Oxygen-dependence of T_1 in lung tissue as observed in isolated, ventilated porcine lung phantoms

Simon Triphan[1,2], Bertram Jobst[1,3], Paul Flechsig[1,3], Felix Breuer[2], Peter Jakob[2], and Jürgen Biederer[1,4]

[1]*Diagnostic and Interventional Radiology, University Hospital Heidelberg, Heidelberg, Baden-Württemberg, Germany,* [2]*Research Centre Magnetic Resonance Bavaria e.V., Würzburg, Bayern, Germany,* [3]*Translational Lung Research Center Heidelberg, Member of the German Lung Research Center (DZL), Heidelberg, Baden-Württemberg, Germany,* [4]*German Cancer Research Center (DKFZ), Heidelberg, Baden-Württemberg, Germany*

Intended Audience

This work contributes to the understanding of oxygen-dependent lung signal changes and may be relevant for anyone interested in oxygen-enhanced lung imaging or lung parameter quantification in general.

Purpose

Breathing pure oxygen (O_2) has been found to accelerate T_1 relaxation in the lungs due to its paramagnetic attributes, which is commonly exploited for oxygen enhanced lung functional imaging using T_1 mapping[1] or signal enhancement. However, this reduction not only reflects ventilation, but is also affected by perfusion and diffusion through alveolar walls[2]. While lung MR signal is dominated by blood, the contribution of surrounding tissue means that the observed T_1 is a compound parameter that is difficult to separate. Our lung phantom[3] is based on freshly excised porcine lung explants and contains only a minimal amount of blood. Thus, only T_1 effects in lung tissue itself are visible, allowing for an isolated analysis. To study the effect of constrained O_2 absorption, a reusable porcine lung explant preserved in glycerol was also examined.

Method

All measurements were performed on a 1.5T clinical scanner. Two freshly excised porcine lung explants and one preserved porcine lung were placed in a dedicated, airtight shell filled with a $NiSO_4$ solution simulating the thoracic cavity. The lungs were inflated by producing a partial vacuum in the surrounding shell and respiratory motion was simulated using a pneumatically controlled artificial diaphragm to exchange gases. Two sets of measurements were performed with the explants ventilated with room air and after Recovery Snapshot FLASH sequence segmented into 8 inversions with a total of 128 differently T_1-weighted contrasts. Each snapshot image was acquired with a matrix of 128x128 over 50x50x1.5cm^3 Field of View with TR=3ms, giving a temporal resolution of 48ms. To compensate for the extremely short T_2*, a 50% asymmetric readout was used to attain TE=750µs. T_1 maps were calculated using a pixel-by-pixel fit, determining T_1 from the effective relaxation time T_1*[4]. Median T_1 values were determined from manually placed regions-of-interest (ROI), dividing the lungs in 10 areas.

Results

At room air, median T_1 values of 661ms±65ms (standard deviation) and 616ms±80ms were found in fresh lungs. After O_2 administration, T_1 dropped to 581ms±54ms and 540ms±48ms, respectively (relative differences were 12.0% and 12.3%, $P<1\cdot10^{-4}$). In contrast, T_1 in the preserved lung was found to be 482ms±67ms, dropping to 442ms±54ms in oxygen atmosphere (8.3% difference, $P< 0.001$).

Discussion

The T_1 values found were considerably shorter than those found in healthy human lungs. Since blood has a T_1 of approximately 1.4s, this is to be expected in the absence of blood. However, the relative T_1 reduction by O_2 in the isolated porcine lung tissue is very similar to the T_1 shortening observed *in vivo* in the lungs of healthy humans. Despite appearing smaller, the O_2 absorption in the preserved lung is still significant.

Conclusion

The experiment demonstrates that as oxygen dissolves in blood capillaries, this also occurs in tissue. This must be considered in oxygen-enhanced lung imaging, since T_1 comes from both compartments. Also, the smaller reduction in the preserved lung shows that alterations in the tissue may affect the observed T_1-effect independently of ventilation.

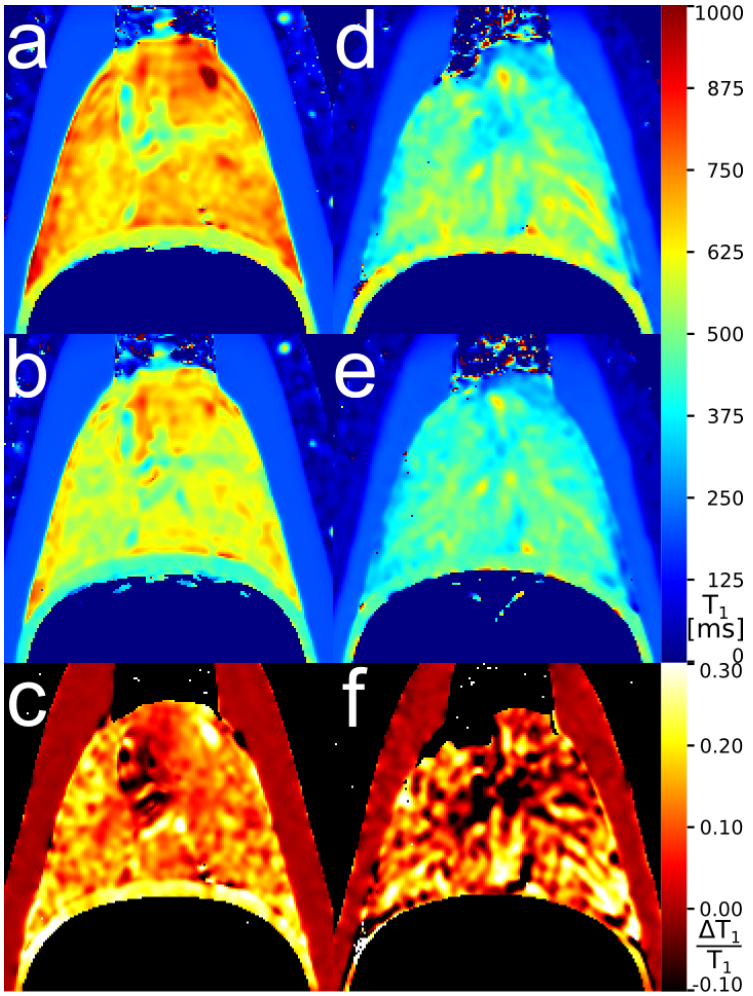

Figure 1: T1 maps of a fresh (a-c) and a preserved (d-f) excised porcine lung measured in room air (a,d) and oxygen atmosphere (b,e), as well as the relative difference (c,f) of both parameter maps.

References

[1]Jakob, P.M. et al.: JMRI 14:795-799(2001)
[2]Jakob, P.M. et al.: MRM 1009-1016(2004)
[3]Biederer, J. et al.: Radiology 227:475-483 (2003)
[4]Deichmann, R. et al.: JMR 608-612 (1992)