

WORKSHOP PRESENTATION

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Venous oxygen saturation estimation from multiple T2 maps with varying inter-echo spacing

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Background

Dependence of blood T2 on O2 saturation has led to non-invasive MRI-based techniques for determining venous O2 saturation (SvO₂) [1-3]. However, applying a general calibration factor derived from in vitro experiments can lead to inaccurate and largely varying SvO₂ estimates in the target population. We aim to show that based on the Luz-Meiboom relation $1/T2 = 1/T2_0 + \text{Hct}(1-\text{Hct}) \tau_{\text{ex}} [(1-\%SO_2/100)\alpha\omega_0]^2 (1-2*\tau_{\text{ex}}/\tau_{180} \tanh(\tau_{180}/2*\tau_{\text{ex}}))$ [4], individual SvO₂ can be determined from multiple T2 maps, each acquired at a specific inter-echo spacing (τ_{180}).

Methods

Three T2 prepared SSFP quantitative T2 maps ($\tau_{180}=10, 12$ and 15 ms, TR >3000 ms, FA = 40°, $2.8 \times 2.8 \times 10$ mm³, 2NEX, free breathing) were acquired in seven

volunteers (age: 32.6 ± 12.2 yrs) on a 3T MRI system (Tim Trio, Siemens Healthcare). T2 preparation involved an MLEV refocusing pulse train with 2, 4, 8 and 12 composite pulses. Venous and arterial blood T2 were measured in each map in an ROI in the ventricles. For each subject, the multiple τ_{180} measurements were processed jointly to estimate SvO₂ along with other nuisance parameters (T2₀ and τ_{ex}) via constrained non-linear least squares fitting in Matlab (The Mathworks Inc, Natick, MA, USA). The values of hematocrit (Hct), arterial O2 saturation (SaO₂), and α were fixed at 41%, 97%, and 0.4 ppm respectively.

Results

Figure 1 shows T2 maps acquired in a volunteer. Table 1 shows mean \pm SD of venous and arterial T2 and

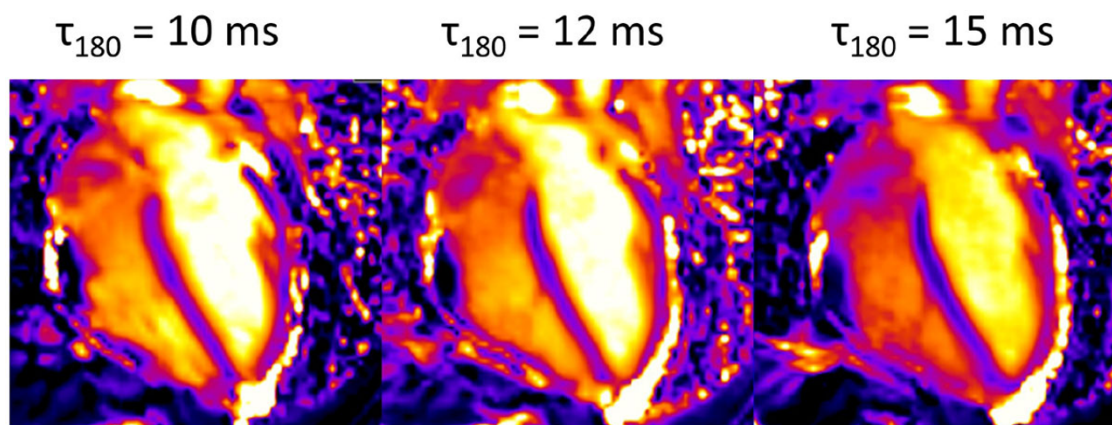


Figure 1 T2 prepared SSFP quantitative T2 maps (four-chamber view) acquired in a volunteer at different τ_{180} (10, 12 and 15 ms).

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Table 1

τ_{180} (ms)	TET2p (ms)	Venous T2 (ms)	Arterial T2 (ms)	Estimated Parameters
10	0,20,40,80,120	125.7 \pm 11.7	169.4 \pm 12.8	SvO ₂ : 72.6 \pm 5.1% T _{2o} : 168.6 \pm 12.8 ms τ_{ex} : 5.4 \pm 3.5 ms
12	0,24,48,96,144	122.2 \pm 9.8	176.4 \pm 22.6	
15	0,30,60,120	110.6 \pm 13.2	161.2 \pm 16.7	

The T2 preparation times (TET2p) at which T2 maps were acquired for a specific τ_{180} , the mean \pm SD of venous and arterial T2 values measured in an ROI in the right and left ventricles in all volunteers, and mean \pm SD of the parameters estimated from the maps.

estimated parameters. Venous and arterial blood T2 agree with previously reported values at 3T [2,3]. Estimated SvO₂ for all volunteers falls within the normal physiological range (60-80%).

Conclusions

The measured T2 of blood is dependent on Hct, O2 saturation, and τ_{180} . We have shown that if these parameters are known, SvO₂ can be non-invasively determined from arterial and venous blood T2 maps acquired at multiple τ_{180} . This provides in-vivo, patient-specific calibration, and may reduce the uncertainty and error in SvO₂ estimation from applying a general calibration factor to the entire patient population. Although in this preliminary study we have assumed a fixed Hct and SaO₂ for all subjects, greater accuracy may be achieved by measuring individual Hct and SaO₂ from a blood sample and a pulse oximeter respectively. Nevertheless, our results show that the proposed approach is feasible, giving reasonable SvO₂ estimates. Future studies will involve validation of the single assumed parameter, α , in the T2-SO₂ model, optimization of the set of τ_{180} times, and further evaluation of the accuracy and precision of T2 mapping in determining blood O2 saturation. This would lead to the development of rapid, accurate, non-invasive, in-vivo quantification of SvO₂ from T2 maps, which would be highly beneficial for heart failure and congenital heart disease patients.

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