

# T1 Mapping of the Lungs Using DESPOT1 Approach with 3D Radial UTE Acquisition

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**INTRODUCTION:** Longitudinal spin-lattice relaxation time (T1) in the lungs has been reported to be in the range of 913-1399 ms by means of Inversion Recovery Single Shot Fast Spin Echo (IR-SSFSE) and IR-Spoiled Gradient Recalled Echo (SPGR) [1,2]. DESPOT1 can also be used to calculate T1 maps using repeated SPGR acquisitions at different flip angles [3]. However, using these techniques to create T1 maps of the lung is difficult due to inherently low proton density and very short T2\*, resulting in extremely low lung signal. Animal models have shown 3D radial Ultrashort TE (UTE) sequences capable of improved sensitivity to short T2\* species by acquiring data before significant signal decay. This has enabled visualization of functional and structural features [4,5]. The purpose of this work was to adapt DESPOT1 methodology to use a 3D radial UTE acquisition to generate high isotropic resolution T1 maps in both phantom and healthy human volunteers.

**METHODS:** This HIPAA compliant, IRB-approved study was performed using a 1.5T clinical scanner (MR450w, GE Healthcare, Milwaukee, WI) with a commercial 8-channel phased array cardiac coil. A 3D radial UTE sequence with the following acquisition parameters was used for all scans: TR/TE = 5/0.08 ms, readout time = 1 ms, 40,000 projections, FOV = 32 × 32 × 32 cm<sup>3</sup>, 1.25 mm acquired isotropic resolution, and scan time = 6:41 min. Five flip angles were chosen based on estimates of expected T1-values from the literature, and included the Ernst angle, two optimal flip angles for DESPOT1 [3], and two outliers. Respiratory motion was minimized with prospective gating to end-expiration through adaptive feedback from the respiratory bellows signal with a 50% acceptance window. Complex images were reconstructed at 3.0 mm isotropic spatial resolution and T1 maps were calculated on a pixel-by-pixel basis using a previously described non-linear least squares fitting method [3,6].

UTE-DESPOT was performed on a phantom consisting of six different aqueous solutions (T1 values ranging from 200-900 ms) at each of 5 flip angles: 3, 5, 8, 13, and 19 degrees. T1 values from 3D UTE MRI were compared to T1 mapping using IR-SSFSE (TE=28.9ms, BW=83.3 kHz, slice thickness = 10mm, 32 cm FOV, 128 × 128) at 12 inversion times (50, 75, 100, 125, 150, 200, 250, 350, 500, 700, 900, and 1100 ms). T1 values were calculated for an ROI covering the entire tube.

Four healthy human subjects were then scanned with the 3D radial UTE sequence at each of 5 flip angles: 2, 4, 6, 9, and 14 degrees. Lung T1 values were calculated by using an ROI that covered the entire lung. Additionally, blood pool T1 values were calculated by placing an ROI in the aorta for an internal control.



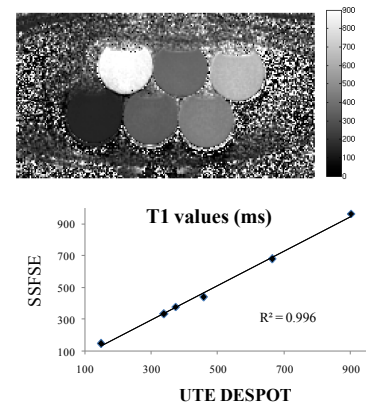
**Figure 2: 3D radial UTE T1 maps.** Qualitatively, images demonstrate sufficient signal for T1 calculations. Axial (left image) and coronal (middle image) T1 maps of Subject 2 show minimal cardiac motion due to the ultrashort TE and radial sampling. Subject 1 (far right image) showed elevated T1 values at the base of the right diaphragm (arrow) possibly due magnetic susceptibility at the lung boundary.

**RESULTS AND DISCUSSION:** Phantom experiments validated T1 measurements acquired by the 3D radial UTE sequence against the commonly used IR-SSFSE sequence (Fig. 1). Calculated T1 values for each lung and aorta are reported in Table 1. Lung T1 values were lower than reported in the literature, which also shows a wide range of values, in all but one subject. However, the ratio of the average T1 values from the right and left lung to that of the blood pool is shown to be on scale with literature values. Subject 1's T1 values are, on average, 20% higher than the other subjects. We hypothesize this is due to a noise bias, arising from magnetic susceptibility at the base of the diaphragm, corrupting the analysis fit (Fig. 2, far right). T1 maps show sufficient signal to calculate T1 values over the entire chest with very good (3mm isotropic) resolution (Fig. 2). T1 maps, however, show susceptibility to B1 inhomogeneities in both the A/P and L/R direction. Correcting for these will be necessary for T1 quantification. We believe this also contributes to the discrepancy of T1 values in the right and left lung. The images are very robust to both cardiac and respiratory motion, especially considering that the total scan time to acquire all flip angles was approximately 30min.

**CONCLUSION:** While future work to correct B1 inhomogeneity must be done in order to strengthen T1 quantification, these preliminary results show the feasibility of using a 3D radial UTE sequence to acquire high-resolution 3D T1 maps of humans lungs with full-chest coverage and without respiratory or cardiac motion artifacts.

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**REFERENCES:** [1] Edelman RR et al, Nat Med (1996), v2, 1236-1239, [2] Mai VM et al, MRM, v43, 760-763, [3] Deoni SC et al, MRM (2003), v49, 515-526, [4] Togao O et al, MRM (2010), v64, 1491-1498, [5] Kuethe DO et al, MRM (2007), v57, 1058-1064, [6] Chang LC et al, MRM (2008), v60, 496-50 and [7] Stanisz GJ et al, MRM(2005), v54, 507-512.



**Figure 1: 3D Radial UTE T1 map of a phantom (top) shows good correlation ( $R^2=0.996$ ) with T1 values acquired with IR-SSFSE acquisition (bottom).**

T1 Values (msec)				
Subject	Right Lung	Left Lung	Blood Pool	Ratio: Lung/Blood
1	1021±221	845±190	922±23	1.01
2	737±73	790±93	1080±32	0.71
3	699±109	787±194	1003±17	0.74
4	720±65	730±71	973±27	0.74
Literature	1000	1000	1400 [7]	0.71

**Table 1: Calculated T1 values with 3D Radial UTE scan are compared to reported literature values. As literature lung T1 values are wide spread, a value in the middle was chosen.**