Imaging Vitreous Oxygen Tension with Modified Look-Locker T1 Measurement

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Target Audience Researchers involved in using MRI to study ocular and retinal diseases.

Purpose Abnormal vitreal oxygen tension has been implicated in a number of ocular and retinal diseases, such as diabetic retinopathy and nuclear cataract of the lens[1,2]. Oxygen content of the vitreous can be measured in animals using invasive techniques that require inserting probes into the eye, and which cannot be used in humans. We have previously demonstrated the ability to measure pO2 in the vitreous using Look-Locker MRI T1 measurements[3]. The aim of this study was to improve MRI methods for non-invasive measurements of the partial pressure of oxygen (pO2) in the human vitreous and the anterior chamber. Experiments were performed using the modified Look-Locker inversion recovery (MOLLI)[5] sequence which can measure T1 much more rapidly than standard T1 measurements reducing partial volume artifacts due to motion and uses a true FISP readout with high sensitivity. In this study we reduced total scan time from our previous study[3] (~4.5m) to 40s and used an improved surface coil to increase SNR allowing increased resolution. We performed a phantom calibration as previously described and measured pO2 in the vitreous and anterior chamber at significantly reduced spatiotemporal resolution using the MOLLI sequence.

Methods Phantoms calibrations were performed as (previously described[3]). *In vivo* studies were performed on 3 normal human volunteers (male, ages 25-34). A receive-only surface coil (7cm diameter) was used to image the right eye. The right eye was closed and gently covered with gauze to help prevent movement and maintain temperature. The left eye remained open to allow subjects to fixate on a reference inside the scanner during acquisitions. T1 measurements were made at 0.5x0.5x3.5mm resolution using a MOLLI sequence[5,6]. Images at all inversion times were acquired in 1 shot with FOV=100x100mm, matrix=196x196, TR=2s inversion times with a minimum inversion time TI=210ms, eleven TI_{eff} were sampled from 210ms to 9300ms (total scan time=40s). A non-linear least squares fit using the equation in (5) was used to fit T1 and M0.

Results Figure 1 shows (a) typical T1 map acquired in 40 seconds using the previous standard Look-Locker method (b) typical T1 map acquired in 40 seconds using the MOLLI sequence showing less noise in the vitreous compared to the first image (c) ROI regions for pO2 measurements (vitreous: 1-6 and anterior chamber 7). In the vitreous regions pO2 was: 1) 24±7, 2) 36±11, 3) 35±4, 4) 21±6, 5) 22±3, 6) 27±1 and in the anterior chamber 7) 381±197, compared to our previous reported values of similar ROIs: 1) 20±8, 2) 20±10, 3) 12±10, 4) 10±10, 5) 28±6, 6) 19±4.

Discussion We improved the spatiotemporal resolution for measurements of pO2 in the vitreous of the eye using a modified Look-Locker inversion recovery sequence and for the first time, image pO2 of the anterior chamber albeit some partial volume effects. The time to acquire a data set was reduced by a factor of ~7 and resolution was improved from 0.6x0.6x6mm to 0.5x0.5x3.5mm.

Our measurements of vitreous pO2 were similar to the previous vitreous pO2 using MRI[3] and electrode[7] measurements. Compared a previous MRI vitreous pO2 measurement[3], our percentage error decreased and vitreous pO2 maps were more uniform and less noisy, indicative of improvement. However, our anterior chamber pO_2 was much higher than those reported by electrode technique and the discrepancy is unknown but partial voluming is likely a contributing factor. There are no previous MRI measurement of the anterior chamber pO2 with which to compare. Future studies will further optimize the protocol to reduce partial volume artifacts to more accurately measure anterior chamber pO2 as well as pO2 adjacent to the retinal surface. MRI offers the only means to non-invasively measure vitreous and anterior chamber pO2 and thus this approach has important application if further improvement can be made and its accuracy can be validated.

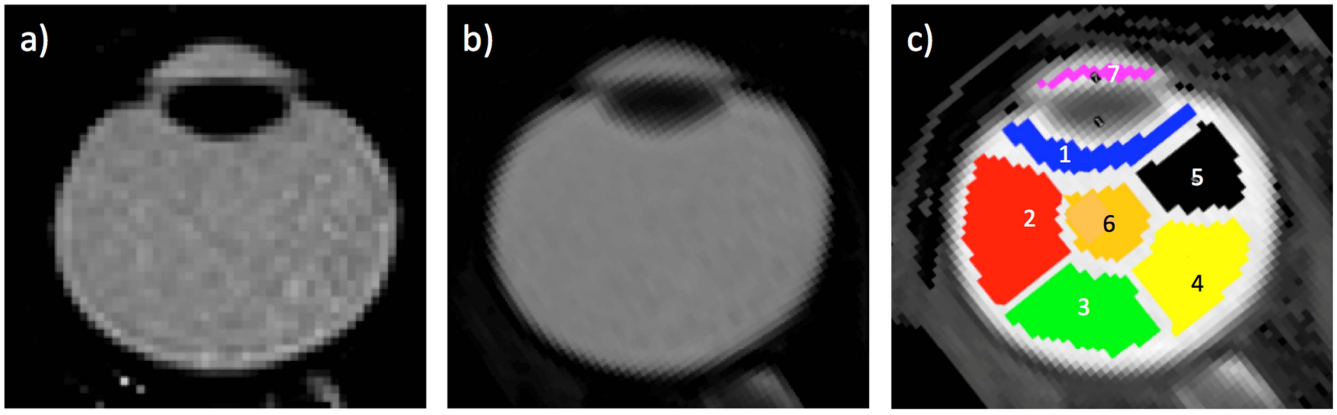

Figure 1. (a) T1 map using Look-Locker with gradient echo readout **(b)** T1 map using MOLLI (**c**) ROI's for calculation of vitreous (1-6) and anterior chamber (7) pO2.

REFRENCES 1) Holekamp et al, Am J Ophthalmol 2005, 139:302. 2) Berkowitz et al, Invest Ophthalmol Vis Sci 1999, 40:2100. 3) Muir et al, Radiol 2013, 266:905 4) Zaharchuk et al, Acad Radiol 2006, 13:1016. 5) Messroghli et al, MRM 2004, 52:141. 6) Brix et al, Magn Reson Imaging 1990, 8:351.