3D Ultrashort TE (UTE) MRI repeatability within the thorax and its application to pulmonary fibrosis.

Alexander Weller[1], Sharon L Giles[2], Veronica A Morgan[2], David Collins[1], David M Higgins[3], and Nandita M de-Souza[1]

[1]CRUK Cancer Imaging Centre, Institute of Cancer Research, Sutton, Surrey, United Kingdom, [2]MRI Department, Royal Marsden Hospital, Sutton, Surrey, United Kingdom, [3]Clinical Science, Philips Healthcare, Guildford, Surrey, United Kingdom

Target Audience: Radiologists, clinical oncologists, radiographers, clinicians and physicists with subspecialty interest in chest imaging

Purpose: In the thorax, ultrashort time to echo (UTE) MRI has been used to quantify T2* of lung parenchyma; T2* values correlate with density derived from CT Hounsfield Unit (HU) values in patients with chronic obstructive pulmonary disease[1]. However, the utility of the technique in characterizing lung tumors and assessing post radiation fibrosis has not been explored. The aim of this study was to evaluate the changes in T2* in irradiated lung and lung tumors post treatment. The repeatability of these measurements and of T2* values for other normal structures within the thorax (thoracic aorta, vertebrae, pericardium) were documented.

Methods: Following ethics committee approval and written informed consent, 6 radiotherapy naive patients aged between 59 and 78 years with primary lung carcinoma underwent two consecutive UTE MRI studies within 1 week. In 1 patient, a further study was performed 3 months following intensity modulated radiation therapy (IMRT). T1W and UTE-T2W images were acquired during shallow free breathing on a clinical 3T MR imaging system (Achieva 3.0T XT, Philips Healthcare, Best, The Netherlands), using a SENSE XL torso coil and a 3D UTE FFE radial acquisition in the transverse plane, from the lung apices to the diaphragm. UTE sequence parameters were: TR 10ms; 192 slices; FOV 350mm, 3.5mm slice thickness, voxel size 3.5x3.5x3.5mm, 1 NSA, 192x192 matrix. The sequence was repeated using TE values of 0.08, 0.2, 0.3, 0.4, 0.5, 0.75 and 1.0ms, with a total imaging time of approximately 40 minutes.

T2* and R2 $(T2^*)^{-1}$ values were derived using linear regression analysis of the logarithmic plot of (mono-exponential) signal intensity decay with increasing TE (ADEPT, ICR, UK). Matched regions of interest (ROI) were drawn using anatomical landmarks on the R2 intensity plots, where necessary correlating with concurrent CT studies. Coefficients of variance (CoV) and Bland Altman plots assessed R2 value repeatability between examinations. Median R2 values between similar anatomical structures, in different MRI experiments, were compared using the independent samples t-test.

Results: Repeatability data is listed in Table 1. For consecutive studies within the same patient, variation was largest for tumor and pulmonary parenchyma (CoV 18.6%) and lowest for bone (vertebra, CoV 6.4%). Differences in R2 before and after IMRT (Table 2) were greater than would be expected from the CoV for lung parenchyma. Fibrotic lung had higher R2 value than non-fibrotic lung (Fig 1, $p<0.0001$) and the R2 of both tumor and surrounding lung were greater after IMRT.

Structure	Overall average median R2(ms^{-1}) (+ sd)	CoV (%)
Lung parenchyma	564 (105)	18.6
Lung tumor	160 (83)	51.9
Aortic wall	987 (131)	13.3
Pericardium	1118 (157)	14.0
Vertebral body	1681 (108)	6.4

Table 1. Coefficients of variance (CoV) between duplicate median R2 values of different structures within the chest.

	Mean difference in median R2(ms^{-1}) values (95% CI)	p-value
Lung post versus pre radiotherapy	144.6 (194.7 to 94.5)	<0.0001
Tumor post versus pre radiotherapy	356.5 (457.8 to 255.2)	<0.0001
Fibrotic lung versus non fibrotic lung (in the same pt)	114.7 (79.9 to 149.5)	<0.0001
Fibrotic lung versus non fibrotic lung (in different pts)	273.2 (248.6 to 297.8)	<0.0001

Table 2. Mean differences in median pulmonary R2 values: Statistically significant differences are present, which are greater than the variation in R2 expected about the mean due to the CoV in lung parenchymal measurements.

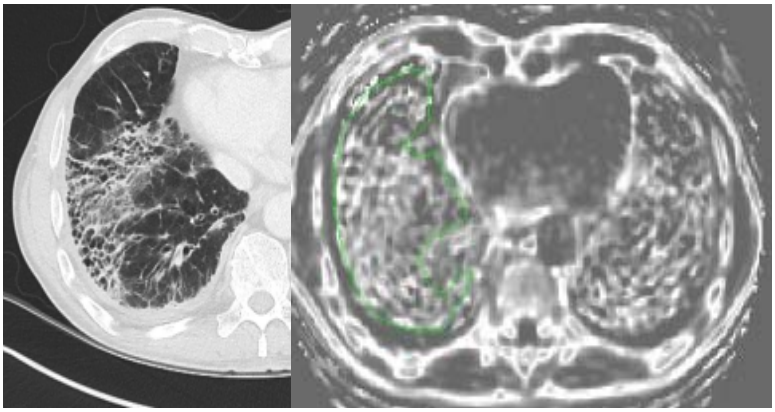

Figure 1: R2 intensity on this axial image through the right lower lobe is greater in pulmonary fibrosis (confirmed on corresponding CT) than in the left lower lobe with no fibrosis. Note high signal intensity of pericardium, periosteum and vertebral body.

Discussion and Conclusion:

Pulmonary fibrosis has been demonstrated in mice on single echo UTE MRI (TE 0.528ms at B0=4.7T), with correlation between signal intensity and collagen deposition on pathological specimens[2]. T2* values derived from multiple echo times should be more specific for short T2, collagen rich elements within the lung. Indeed, values obtained within this study for fibrotic lung and the effect of IMRT on T2* signal from both background lung and pulmonary carcinoma indicate T2* shortening with fibrosis. T2* values therefore have potential for differentiating fibrosis from non-specific pneumonitis on CT. In addition, the change in T2* within primary tumor and surrounding lung following IMRT may provide early identification of pulmonary fibrosis and deserves further investigation. Given the repeatability of the measurements in vivo, UTE MRI also has additional potential role in characterising aortic, vertebral body and pericardial pathology, as previously demonstrated for carotid and coronary arteries ex-vivo[3,4].

References:

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