Vitreous Oxygenation Measured by T_1 mapping in the Eye Reveals No Increased Oxygenation Following Vitrectomy

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Aim: To determine whether the partial pressure of oxygen (pO_2) of the vitreous humour (the clear gel that fills the eyeball between the lens and the retina) is increased in patients undergoing a vitrectomy (the extraction of the vitreous).

Background: Vitrectomy is a surgical procedure that involves the replacement of the vitreous humour with a balanced salt solution (BSS) of $CaCl_2$, $MgCl_2$, NaCl, KCl and $C_6H_5Na_3O_7$. It is conducted as a therapy for various eye conditions such as retinal vascular disease and diabetic retinopathy. It has been proposed that the beneficial effect of vitrectomy may be due to improved oxygenation of the inside of the eye and hence the retina [1]. However, owing to the highly invasive measurement techniques currently available, there have been no post-operative or longitudinal pO_2 measures in a group of patients who have undergone a vitrectomy to confirm this hypothesis. MRI may be used to measure pO_2 indirectly since T_1 is subtly reduced by the presence of paramagnetic O_2 (a change of T_1=6 ms for every 1 mmHg change in pO_2 at physiological oxygenation and pressure). [2-5]. Here, we perform T_1 measurement on 11 patients pre- and post-vitrectomy to determine whether the extraction of the vitreous humour provides an increase in pO_2.

Methods: *Participants.* 11 patients (7 female, 4 male, age range 59-84) diagnosed with a macular hole (MH) or an epiretinal membrane (ERM) volunteered for this study. Each was scanned less than 1 week before vitrectomy and invited to return for an identical scanning session 1 month post-operation (two participants declined a post-operative scan). Vitreous oxygenation was also measured peri-operatively with a polarographic oxygen probe (Licox, Integra NeuroSciences) that was inserted into the eye cavity during vitrectomy.

Scanning Protocol. Images were acquired with a Siemens Avanto 1.5 T scanner. T_1 mapping was performed using an inversion recovery (IR)-trueFISP sequence with 17 inversion times in the range TI=0.7s – 30s. A single slice was positioned through the centre of both eyes in the axial oblique plane. Other trueFISP parameters were: TR=(20+TI) s, TE = 1.52 ms, FA = 80°, matrix = 256x256, voxel dimensions = 0.9x0.9x4 mm^3. The total scan time for T_1 measurement was 15 mins. Eye movement was controlled by instructing the participant to fixate on a target attached to the scanner room wall and visible via the mirror attached to the head coil. Fixation was only required for the duration of k-space acquisition for each TI (approx. 1 sec only) [6].

Data Analysis. T_1 mapping involved a pixel-by-pixel three-parameter fit of the signal intensity S (at each TI) to the equation $S(TI) = A + Be^{-TI/T1}$; A and B are parameters that account for inversion pulse flip angle, equilibrium signal intensity and TR. Since flip angle is included, the technique is resilient to B_1 errors. Absolute pO_2 was determined using the peri-operative pO_2 measures and a phantom study that quantifies the dependence of oxygenation on T_1.

Results: Peri-operative pO_2 measured in the affected eye with a polarographic O_2 probe showed that all patients had pO_2 readings in the range 6.5-8.1 mmHg (mean 7.2, SD 0.6). Undistorted T_1 maps of the eyes were obtained (Fig 1) with estimated Bland-Altman [7] within-subject variability of T_1 < 1% (equivalent to pO_2 ~ 8 mmHg), and between subject variability of T_1 < 1.5% (equivalent to pO_2 ~ 12 mmHg). The pO_2 determined pre- and post-operatively by this technique revealed that there is no detectable change in pO_2 (ΔpO_2) in the affected eye, with a mean difference of 0 mmHg across all participants. The normal eye was used as a control for this technique and again showed no statistical difference between pO_2 measured before and after surgery (Table 1).

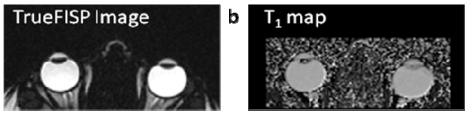

Figure 1 (a) TrueFISP and (b) T1 map of the eyes, both undistorted by magnetic susceptibility or movement artefacts.

	Vitrectomy Eye	Normal Eye
Mean ΔpO2	0.0	3.9
95% CI	17.0	16.9

Table 1 MRI-determined mean change in pO_2 (ΔpO_2) measured for 11 vitrectomy patients pre- and post-surgery together with the 95% confidence interval.

Discussion and Conclusion: This study has revealed that vitrectomy does not provide a significant improvement in oxygenation of the eye. Only 1 study [1] reported large pO_2 increases (up to 60 mmHg) as a result of vitrectomy, but these measures were made with an O_2 probe *during* surgery. At this time, elevated pO_2 was probably observed due to atmospheric levels of oxygen present in the replacement BSS. Within a few hours, the pO_2 would be expected to return to physiological levels but, until now, this has only been speculated. This current work strongly suggests that, indeed, such large improvements in oxygenation do not occur. This finding could have important implications for understanding the therapeutic mechanisms of vitrectomy and may lead to new considerations for patient treatment. Furthermore, we have shown this technique provides a non-invasive measure of pO_2 that will permit serial or longitudinal study of the oxygenation mechanisms in the eye and may be of wider benefit to other eye studies e.g. retinopathy or optic nerve.

References: [1] Williamson *Graefes. Arch Clin Exp Opthal* **2009**;247:1019-1023, [2] Dowell *Proc. ISMRM* **2011**;4356, [3] Tofts *MRM* **2008**;59:190-195, [4] Zaharchuk *MRM* **2005**;54:113-121, [5] Berkowitz *MRM* **2001**;46:412-416, [6] Dowell *Proc. ISMRM* **2010**;2408 [7] Bland *Lancet* **1986**;1(8476):307-310.