3Tesla gradient-echo 3-point Dixon imaging for robust water-only imaging of the extra-ocular muscles

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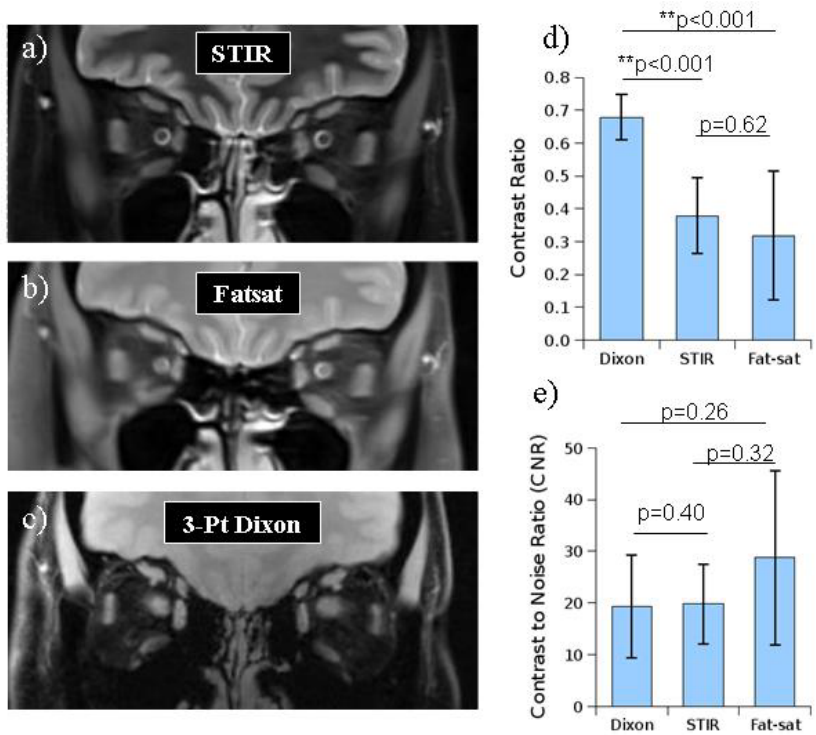
Introduction The extra-ocular (EO) muscles control movement of the eyes and are pathologically involved in conditions including thyroid eye disease [1] and progressive external ophthalmoplegia (PEO) arising from mitochondrial diseases [2]. Pathologies such as inflammation and atrophy of these muscles are routinely investigated on clinical MRI using techniques that suppress potentially confounding background signal due to the surrounding fatty adipose substrate. Spectral fat-saturation (fatsat) and short tau inversion recovery (STIR) [3] are both sequences frequently used for this purpose although both have potential shortcomings in the homogeneity and efficiency of fat-suppression. The so called 'multi-point Dixon' [4] and IDEAL methods [5] are commonly used to separate and quantify fat and water signals in organs including the liver and skeletal muscle. Despite an encouraging initial report using spin-echo-based 3-point Dixon imaging to increase contrast to noise ratio (CNR) between background fat and extra-ocular muscle, as compared to STIR imaging in pediatric patients at 1.5T, [6] there appears to have been limited investigation in this area since. In the present work we evaluated gradient-echo 3-point Dixon in comparison to STIR and fatsat imaging of the extra-ocular muscles in adult subjects at 3T, with a view to application in fat-suppressed imaging studies of extra-orbital myopathy.

Methods 12 coronal slices of the orbits of 7 healthy subjects (age 34.5±6.3y (mean±sd)) were acquired at 3T (Siemens TIM Trio) with a 32-channel receive head coil using 3 different fat-suppression schemes with the same coverage and acquisition time (200x163mm FOV, 256x208matrix, 3mm slices, 0.3mm separation. Method 1) STIR (TSE, TR/TE/TI=6000/7.9/220ms, refocusing flip angle (fa)=120°, NEX=3, bandwidth (BW)=260Hz/pixel, acquisition time (TA)=3:44), Method 2) Vendor-supplied fat-saturation TSE (TR/TE=6000/8.6ms, BW=230Hz/pixel, NEX=3, TA=3:44) and Method 3) 3-point Dixon fat-water decomposition (2D-GRE, TR/TE1/TE2/TE3=120/3.45/4.6/5.75ms, NEX=3, excitation fa=10°, BW=330Hz/pixel, TA=3:47). Phase unwrapping was performed offline with the 'Prelude' tool in FSL (FIMRIB, Oxford) and the water-only image calculated according to [4]. Regions of interest were drawn in the central portion of the 5 EO muscles of the right eye and in the central fatty tissue between the muscles, and on an extracranial background region (bg). Mean and standard deviations (σ) in each region were determined, and the contrast ratio (CR) between muscle signal S_M and the suppressed fat-signal S_F, $CR=(S_M-S_F)/(S_M+S_F)$, and the CNR, $CNR=0.66(S_M-S_F)/\sigma_{bg}$ were calculated. Mean values across subjects for the 3 methods were compared using non-parametric statistics (Kruskal-Wallis test against identical means and the Mann-Whitney U test).



Results Examples of orbital images from a representative volunteer using the 3 methods are shown in Fig. 1a-c) with the CRs and CNRs for 7 subjects in Fig1d&e). The CR between muscle and suppressed fat using the 3pt-Dixon method was higher than for both the STIR and fatsat methods (p<0.001). There was no statistical difference between CNR in the 3 methods in this implementation (p=0.4).

Discussion The visually-apparent superior CR of the 3-pt Dixon method indicates a very good quality of fat signal elimination compared to STIR and fatsat in images with the same resolution and coverage (Fig 1c&d). The acquisition time of 3:47min was within acceptable limits for clinical imaging. The high in-plane resolution (0.78mm) allowed clear visualization of small structures, facilitated by the advantages of imaging at a 3T. The relative CNR of the 3-pt Dixon method might be further improved by using an IDEAL fat-water decomposition, where the TEs can be adjusted to increase the overall SNR [5] or with a 3D-GRE implementation which offers implicitly higher signal-to-noise. The superior suppression of background fat using 3-point Dixon methods offers further advantages in areas beyond the radiological evaluation of muscle pathology, such as a more precise definition of muscle boundaries essential for automatic segmentation and muscle atrophy measurement, in addition to the quantification of intra-muscular fat-fraction, a presumed index of pathology, inherently provided by the 3-point Dixon approach.

References[1]Ulmer et al. AJNR, 19, p943 (1998) [2] Schoser & Pongratz, Strabismus, 14, p107 (2006) [3] Bley et al. JMRI, 31, p4 (2010) [4] Glover & Scheider, MRM, 18, p371 (1991) [5] Reeder et al. JMRI, 25, p644 (2007) [6] Rybicki et al. AJNR, 22, p1798