("texture analysis" measures) characterizing the spatial distribution or uniformity of fat within the muscle may more sensitively quantify pathological progression. In this work we examined posterior thigh-muscle 3-point Dixon f.f. map texture measures in a group of patients with the representative muscle condition inclusion body myositis (IBM), imaged at baseline and after 1 year, to determine the sensitivity of f.f. map texture analysis metrics to longitudinal disease progression.

Methods The thigh muscles of 17 patients with IBM (8f, mean age 60.1y (23.8-81.0y) and 24 healthy volunteers (10f, 51.9y(19.4-77.6y)) were imaged at 3T (Siemens TIM Trio) using surface matrix coils. Three-point Dixon imaging (2D gradient echo TR/TE$_{1,2,3}$=100/3.45/4.6/5.75ms, 10x10mm slices, 10mm gap, 512x256matrix, FOV 410x205mm) was used to generate percentage f.f. maps using the algorithm described by Glover et al. [2]. Imaging was repeated after a 1 year interval (t_0 & t_1). In all subjects, the whole-muscle ROIs were defined for each limb on a single central slice of the TE=3.45ms image set using the ITK-SNAP software. Texture analysis was performed for the posterior hamstring muscles of the thigh bilaterally (semitendinosus, semimembranosus and biceps femoris). The segmentations were applied to the f.f. maps to obtain average f.f. in each muscle. 2D gray level co-occurrence matrices (GLCM), C(i,j) [3] with N=16 f.f. bins were calculated for each muscle using a 10 pixel horizontal kernel in Wolfram Mathematica 9. The summary parameters Contrast= $\sum_{i=1}^{N}\sum_{j=1}^{N} C(i,j)$ and Homogeneity= $\sum_{i=1}^{N}\sum_{j=1}^{N} C(i,j)^2$ were calculated for each GLCM. Horizontal run length matrices (RLM) [4] with 16 f.f. bins and up to 10 pixel runs were calculated for each muscle and Long and Short run length emphasis summary parameters calculated for each RLM. The mean change (Δ) over 1 year was calculated for each parameter and the sensitivity to change evaluated using the standardised response mean (SRM), defined as the ratio of mean change to standard deviation of the change (S.D.) SRM=mean(Δ)/S.D.(Δ). Larger absolute values of SRM (±>0) indicate greater sensitivity to change and are a key determinant of study power assessing suitability as longitudinal outcome measures for clinical trials. Group mean changes were assessed with paired t-tests.

Figure 1

a) Volunteer

3-point Dixon fat fraction

b) IBM Patient

Figure 2

a) Semitendinosus f.f. map b) c) d) f.f. (%)

e) GLCM d=10,θ=0 f) d=10,θ=0 g) d=10,θ=0 h) d=10,θ=0

Average f.f =. 5.1% Average f.f. = 7.7% Average f.f. = 23.2% Average f.f. 82.8%

n=102 IBM Muscles	IBM Mean t_0	IBM Mean t_1	IBM Δ (t_1- t_0)	p value	SRM	Controls Mean t0
Average f.f. (%)	17.8 ± 19.6	19.8 ± 19.6	2.1 ± 2.7	<0.001	0.76	4.62 ± 2.67
GLCM Contrast	0.019 ± 0.018	0.022 ± 0.019	0.004 ± 0.011	<0.001	0.34	0.005 ± 0.008
GLCM Homogeneity	0.146 ± 0.057	0.133 ± 0.053	-0.013 ± 0.026	<0.001	-0.49	0.212 ± 0.044
RLM Long run emphasis	5.30 ± 2.05	4.87 ± 1.83	-0.43 ± 1.15	<0.001	-0.37	7.55 ± 2.23
RLM Short run emphasis	0.680 ± 0.076	0.695 ± 0.072	0.014 ± 0.042	<0.001	0.34	0.613 ± 0.047

Results Example fat-fraction maps of the thighs of a volunteer (a) and IBM patient (b) are shown in Figure1, demonstrating widespread fat-infiltration in IBM. Segmentations of the right semitendinosus muscle of 4 IBM patients with representative increasing fat-infiltration are shown in Figure 2 (a-d) with accompanying GLCMs in (e-h). Changes in texture parameters for the combined hamstring muscles (IBM group) are given in the table; mean f.f. increased at 1 year (Δ=+2.1 %.), the greatest fractional mean change for any parameter over this period. There were small significant increases in the Contrast and Short Run Emphasis texture parameters and reductions in Homogeneity and Long Run Emphasis, reflecting the visually apparent changes in muscle fat infiltration patterns. Mean values at t_0 are given in the table for the volunteer control group. There were no significant changes in any parameter over 1 year (p>0.3 all parameters) in the healthy control group.

Discussion In this disease group, mean f.f. remained the parameter most sensitive parameter to change over 1 year with a SRM in the hamstrings of 0.8. However, concomitant significant changes in image texture measures suggest that texture analysis can quantify visually apparent changes in muscle-fat distribution patterns beyond this mean f.f. increase. As a given muscle becomes more fat infiltrated it is intuitive that the spatial homogeneity will decrease transiently with accompanying increases in f.f contrast. This trend was reflected in the texture parameters examined, texture analysis providing a means to quantify these appearances, both in cross-section and longitudinally. Fat-fraction mapping is reasonably robust to acquisition inhomogeneities providing superior source-data for texture analysis than the more often used T1-weighted imaging. It will be particularly interesting to evaluate how well these texture parameters predict change in muscle strength over one year, permitting optimal choice of individual muscles for assessing progression, or optimal selection of patients that are most likely to respond to a potential intervention in a clinical trial.

Refs:[1]Mercuri et al. JPN,6,309(2002) [2] Glover et al. MRM,18,371(1991) [3] Haralick, IEEESysManCyb,3,610(1973) [4] Galloway, CompGraphImProc, 4,172(1975)