Comparison of TRUST, projection-based T2 imaging with susceptometry-based oximetry for the quantification of venous oxygen saturation

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Introduction: Venous oxygen saturation (SvO_2) is an important physiological parameter, e.g. quantification of SvO_2 in the superior sagittal sinus (SSS) or jugular veins allows quantification of global $CMRO_2$. So far, two approaches have been practiced: In T_2-based approaches the blood signal is isolated using subtraction techniques analogous to arterial spin labeling (ASL) [1] or phase-contrast MRA[2, 3], following a T_2-preparation CPMG train. In susceptometry, estimation of SvO_2 relies on phase mapping. The purpose of this work was to compare three different techniques (two T_2-based[3, 4] and one susceptometry-based[5]) for quantifying SvO_2 in the human brain at the level of the SSS.

Methods: *T_2-based methods:* The TRUST blood signal was isolated in the usual manner[4] and mapped as a function of eTE determined by the duration of the T_2-preparation CPMG train (0, 36.6, 73.2, 146.5 ms). In the projection-based T_2 (PT_2)[3] measurement the blood signal was isolated by taking the complex difference between velocity-encoded projections as a function of eTE (18.3, 36.6, 73.2, and 146.5 ms). *Susceptometry*: SvO_2 was quantified as described in ref [6] based on a field map to estimate the susceptibility difference between the intravascular blood and surrounding tissue. The pulse sequence[5] is designed to quantify SSS SvO_2 and cerebral blood flow (CBF) in the major vessels feeding the brain simultaneously by means of two interleaved phase difference images yielding SvO_2 and CBF maps. *Pulse-sequence parameters:TRUST*: Thickness of imaging slice= 5 mm, thickness of labeling slab= 50 mm, and gap between imaging slice and labeling slab is 25 mm. Field of View (FOV) =230 x 230 mm^2, matrix size= 64 x 64 with partial Fourier acquisition, repetition time (TR) = 3000 ms, EPI echo time = 7.47 ms, and inversion time (TI) for the blood to flow from the labeling slab to the imaging slice = 1200 ms. *PT_2*: FOV= 176 × 176 mm^2, matrix size=176×1, TR=1875 ms, TE=10.2 ms, and VENC=20 cm/s which is close to the average blood flow velocity in the SSS to minimize sensitivity of T_2 to the SSS pulsatility. *Susceptometry-based oximetry (SBO)*: FOV=208 x 208 mm^2, matrix size=208×208, TR=35 ms, VENC=60 cm/s, and the echo spacing between the same-polarity echoes (ΔTE=7.04 ms). *In-vivo studies-* SSS SvO_2 was measured at resting state in eight healthy subjects (mean age 32±6 years) at 3T (Siemens TIM Trio) using the three techniques in the same session with 10 successive measurements being made for each method.

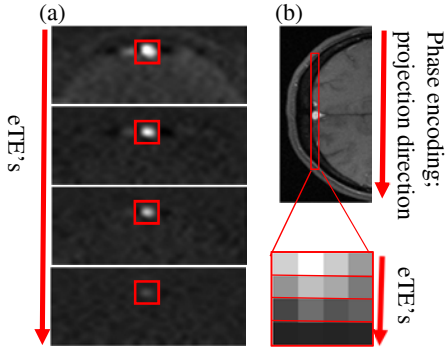


Figure 1: (a) TRUST: Difference images at four eTEs. (b) Weighted projections at four eTEs, both at the level of the SSS.

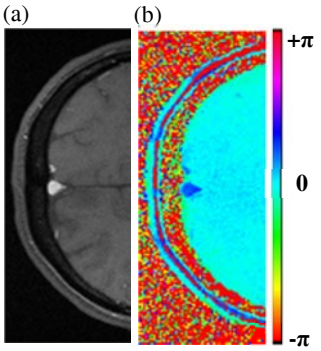
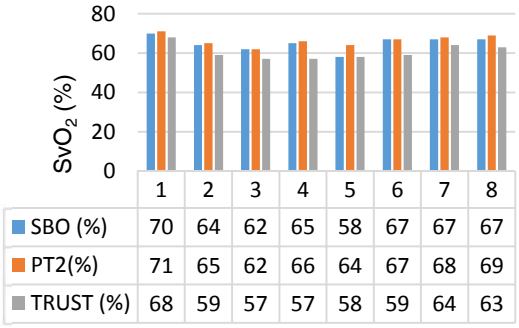


Figure 2: (a) magnitude and (b) phase image at the level of SSS to derive SvO_2.



	1	2	3	4	5	6	7	8
SBO (%)	70	64	62	65	58	67	67	67
PT2(%)	71	65	62	66	64	67	68	69
TRUST (%)	68	59	57	57	58	59	64	63

Figure 3: SvO_2 derived with the three methods: susceptometry-based oximetry (SBO), projection T_2 (PT2) and TRUST in eight subjects.

Results: Figure 1a shows cropped TRUST difference images as a function of eTE. Localizer and projection images versus eTE are given in Figure 1b. An example of a magnitude and phase image obtained by SBO is presented in Figure 2. The bar graph in Figure 3 compares SvO_2 derived with the three methods. Mean SvO_2 for the three methods was 65± 4% (SBO), 67± 3% (PT_2), and 61± 4% (TRUST). ANOVA indicated PT_2 and SBO results not to be different ($p>0.05$) but TRUST yielded mean values that were slightly lower than those obtained by PT_2 ($p=0.01$).

Conclusions: There was good agreement among the three methods based on measurement of venous blood T_2 (TRUST and projection T_2), and susceptometry. The reasons for the slightly lower values for TRUST need further scrutiny. The main advantage of the susceptometric technique is that is simultaneously measures CBF and SvO_2, therefore generally providing superior temporal resolution. On the other hand, T_2-based methods are vessel geometry independent.

References: [1] Detre et al, EJR 1999, [2] Krishnamurthy et al, MRM 2013, [3] Jain et al, MRM 2012, [4] Lu et al, MRM 2008, [5] Jain et al, JCBFM 2010, [6] Haacke et al, Magnetic resonance imaging: physical principles and sequence design. New York: John Wiley & Sons; 1999.

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