Correlation of proton spin density with T1 relaxation of the lung in patients with cystic fibrosis

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Introduction: Recently, a rapid lung ^{1}H MR T_1-mapping technique based on an IR snapshot FLASH sequence has been successfully demonstrated in healthy volunteers (1). As a by-product of this technique, the corresponding lung proton spin density, M_0, maps were also obtained. The purpose of this work is to study the correlation of M_0 with T_1 of the lung in ten patients with cystic fibrosis (CF).

Theory: According to a simplified, fast-exchange, two-compartment model (2), the observed lung T_1 relaxation is given by **Equation 1, $1/T_1 = P_f/T_{1f} + P_b/T_{1b}$,** where P_f is the free-water fraction, P_b is the fraction of water bound to macromolecules such as present in the matrix of the lung, e. g. collagen, T_{1f} is the free-water T_1 and T_{1b} is the bound-water T_1.

Methods: Ten patients with CF were examined in the supine position on 1.5-T VISION, Siemens. A coronal, dorsal lung T_1 map and the corresponding M_0 map in each patient were acquired simultaneously during a single breathhold on end-expiration using a rapid ^{1}H MR T_1-mapping technique (1). No ECG triggering was used in all studies. In each patient, two representative ROIs including 100 pixels, one with higher M_0 values and the other with lower M_0 values, were defined according to the M_0 map. The two M_0 values averaged over the ROIs (mean ± SD) and the two corresponding T_1 values were then measured.

Results: As a typical example, Figure 1 and Figure 2 show a lung M_0 map scaled from 0 to 200 in arbitrary units (a. u.) and the corresponding T_1 map scaled from 0 to 1400 ms in a 28-year-old male patient with CF. The M_0 map and the T_1 map both appear inhomogeneous. The areas with higher M_0 in Figure 1 match the areas with normal T_1 in Figure 2 well. The areas with lower M_0 also match the areas with abnormally decreased T_1 well. M_0 of 106 ± 14 and 33 ± 15 in a. u. were measured in ROI 1 and ROI 2 in Figure 1 respectively. The corresponding T_1 of 1319 ± 130 and 987 ± 176 ms were measured in Figure 2. The results from all patients with CF were summarized in Table 1, and reveal that in each patient with CF higher lung M_0 correlates with normal lung T_1 and lower lung M_0 correlates with abnormally decreased lung T_1.

Discussion: A good correlation of lung proton M_0 with T_1 was successfully demonstrated in ten patients with CF using a rapid ^{1}H MR T_1-mapping technique. According to Equation 1, changes in the bound-water to free-water ratio are reflected in the observed lung T_1. For this reason, the accumulation of macromolecules, which is expected to increase the bound-water fraction, and lower lung M_0, which is expected to decrease the free-water fraction, may account for the lower lung T_1 in patients with CF.

References:

1. Jakob PM, et al. J Magn Reson Imaging 2001;14:795–799.
2. Cutillo AG. Application of magnetic resonance to the study of lung. New York: Futura; 1996. p 115–139.

Table 1. Measured M_0 and the corresponding T_1 of two defined lung ROIs in each patient with CF.

CF-Patient	Age/Sex	M_0 [a.u.]	T_1 [ms]	CF-Patient	Age/Sex	M_0 [a.u.]	T_1 [ms]
1	34/M	192 ± 26	1395 ± 116	6	27/F	206 ± 40	1518 ± 96
		63 ± 10	1100 ± 99			143 ± 35	1015 ± 116
2	25/F	224 ± 44	1207 ± 65	7	12/M	140 ± 25	1084 ± 91
		88 ± 10	879 ± 76			93 ± 25	903 ± 131
3	12/M	198 ± 29	1171 ± 40	8	18/M	96 ± 25	1346 ± 111
		127 ± 17	1039 ± 43			59 ± 18	1109 ± 91
4	13/M	290 ± 60	1191 ± 72	9	28/M	106 ± 14	1319 ± 130
		152 ± 24	1026 ± 57			33 ± 15	987 ± 176
5	14/F	178 ± 36	1171 ± 94	10	15/F	76 ± 18	1383 ±318
		71 ± 15	702 ± 72			64 ± 19	845 ± 149

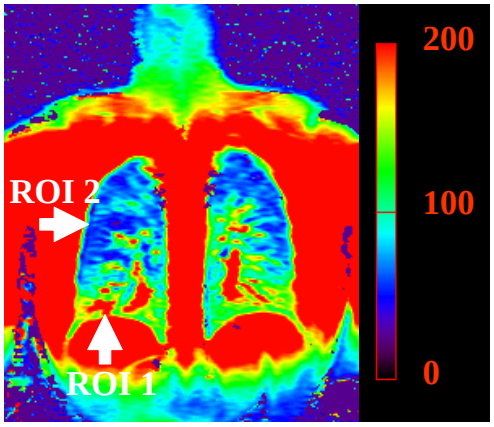

Figure 1

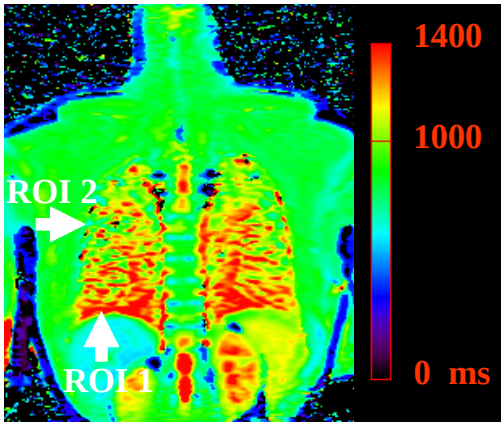

Figure 2

Figure 1. Coronal dorsal lung M_0 map scaled from 0 to 200 in arbitrary unites in a 28-year-old male patient with CF. Two ROIs including 100 pixels, ROI 1 with higher M_0 and ROI 2 with lower M_0, were defined. M_0 of 106 ± 14 and 33 ± 15 were measured in ROI 1 and ROI 2 respectively.
Figure 2. Corresponding T_1 map scaled from 0 to 1400 ms in the same patient in Figure 1. T_1 of 1319 ± 130 and 987 ± 176 ms were measured in ROI 1 and ROI 2 respectively.