Signal-to-noise analysis of T1-based fluid oxygen partial pressure measurements

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An MR method of quantifying oxygen content within low-protein body fluids using a T1 mapping technique has been recently described (1). To determine the smallest pO2 change that can be detected with this method in different body fluids, it is critical to quantify the noise associated with such measurements. Therefore, we studied repeated pO2 measurements of human CSF and bladder urine using a saturation recovery T2-prep SSFSE method in healthy volunteers.

Methods: In 4 volunteers, we obtained pO2 images at 1.5T (GE Signa) for CSF (8-channel phased-array coil) and for bladder urine (8-channel body array/full FOV mode) using a saturation-recovery T2-prepped (700 ms) SSFSE sequence (1) with slice thickness 5mm, FOV 24cm (brain) or 30cm (bladder), matrix 256x256 zero-padded to 512x512, TE 60 ms, BW 31kHz. For CSF and bladder urine, 90 image pairs (with Tsat of 3 and 10 s; 15s/pair with readout time) were acquired (22'30" of continuous imaging). From each image pair, an R1 (=1/T1) map was obtained using an iterative process (2). R1 maps were then converted to pO2 maps using the formula pO2 (mmHg) = (R1 – 0.2127 s^{-1})/(2.49e-4 s^{-1}/mmHg) (1). VOI's were composed of 100 voxels (110 mm^3) for lateral ventricular CSF and 400 voxels (700 mm^3) for bladder urine. Since a prior study of CSF pO2 changes during 100% oxygen inhalation reported a time constant of 2.5 min (3), 10 individual images were averaged (2.5min) to reduce noise. The square root of the variance through the time series of each VOI (standard deviation, or SD) was determined for the individual 15s as well as mean 2.5min pO2 measurements.

Results: Fig 1 shows examples of bladder urine and CSF pO2 maps. Swirling artifact in the urine is likely caused by ureteral jets. Table 1 details pO2 measurements and SD for the 15s and 2.5min measurements, including 95% confidence intervals normalized to 1 cc of fluid. Fig 2 shows pO2 plotted vs time for bladder urine and CSF in a representative subject.

Discussion: The saturation recovery T2 prepped SSFSE method described in (1) is only one of many potential methods for measuring R1, and hence pO2. To compare with other T1 mapping sequences, it is important to document the variance of repeated measurements. We found that 15s pO2 images were noisy for both fluid collections, but that 2.5min temporally smoothed images yielded 95% CI for pO2 of 1cc of fluid of 23 mmHg (urine) and 2 mmHg (CSF). We attribute the improved sensitivity in the CSF pO2 measurement to the close proximity of the phased array coil to the brain as well as the lack of significant CSF flow. In contrast, the presence of swirling artifact in the bladder and the larger distance between the bladder and the body coil likely degraded urine pO2 measurements. We conclude that SNR for CSF pO2 is adequate for assessing small changes. However, the lower SNR of the body array coil and the turbulence from ureteral flow jets limit the sensitivity for measuring small changes in bladder urine pO2. This may be addressed by improved sequences, higher SNR coils, or larger VOI pO2 measurements.

			Individual 15 s images		2.5 min temporal smoothing	
Region	Vol MM^3	pO2 Mean (Min-Max)	SD (Min-Max)	95% CI/cc (Min-Max)	SD (Min-Max)	95% CI/cc (Min-Max)
Bladder urine	700	78 (46-92)	37 (20-59)	52 (28-83)	16 (6-27)	23 (8-38)
Lat vent CSF	110	47 (36-60)	25 (14-42)	5 (3-9)	9 (5-12)	2 (1-3)

Table 1: Mean (min and max values, n=4) for pO2, SD of individual 15s measurements and for 2.5 min temporally smoothed images. pO2 95% confidence interval per cc fluid is also reported. All values are in mmHg.

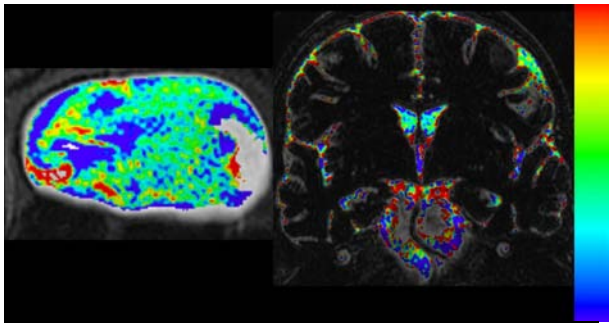

Fig 1: pO2 maps of bladder urine (left) and CSF (right). Colorbar range is (blue=0, red=190 mmHg) Swirling pattern in bladder is due to ureteral jets.

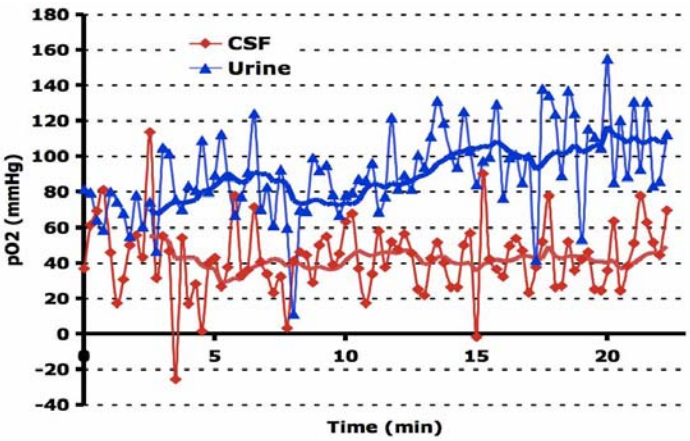

Fig 2: Individual 15s (markers) and mean 2.5 min (line) pO2 measurements for lateral ventricular CSF and bladder urine. VOI is 700 mm^3 for bladder urine and 110 mm^3 for CSF.

References: 1) Zaharchuk et al., Acad Rad 2006;13:1016. 2) Busse et al., ISMRM 2005;2194. 3) Zaharchuk et al., MRM 2005;54:113.