Effect of Partial Oxygen Pressure and Hematocrit on T1 Relaxation in Human Blood

Introduction:
Molecular oxygen can be used as a paramagnetic contrast agent in magnetic resonance imaging. The feasibility to use it for assessment of lung ventilation was first shown by Edelman et al [1].

The amount of dissolved oxygen in the pulmonary blood increases during a patient is breathing pure oxygen resulting in signal enhancement in the lung. Chen et al. [2] demonstrated in phantom experiments using isotonic saline the relation between T1 and amount of dissolved oxygen.

We performed phantom experiments with human blood samples to explore the influence of partial oxygen pressure on T1 relaxation and the dependency on hematocrit to further understanding of oxygen enhanced lung MRI.

Methods and Materials:
All MR measurements were performed on a Siemens Vision Magnetom 1.5 T Scanner using the head coil.

Eight phantoms of human blood plasma and eight phantoms with an concentrate of erythrocytes which had a hematocrit of 60 % were produced from conventional transfusion bags.

A clinical respiratory system was used to bubble various proportions of oxygen and air into the samples. The probes were taken into syringes as in clinical use for blood gas determining.

Partial oxygen pressure of the samples was measured using a blood gas analyser (Radiometer ABL 500). The temperature of all samples was approximately 37°C.

T1 relaxation times were measured by use of an inversion recovery single shot turbo spin echo sequence (RARE). The imaging parameters were as follows: $T_{\text{eff}} = 4.2 \text{ ms}$, inter-echo time $= 4.2 \text{ ms}$, slice thickness $= 10 \text{ mm}$, FOV $= 240 \text{ mm} \times 240 \text{ mm}$. The inversion time (TI) was adjusted to 16 different values in the range between 50 ms and 9000 ms for each T1 measurement.

Calculation of the T1 values was done by a three-parameter-fit corresponding to the following equation: $S(TI) = a + b \exp(-T1/T1)$. This fit compensates for the influence of imperfect inversion pulses on the calculated T1 values.

Results:
Fig. 1 shows the calculated relaxation rates ($R1=1/T1$) as a function of the partial oxygen pressure.

The large number of T1 values allowed fitting of the data to the signal equation with fitting errors below 1%.

Discussion and Conclusions:
A good correlation is shown between $pO_2$ and the T1 relaxation rate in human blood samples (see correlation coefficients $R$). For quantitative evaluation of blood oxygenation it is important to recognize that the T1 relaxation is strongly dependent on the level of hematocrit. This has to be taken into account for oxygen enhanced MRI of the lung, because it is known that the level of hematocrit in the pulmonary blood changes dependent on the diameter of the lung vessels [3].

In conclusion the observed signal enhancement in pulmonary blood due to molecular oxygen is not only dependent on the amount of dissolved oxygen but also on blood hematocrit.

References:
[2] Chen, Q et al. 7th Proc. ISMRM, 1999