PD, T1, and T2 Quantitative MRI Spectroscopy of the Orbit: an Application of the Mix-TSE Pulse Sequence

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ABSTRACT
Purpose: To develop a structural MRI technique for the assessment and quantitative characterization of the main structures and tissue types in the human orbit. Methods: Structural segmentation was accomplished by interrogating every pixel as to whether it is contained in a certain PD, T1, T2 Q-MRI space volume and also as to whether it was clustered with other Q-MRI-similar pixels in direct image space. Conclusion: A technique for resolving into structural segments and characterizing by Q-MRI spectroscopy the main components of the human orbit has been developed. The technique is semi-automated requiring only a few numerical inputs from the user.

PURPOSE
To develop a structural MRI technique for the assessment and quantitative characterization of the main structures and tissue types in the human orbit. More specifically the purpose was to develop a quantitative Q-MRI technique for segmenting the extra-ocular muscles and **optic nerve** and to generate quantitative MRI spectra representing the PD, T1, and T2 distributions.

METHODS
Images were acquired with a 1.5 T superconducting MR imaging system (NT-Intera Philips Medical Systems, N.A.) with a maximum gradient of 23 mT m^{-1} and a maximum slew rate of 105 mT m^{-1} ms^{-1}. Mixed turbo spin echo [1,2] (mix-TSE) is a multislice 2D pulse sequence that combines (see Fig. 1) the principles of T_1-weighting by inversion recovery and T_2-weighting by multi-echo sampling into a single mixed MRI acquisition. More specifically, mix-TSE is a fast dual inversion times ($TI1$, $TI2$) and dual effective echo times ($TE1_{eff}$, $TE2_{eff}$) multipoint pulse sequence, with which four differently T_1- and T_2-weighted images per slice are generated. Mix-TSE is particularly useful for quantitative MRI because it can be used to generate with a single acquisition, volumetric distributions of $PD^{(MR)}$, T_1, and T_2 that are spatially self-coregistered, that encompass wide anatomic areas with high spatial resolution and that exhibit minimum susceptibility artifacts. The pulse sequence consists of two double-echo TSE sequence modules that are applied at different times after the application of an initial inversion pulse. Directly acquired images were transferred to a personal computer in which these were post-processed, first with a Q-MRI algorithm to generate the PD, T1, and T2 maps and then with a Q-MRI based segmentation algorithm with which structural segmentation is accomplished by interrogating every pixel as to whether it is contained in a certain Q-MRI space volume and also as to whether it is clustered with other Q-MRI-similar pixels in direct image space.

RESULTS
The PD, T1, and T2 Q-MRI spectra corresponding to all non-lipid tissues of the orbit of a healthy volunteer are shown in Figure 2. While the PD and T2 spectra are approximately unimodal, the T1 spectrum exhibits separate peaks for CSF (T1>1.2 s), extra-ocular muscles and optic nerves (750<T1<1.2 s), and a muscle-fat partial volume peak with a maximum at T1~600ms. The measured volume of the non-lipid tissues was 5 cc. Compared to facial muscles; extra-ocular muscles are approximately 50% richer in proton density in a healthy subject.

CONCLUSION
A technique for resolving into structural segments and characterizing by Q-MRI spectroscopy the main components of the human orbit has been developed. The technique is semi-automated requiring only a few numerical inputs from the user. The technique could be useful in the diagnosis of orbital myositis, such as Grave's disease and idiopathic orbital inflammation and optic neuritis.

REFERENCES
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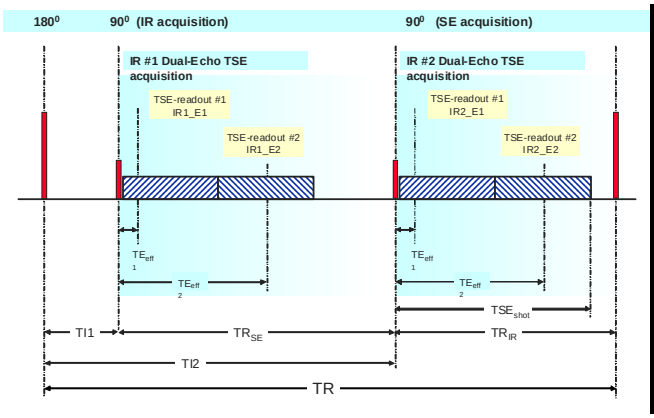

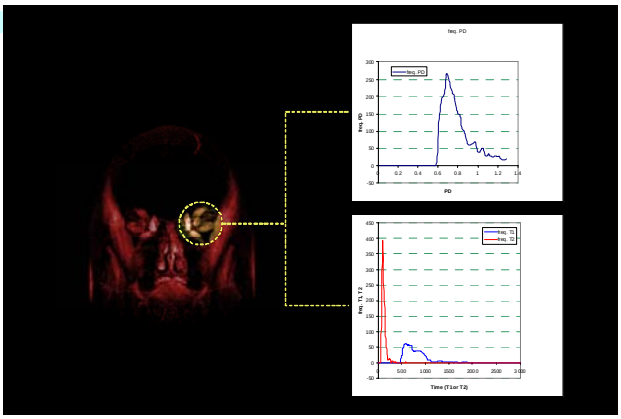

Figure 1: Timing diagram of mix-TSE pulse sequence.
Figure 2: Q-MRI spectral analysis of the left orbit of a healthy volunteer. Extra-orbital tissues have been superimposed to a coronal image through the face.