Supplemental Digital Content 1

Methods and Materials

Characterization of the MRI-characteristics Silicon Oil (SiOil)
The resonance frequency of the SiOil (RS-OIL ECS 1000cS , AL.CHI.MI.A. SRL, Ponte S. Nicolo, Italy) was determined at 7 Tesla (T) through single-voxel MR-spectroscopy using a phantom consisting of water and SiOil.

The T_1-relaxation time of the SiOil was determined on 3 & 7 T by performing single-voxel MR-spectroscopy (3T: PRESS, TE/TR:15ms/3s, voxel size: 21x20x15 mm, NSA 4 ; 7T PRESS, TE/TR: 52ms/6s, voxel size: 15x22x31 mm, NSA 4) for 20 inversion times ($T_{inversion}$=50,150,…,1950ms). A single exponential fit was performed in MATLAB R2016b (Matworks, Natick, MA, USA) through the integrated signal intensity of the SiOil-peak.

At 7 T, the T_1 and resonance frequency of SiOil were subsequently used to set the correct frequency offset and inversion times for SPIR (-1.4 kHz) and SPAIR (-1.4 kHz, T-inv: 700 ms) suppression of the SiOil. A comparison showed good suppression for both techniques. As the SPAIR SiOil suppression is relatively time consuming due to the longer T_1 relaxation time of SiOil, SPIR suppression was chosen for subsequent scans. At 3T, the conventional settings of the SPIR fat-suppression, resulted already in suppression of the SiOil, as the bandwidth of the SPIR pulse was sufficiently broad to cover both the fat and the SiOil.

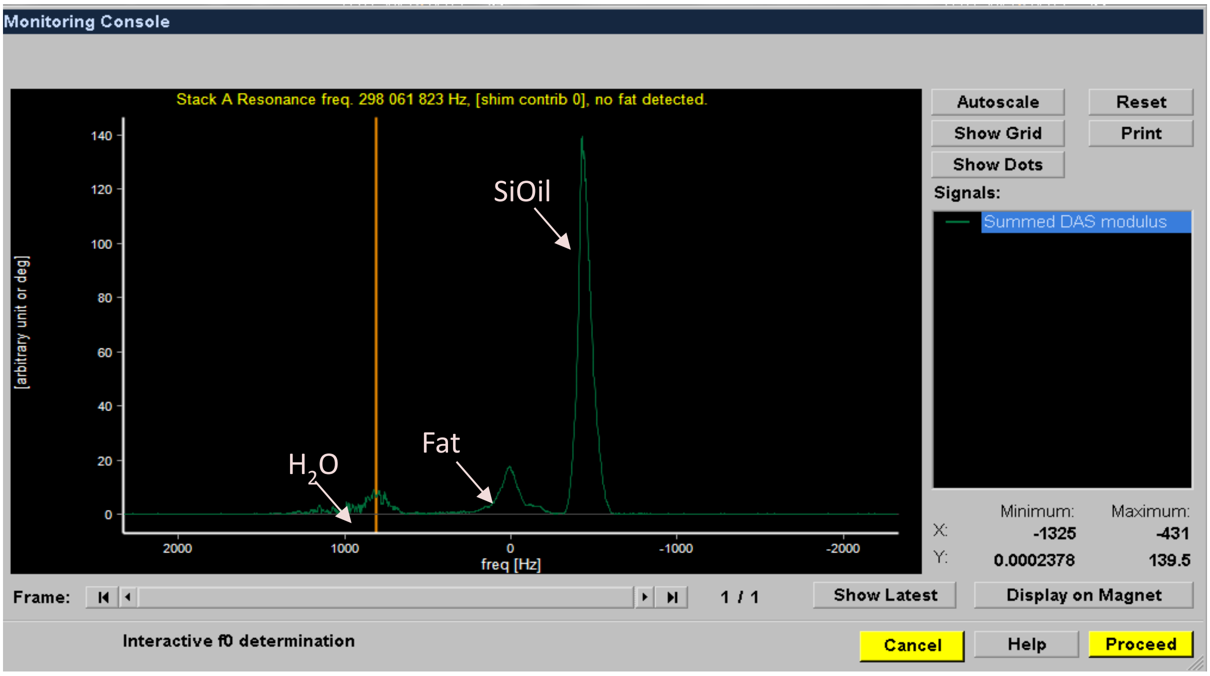
Phantom for protocol development and validation

To facilitate the development and testing of the MRI-protocol for SiOil patients, a phantom was designed to mimic the subject anatomy. The phantom consisted of a large, 3L, bottle of water with 100 mm NaCl, which mimics the head. Attach to this bottle were two 50ml tubes, one filled with SiOil and H2O, mimicking the eye, and one filled with vegetable oil, resembling the signal of the orbital fat.

General MRI-setup and preparation for patients with SiOil

For optimal image quality, a surface coil should be used for MR-imaging of the orbit [1,2,3]. On 7T a house build dedicated eye coil was used in combination with the Nova Medical transmit coil (Nova Medical, Inc., MA, USA), whereas at 3T a 47 mm surface receive coil (Philips Healthcare) in combination with the body transmit coil was used. As these surface coils have a very local sensitivity, they mainly receive signal from the SiOil, which has a 4.5 ppm offset compared to water. At the beginning of every MRI-protocol, a number of patient-specific calibrations, including F_0 determination, power calibration and shimming, need to be performed. As these calibrations assume that the majority of the signal is originating from water, this calibration is hindered significantly by the SiOil. As a result, the conventional MRI-protocols have significant artefacts, shown in the main text figure 1 D, which prevent an clinical interpretation of the images.

To determine the correct settings of the MRI-scanner in the presence of the strong off-resonance of the SiOil, the automatic preparation was split into two manual steps. First, an initial estimate of F_0 and power settings are determined by making a low-resolution scan of the complete head with the transmit coil, the body-coil or head-coil for 3T and 7T respectively. As for this specific scan the majority of the signal is originating from the brain, the automatic calibration succeeds in acquiring an correct calibration for the brain. These settings are subsequently used as an initial estimate to determine the correct calibration settings for the eye. This was done by performing a single-voxel MR spectroscopy (7T PRESS, TE/TR: 52ms/6s, voxel size: 15x22x31 mm), using the eye-coil for receive, on the affected eye. For most calibrations, the estimates from the low resolution head-scan were sufficient for the scanner to converge to the correct settings for the eye. However, as the scanner assumed the SiOil signal to be the water signal, the F_0-determination needs to performed manually (see Supplementary figure 1). These power and F_0 settings were fixed for all subsequent imaging scans. Moreover, at 7T the shim-settings from the MR spectroscopy (determined by 1st order pencil-beam) were also used for subsequent scans, whereas at 3T the scanner's automatic shimming routine sufficed.



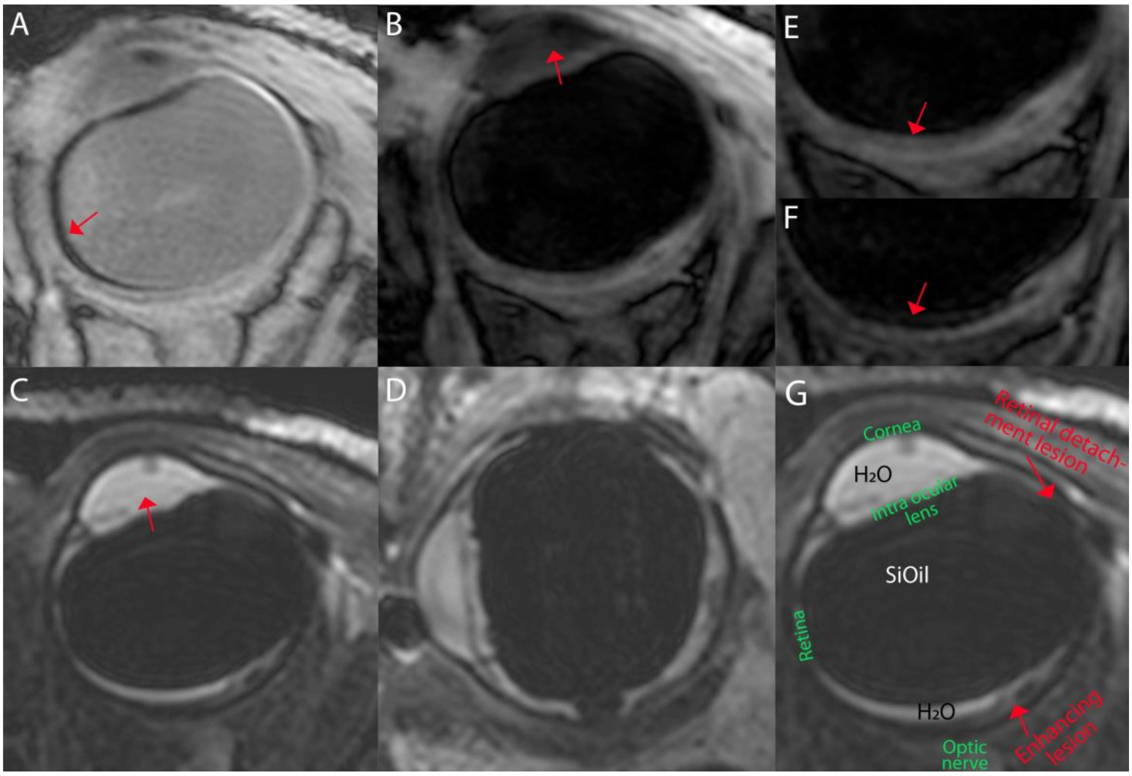
Supplementary figure 1. Manual F_0-determination. The MRI would normally automatically converge to the SiOil peak (right peak). The water peak is therefore selected manually.

Initially, these protocols were developed at a 7T MRI. After the first scans, these protocols were translated to 3T MRI as 3T scanners are more widely available than 7T scanners. On the 7T a cued-blinking paradigm was implemented to minimize eye-motion[2,3,4], while on 3T the patients were asked to keep their eyes closed.

Results

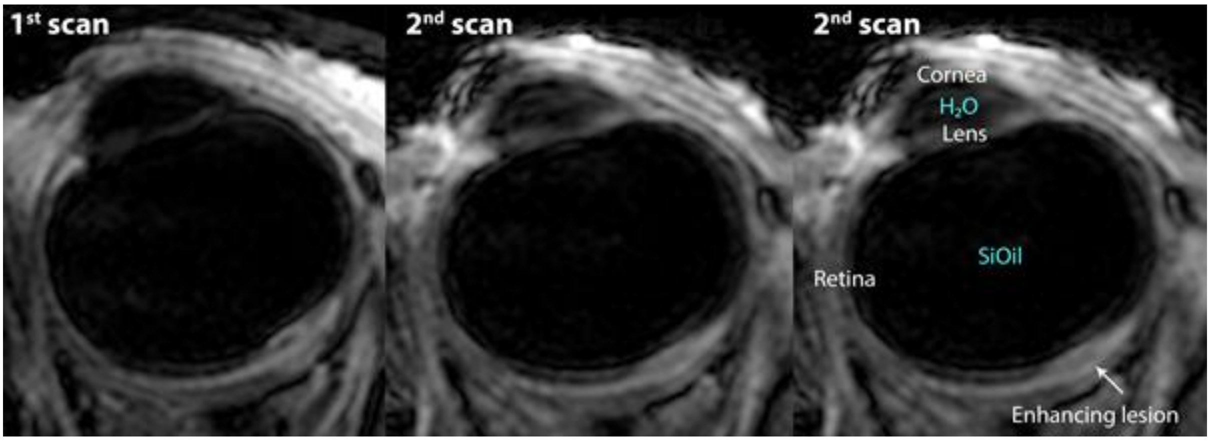
A more comprehensive overview of the MR-images and interpretation is shown in Supplementary figure 2, 3, 4 and 5.

Supplementary figure 2.



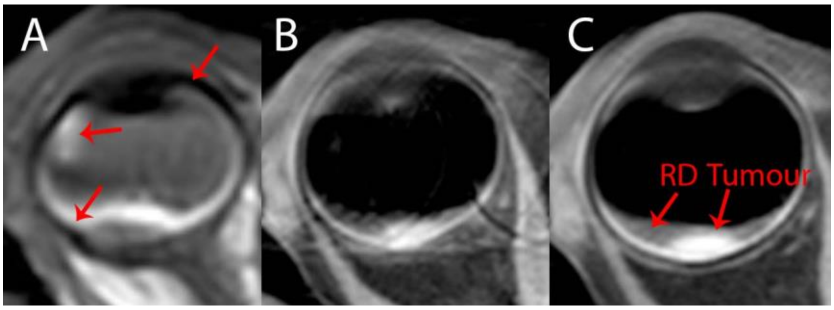
MR images of patient 1 scanned at 7T are shown in this figure. A and B show a T1 weighted 3D scan without (A) and with (B) SPIR SiOil suppression. The chemical shift (arrow) between the SiOil and sclera is increased compared to the conventional water-fat shift due to the increased frequency difference. (C, D) show a T2 weighted 3D Scan with SPIR SiOil suppression in two ortogonal planes. The anterior chamber (arrow) still appears hyperintense as it consists of free water. (E, F) show a T1 weighted 3D scan with SPIR SiOil suppression without (E) and with (F) additional free water suppression (MPRAGE) after contrast. In (E) a thin layer of vitreous (arrow) is still present around the enhancing lesion, which is suppressed in (F). The annotated image (G) shows the result of the combined interpretation of the images.

Supplementary figure 3.



Post contrast T_1 – weighted scan with SiOil and free water suppression of the same patient of Supplementary figure 2. During the first scan several small enhancing lesions were seen. The patient was scanned a second time to determine whether the enhancement was tumour reoccurrence or reaction of the tissue due to radiation exposure. As the lesion did not grow, it was determined to be tissue reaction and not tumor reoccurrence.

Supplementary figure 4.



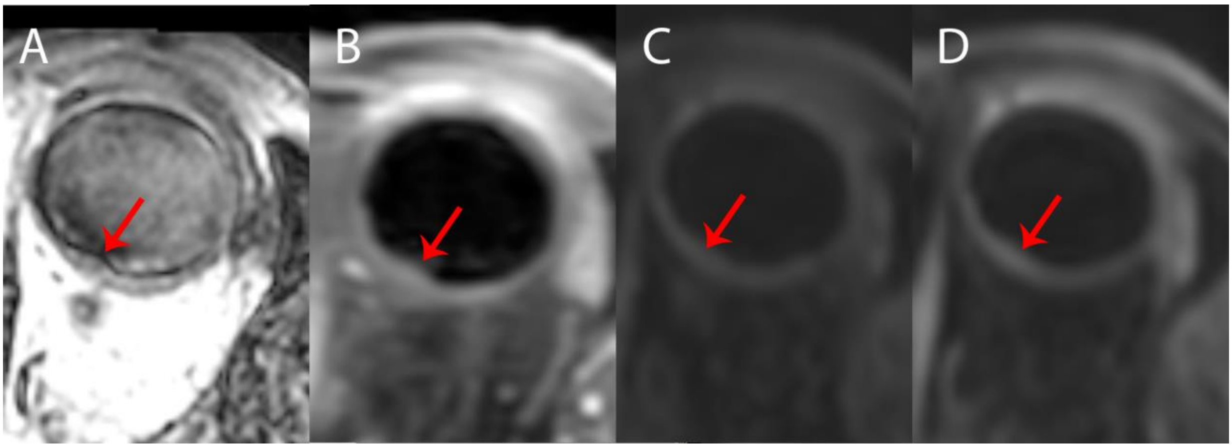
Different MR-images of patient 2 scanned at 3T.

A) this multi slice T1 MS without SPIR fat suppression suffers from large chemical shift (upper and bottom arrow) and B0 artefacts (arrow middle). The large black and white rim are chemical shift and the black and white focal points are most likely caused by B_0 inhomogeneities.

B) in this T1 MS with SPIR fat suppression motion artifacts occur as ghosting most prominent in the phase encoding direction.

C) The same scan as B, but in this case the patient did not move, showing clearly an enhancing lesion (arrow) and partly suppressed fat.

Supplementary figure 5.



Different MR scans of patient 3 scanned at 3T. A small lesion can be observed in scans (A & B) at the arrow on T1 weighted 3D scans with and without SPIR after contrast. Next two scans (C & D) are two images of a dynamic scan before contrast (C) and e after contrast (D). The lesion enhances like shown in the graph in main text figure 2 F.

Bibliography

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