Investigation of the dependence of measured lung T_1 on TE using UTE

Simon MF Triphan[1,2], Bertram J Jobst[1], Felix A Breuer[2], Mark O Wielpuetz[1], Claus Peter Heussel[3], Hans-Ulrich Kauczor[1], Juergen Biederer[1,4], and Peter M Jakob[2,5]
[1]*Diagnostic and Interventional Radiology, University Hospital Heidelberg, Heidelberg, Germany,* [2]*Research Centre Magnetic Resonance Bavaria e.V., Wuerzburg, Germany,* [3]*Dept. of Radiology, Thoraxklinik Heidelberg, Heidelberg, Germany,* [4]*Radiologie Darmstadt, Darmstadt, Germany,* [5]*Experimental Physics 5, University of Wuerzburg, Wuerzburg, Germany*

Target audience:
This work is relevant for researchers working in T_1 quantification in the lung (and possibly other compartmentalized tissues) as well as functional lung imaging in general.

Purpose
In this work, it is demonstrated that the T_1 measured in the lungs depends significantly on the applied echo time *TE*. This dependence is especially apparent when using ultra short *TE*s which are otherwise beneficial to overcome the short T_2* found in the lungs.

Methods
All measurements were performed on a clinical 1.5T scanner, using a multi-gradient-echo 2D UTE sequence described previously[2], using a segmented, golden angle[3] encoded inversion recovery. 10 healthy non-smoking volunteers and one COPD patient were examined in single coronal slices. This allows for the calculation of T_1 maps[4] at 5 different *TE*s between 70µs and 2.30ms, acquired during free breathing. Average T_1 values were calculated by fitting the mean signal inside ROIs drawn over the entire lungs.

Results
Figure 1 shows T_1 maps of a healthy volunteer and a COPD patient, each sorted by *TE*. A gradual increase in T_1 as *TE* rises is visible in the lung, while relaxation in long-T_2* tissue such as muscle appears almost unaffected. This increase of T_1 with *TE* is apparent in all 10 volunteers investigated: The median T_1 found at the investigated *TE* were $T_1(TE_{1\text{-}5})$= 1051±57 ms, 1240±77 ms, 341±72 ms, 1335±80 ms, and 1408±73 ms, showing a significant increase of T_1 with *TE* ($p<0.001$). This is also apparent in the T_1 measurements from a subset of volunteers shown in table 1, as well as those from a COPD patient.

Discussion
The dependence of measured T_1 on *TE* shown can be explained by two separate compartments in the lungs with both different T_1 and T_2*. We assume that these compartments represent blood and extravascular lung water, with the extravascular compartment having shorter T_1 and T_2*, and the blood protons longer relaxation times but still much shorter T_2* than other tissues.

Conclusion
In consequence, this leads to two main conclusions: When comparing lung T_1 values measured in different subjects or experiments, the *TE* used should also be given to ensure comparability. However, it may also be exploited to gain diagnostic information since it is determined by the composition of lung tissue. The patient data so far is only preliminary and further studies are necessary to evaluate this effect in lung disease patients.

Acknowledgements
This work was supported by the German Centre for Lung Research (DZL) through grants from the Bundesministerium für Bildung und Forschung (BMBF) of the federal government of Germany (82DZL00401, 82DZL00402, 82DZL00404), as well as the German Research Foundation (DFG), grant numbers DFG JA 827/8-1 and DFG JA 827/8-2.

References
1. Jakob P, Wang T, Schultz G, et al. Magn Reson Med 2004;51(5):1009-1016.
2. Triphan S, Breuer F, Gensler D, et al. J Magn Reson Imag 2014
3. Winkelmann S, Schaeffter T, et al. IEEE Trans Med Imag 2007;26(1):68-76.
4. Deichmann R, Haase A. J Magn Reson Imaging 1992;96(3):608-612.

	T_1[ms]				
TE[ms]	0.07	0.50	1.20	1.65	2.30
	1140	1261	1373	1400	1426
healthy	1105	1260	1391	1388	1485
	1079	1277	1381	1421	1470
COPD	761	911	940	993	986

Table 1: Average T_1(TE) values measured in the lungs of 3 volunteers and a COPD patient.

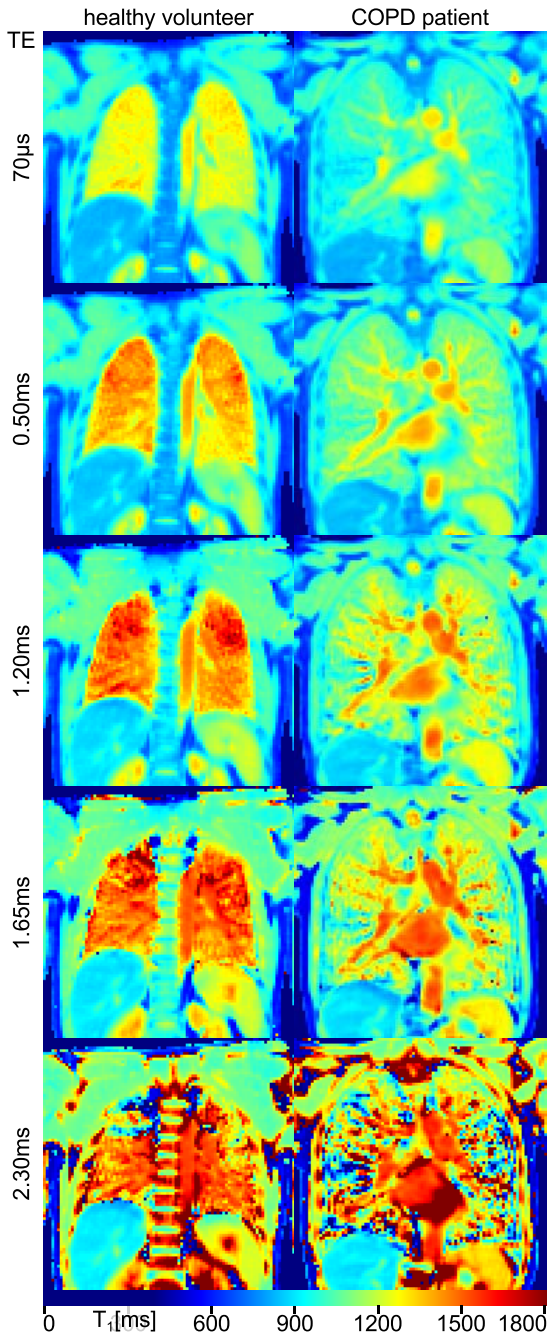

Figure 1: T_1 maps acquired at 5 TEs between 70µs and 2.30ms. Due to the short T_2, T_1 quantification fails in some voxels at long TEs.*