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

H. Jara¹, K. Fleming¹, O. Sakai¹
¹Boston University Medical Center, Boston, MA, United States

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 (mix-TSE) is a multislice 2D pulse sequence that combines (see Fig. 1) the principles of T₁-weighting by inversion recovery and T₂-weighting by multi-echo sampling into a single mixed MRI acquisition. More specifically, mix-TSE is a fast dual inversion times (T₁₁, T₁₂) and dual effective echo times (T₁eff₁, T₁eff₂) multipoint pulse sequence, with which four differently T₁- and T₂-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(MRI), T₁₁, and T₁₂ 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

![Figure 1: Timing diagram of mix-TSE pulse sequence.](image1)
![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.](image2)