High Spatial Resolution Ophthalmic MRI at 7.0 Tesla in Healthy Subjects and in Patients with Intraocular Masses

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Target Audience: Imaging scientists, clinical scientists, radiologists and experts interested in *in vivo* MRI of the human eye at 7.0 T.

Introduction: *In vivo* imaging ocular masses is an emerging MRI application. MRI of subtle ocular structures requires a sub-millimeter spatial resolution over a small FOV [1]. Realizing this constraint as well as the opportunities given by the signal-to-noise ratio (SNR) gain inherent to ultrahigh field (UHF) MRI – which can be translated into spatial resolution enhancements - it is conceptually appealing to pursue *in vivo* ophthalmic MRI at 7.0 T. To this end this work examines the applicability of a local six-channel TX/RX RF array [2] for imaging the human eye, optical nerve and orbit in healthy volunteers and patients with intraocular masses (uveal melanoma). For this purpose *in vivo* image quality is assessed by determining SNR, lens/vitreous body contrast ratio and signal intensity (SI) uniformity across the lens or the vitreous body.

Materials and Methods: Ophthalmic MRI was performed in healthy volunteers (n=17, age 34±11 years) and in patients with intraocular masses (uveal melanoma, n=5, age 57±6years) using a whole body 7.0 T MR system (Magnetom, Siemens Healthcare, Erlangen, Germany). The protocol included: **(i)** 3D gradient echo (3D GRE, spatial resolution of (0.3 x 0.3 x 1.0) mm^3, TR=10.3 ms, TE=3.6 ms, α=6°, 24 slices per slab, NA=2, ACQ_{total} =3:12 min); **(ii)** inversion recovery 3D gradient echo (3D IR GRE, spatial resolution of (0.4 x 0.4 x 1.0) mm^3, TR = 13.6 ms, TE = 6.5 ms, TI= 1900 ms, α=6°, 24 slices per slab, NA=2, ACQ_{total} 1:43 min); and **(iii)** 2D T_2 weighted fast spin-echo (2D FSE, spatial resolution=(0.25 x 0.25 x 0.7) mm^3, TR=2940 ms, TE=85 ms, $\alpha_{refocussing}$= 100°, 6 slices, NA=4, R=2, ACQ_{total}=7:26 min. For comparison, 2D FSE was repeated using a dedicated head coil (Nova Medical Inc., Wilmington MA, USA) equipped with 24 receive channels. For this purpose, the FOV was adjusted for the head coil to avoid aliasing artifacts while all other imaging parameters were held constant for both coils. Subject preparation to reduce susceptibility artifacts was used [3] together with an audiovisual triggering setup to allow for blinking and relaxation periodes between the acquisition windows.

Results: Fig. 1 demonstrates the feasibility of high spatial resolution 3D GRE imaging using transversal view of the eye and a spatial resolution of (0.2 x 0.2 x 1.0) mm^3 (Fig 1a), which helped to clearly discern the anterior/posterior chambers, lens nucleus, lens cortex, vitreous body and orbital muscles. The feasibility of IR 3D GRE using a spatial resolution of (0.4 x 0.4 x 1.0 mm)^3 and of T_2-weighted 2D FSE with a spatial resolution of (0.25 x 0.25 x 0.7 mm)^3 is demonstrated in Fig. 1b,e. For 3D GRE rather uniform SI was observed across the eye (Fig. 1c,d). Across the short axis of the lens ΔSI=7% was observed (Fig. 2d). For a profile perpendicular to the line connecting the lens with the retina ΔSI=2% was determined (Fig. 2d). Along a line connecting the center of the lens with the retina ΔSI=15% was observed within the vitreous body (Fig. 1d).The mean SNR of the lens was ≈35. The vitreous body provided a mean SNR of ≈30. The lens-vitreous body CNR was 8, which allows good differentiation between the lens and the vitreous compartment. Fig. 1 e-h show a sagittal view of the eye of a healthy subject derived from 2D FSE using the 6 channel TX/RX coil (Fig. 1 e) and the dedicated head coil (Fig. 1 g). For the 6 channel TX/RX coil, rather uniform SI was observed across the eye (Fig. 1e). For a profile perpendicular to the line connecting the lens with the retina a mean ΔSI<5 % was determined (Fig. 1 f). In comparison, the dedicated head coil showed ΔSI=90 % (Fig. 1 h). The applicability of the six-channel TX/RX imaging ocular tumor masses is demonstrated in Fig. 2. Using a 3D GRE (spatial resolution=(0.3 x 0.3 x 1.0) mm^3), tumor mass and retinal detachment within the eye of patients suffering from choroidal melanoma can be clearly depicted in both sagittal (Fig. 2 a) and transversal views (Fig. 2 b). For comparison, the sagittal view is also shown for a 3D GRE image using an enhanced spatial resolution of (0.2 x 0.2 x 1.0) mm^3 (Fig. 2 c). The retinal detachment of a malignant melanoma of choroidea is also clearly depicted by 2D FSE using a spatial resolution of (0.25 x 0.25 x 0.7) mm^3 (Fig. 2 e).

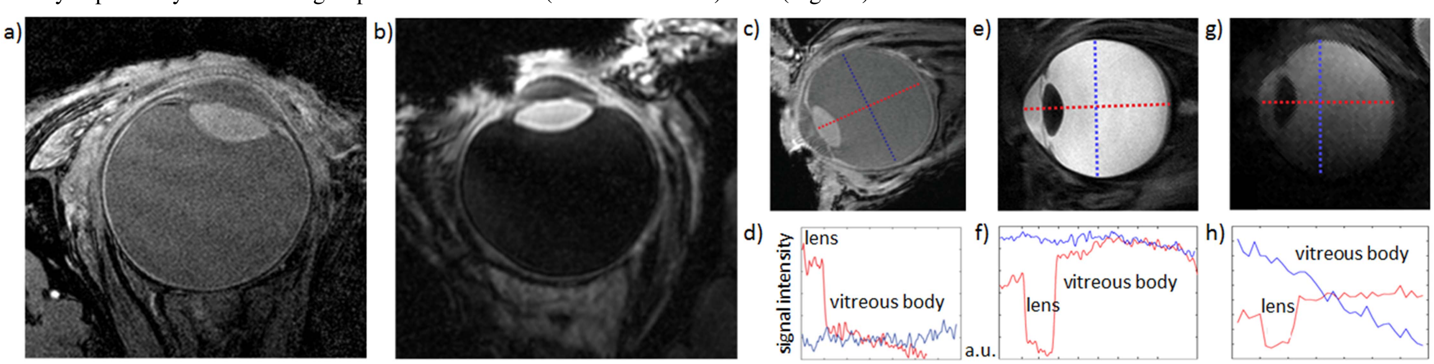
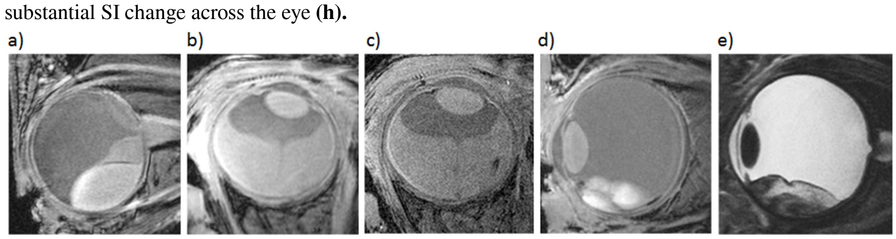


Fig. 1: a) Transversal view of the eye derived from 3D GRE using a spatial resolution of (0.2 x 0.2 x 1.0 mm)^3 **b)** IR 3D GRE using a spatial resolution of (0.4x0.4x1.0 mm)^3 **c)** 3D GRE (0.3 x 0.3 x 1.0 mm)^3 sagittal view of the human eye indicating rather uniform signal intensity **d)** of the lens and the vitreous body. **e-h**) Comparison of results derived from T_2-weighted 2D FSE using **e)** a 6 channel TX/RX local array and **g)** a dedicated head coil. For the 6 channel TX/RX coil, rather uniform SI was observed across the eye **(f)**. The dedicated head coil provided a substantial SI change across the eye **(h).**

Fig. 2: a) Sagittal and **b)** transversal 3D GRE eye images (resolution (0.3 x 0.3 x 1.0) mm^3) of a patient suffering from a malignant melanoma of choroidea with retinal detachment. **c)** transversal view with high spatial resolution (0.2 x 0.2 x 1.0) mm^3. **d)** 3D GRE and **e)** 2D T_2-weighted FSE image (spatial resolution (0.25 x 0.25 x 0.7) mm^3) of another patient with an intra ocular mass.



Discussion: Our results demonstrate that high spatial resolution ophthalmic MRI in patients with intraocular masses at 7.0 T is feasible within clinically acceptable scan times. The comparison with the conventional multi-channel RX head coil underlined the advantages of a dedicated eye coil. The benefits of such improvements would be in positive alignment with explorations designed to examine the potential of MRI for the assessment of spatial arrangements of the eye segments and their masses with the goal to provide imaging means for guiding treatment decisions.

References: [1]Patz B et.al. J.Magn.Reson.Imag 2007;26(3):510-8. [2] Graessl A et.al ISMRM 2013, p. 2747. [3] Richdale K et.al., J. Magn. Reson. Imaging 2009;30(5):924–32.