Magnetization Transfer Effect in the Lung Parenchyma: Dependence on the Presence of the Blood Signal

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Introduction: ^{1}H-lung MRI is a promising tool for the anatomical and functional assessment of the lung parenchyma. In particular, Magnetization Transfer Contrast (MTC) has the potential to deliver useful diagnostic information on structural changes of the underlying lung tissue, in particular for lung diseases, where the content of the MT-visible tissues (like collagen) is increased. Even though lungs show measurable MTC effects [1,2,3], the detailed origin of the MT mechanisms in the tissue is still rather unexplored. Therefore, the aim of this study was to investigate the influence of blood on the measured MTC in the lung parenchyma. For this purpose the MT effect in bloodless *ex vivo* pig lung phantoms and *in vivo* human lungs was studied.

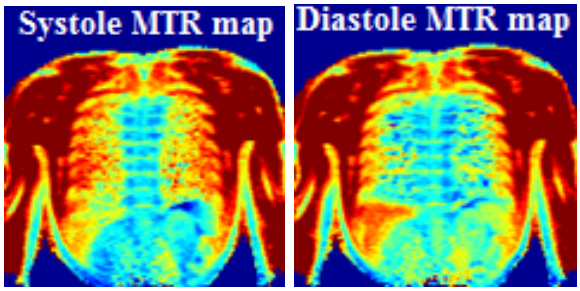
Theory: MTC creates tissue contrast between two proton groups called A pool and B pool [4]. The A pool includes the "free" protons of liquids (blood and extravascular water); the B pool contains only protons strongly bound inside the macromolecular structure (parenchyma – the lung walls etc). The MT effect can be calculated from the A pool signal using the Magnetization Transfer Ratio (MTR) which is the normalized difference between the signal of total lung water S_{TLW} and its saturated signal S_{SAT} (after off-resonance irradiation). Since blood *in vivo* shows no measurable MTC effect [4] but still contributes to S_{TLW} this makes a significant difference in MTR calculation for *ex-vivo* (equation 1) and *in-vivo* (equation 2) lungs, where the A pool either contains signal of extravascular lung water S_{EVLW} only (bloodless pig lung), or both S_{EVLW} and intravascular lung water S_{IVLW} (= human lung):

$$MTR_{EX\_VIVO} = \frac{S_{EVLW} - S_{SAT}}{S_{EVLW}} \quad \text{(equation 1)} \qquad MTR_{IN\_VIVO} = \frac{(S_{EVLW} + S_{IVLW}) - (S_{SAT} - S_{IVLW})}{(S_{EVLW} + S_{IVLW})} = \frac{S_{EVLW} - S_{SAT}}{(S_{EVLW} + S_{IVLW})} \quad \text{(equation 2)}$$

To investigate the influence of the blood signal *in-vivo* experiments were designed where the MTC-effect could be measured with and without blood suppression by using a motion-sensitive STEAM preparation [5]: 1) "Bloodless" lung MTC": STEAM in the systolic phase with the highest blood flow velocity, 2) lung MTC including blood: STEAM in the diastolic phase.

Methods: All measurements were performed by a MTC-prepared STEAM-HASTE sequence (TR/TE: 2000/4ms, 50 MTC pre-pulses, total duration 10s) on a 1.5T clinical MRI scanner during full expiration. For each set two images (with and without MT preparation) with 6s delay in between for magnetization recovery were acquired. *In vivo* measurements were ECG triggered and measured in systolic (blood suppression) and diastolic (no blood suppression) cardiac phase on 5 healthy volunteers. In addition *ex vivo* experiments were performed using a "bloodless" pig lung phantom (artiChest system).

Results: Obtained *in vivo* data correlate well with the theoretical predictions: MTRs of blood suppressed data were significantly higher than without; average values of *in vivo* measurements were 28% MTR in systole with blood suppression and 25.2% MTR in diastole without blood suppression, see Table 1. This was also confirmed by the "bloodless" *ex vivo* experiments where a 33% MTR_{EX_VIVO} was measured.



Volunteer	SYSTOLE [%MTR]	DIASTOLE [%MTR]	Difference [%]
F/29y	**27,4**	**24,7**	9,8
M/26y	**26,7**	**24,6**	7,9
F/27y	**29,6**	**26,0**	12,0
M/28y	**29,5**	**27,1**	8,1
M/25y	**26,5**	**23,6**	11,0

Table 1: Individual average MTR values of healthy volunteers group

Fig. 1: MTR maps in systole and diastole (scale set for better visualisation of the blood influence on the MTR values)

Conclusion: The results confirm that the absence/presence of lung blood does affect the observed MT effect and that the source of the MT effect in the lung parenchyma is mainly the extravascular lung water. Thus the presence of blood and corresponding cardiac cycle dependent variations in the cardiac cycle can have a major influence on the measured MTR values. These findings are supported by the *ex vivo* MTR values. In summary, for future MTC studies of the lung parenchyma blood suppression needs to be employed to assess the "pure" MTC effect of the lung parenchyma alone.

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