Whole Orbit Soft Tissue Deformation Acquired by Accelerated 3D CSPAMM Tagging during Eye Motion

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Introduction: Static MRI and CT are essential clinical tools for detecting mechanical disorders of the orbit [1]. In complex cases, however, there is an additional need to better understand the dynamics of ocular movements for potentiating more effective surgery. A lack of movement may be due to contraction or relaxation deficits of the six extraocular muscles or due to rigid surrounding orbital connective tissue. The pattern of the lack of movement within the orbit has not been understood yet [2]. 2D Tagging, recently presented [3], allows to track only 2 muscles out of 6, and requires accurate planning. This study will provide basics for a new fast scanning method that provides 3D CSPAMM (Complementary SPAtial Modulation of Magnetization [6,9]) high-resolution MR images of the whole orbit, in a scantime short enough to enable motion reproducibility [4].

Methods: A fMRI setup as described in [4] has been used for a reproducible and accurate eye movement during image acquisition (horizontal sinusoidal moving target, 2s period, peak velocity 64°/s, amplitude ±20°). A microscopy coil (47mm diameter) at 1.5T was placed on one orbit to acquire 3D CSPAMM TFEPI-images (40x18x18 scan-matrix, FOV=51x51x51mm^3, scantime 8min., 15 time phases of 70ms, rec.-resolution: 0.4x0.4x2.8 mm^3 , EPI factor: 3, TFE factor: 3, tag-line distance: 3mm). Three datasets which were each motion encoded in one spatial dimension were acquired. A reduced field-of-view method with a localized tagging preparation was applied in order to keep acquisition time short. In order to prevent tag fading, an optimized ramped flip angle approach was applied (final flip angle=47º) [5,6].

For data evaluation peak-combination HARP [7] was adapted to 3D. Three to five contours consisting of multiple landmark points were defined on three muscles: medial (MRM), lateral (LRM) and inferior (IRM) rectus muscle and the optic nerve (ON) (Figure 3). The contours were subsequently HARP-tracked [8] in 3D space over all time frames.

Results: The 3D CSPAMM motion encoded images provided information of the deformation also within homogeneous regions of the orbit like the vitreous humor, the muscle, and the orbital fat (Figure 1&4). The sinusoidal movement of the contracting and relaxing horizontal rectus muscles, and the non-contracting optic nerve and inferior rectus muscles were reliably tracked and clearly separated from each other (Figure 2).

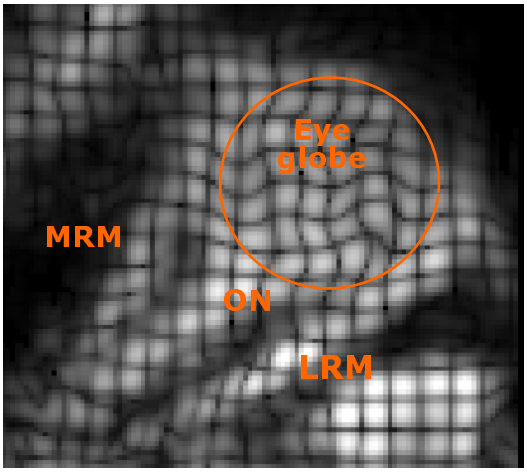

Figure 1: *Central slice of 3D CSPAMM dataset on the 5th time phase (out of the 15).* MRM: *medial rectus muscle.* ON: *optic nerve.* LRM: *lateral rectus muscle.*

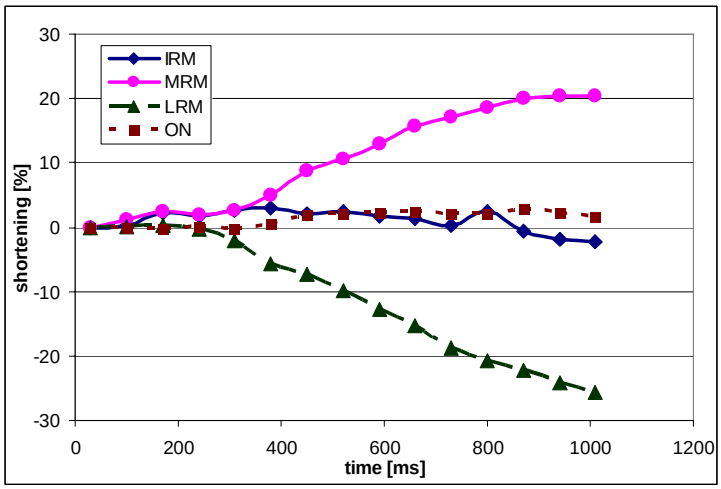

Figure 2: *Contours averaged strain, in function of time, for the relaxing LRM, the non-contracting ON and IRM, and the contracting MRM.*

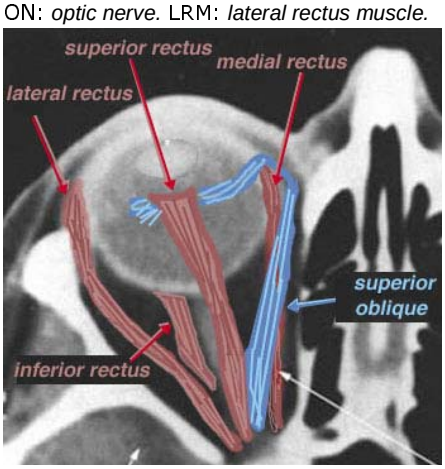

Figure 3: *CT transverse scan with drawn muscles.*
http://webvision.med.utah.edu/imageswv/scan.jpeg

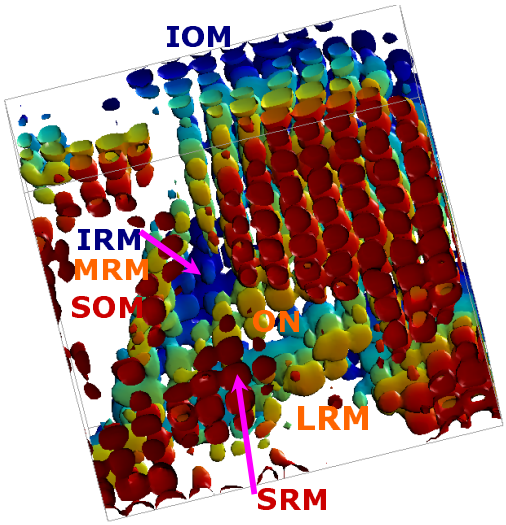

Figure 4: *3D isosurfaces representation of the tagging dataset representing the eyeball, the optic nerve and the six extraocular muscles. Color encoding correspond to the cranio-caudal coordinate so, that the orange level is approximately the slice of Figure 1, with the MRM, ON and LRM in orange; in red are the lower part of the superior rectus (SRM) and the superior oblique muscles (SOM) (the top is cut for visualization); in blue: the inferior rectus and the inferior oblique muscles.*

Conclusion: The accelerated 3D tagging acquisition technique used in this study enabled to track the deformation of extraocular muscle, in a tolerable scantime. Further studies plan to investigate the ability of this technique to differentiate pathologic from the physiologic muscle contraction pattern.

References:

[1] Demer JL, et al. J AAPOS 2002; 6(6): 331-47. [2] Miller JM, et al. JOV 2006; 6: 616-624. [3] Piccirelli M, et al. Proc. ESMRMB 2006 #744. [4] Piccirelli M, et al. Proc. ESMRMB 2005 #418. [5] Rutz A, et al., 2007, Proc ISMRM: 759. [6] Rutz A, et al., MRM, in press. [7] Ryf S, et al. JMRI 2004; 20: 874-880. [8] Osman NF, et al., 1999, MRM 42(6): 1048-60. [9] Fischer SE, et al., 1993, MRM 30: 191-200.