Comprehensive structure/function MRI of cystic fibrosis

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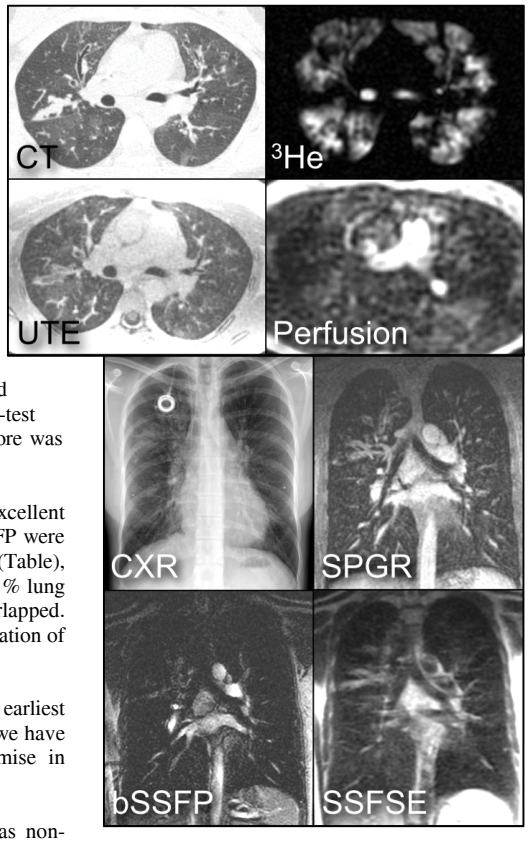
Target Audience: Cardiothoracic radiologists and MRI physicists interested in clinical and translational research

Purpose: The use of MRI for longitudinal surveillance of cystic fibrosis (CF) has significant potential advantages over CT or chest x-ray (CXR) with respect to reduced radiation dose, ability to image regional function, and the potential for earlier detection of disease progression or treatment response. The purpose of this study is to evaluate the performance of several alternative MRI methods in detecting cystic fibrosis (CF) lung disease.



Methods: *Acquisition:* The first 6 subjects (3:3 M:F, age: 11-27, FEV_1: 52%-119% predicted) of an ongoing, prospective 5 year evaluation of MRI as a means for characterizing CF lung disease were included in this analysis. CXR, inspiratory/expiratory chest CT, and MRI were performed on all subjects at their baseline state of health. MRI included both functional (^{3}He ventilation and dynamic contrast-enhanced perfusion[1]) and anatomic/structural methods, including a 3D radial ultrashort echo time (UTE) approach[2]. MRI was performed on a 1.5T clinical scanner (Signa HDx, GE Healthcare) using a commercial 8-channel cardiac phased array coil (GE Healthcare, Waukesha WI) for the proton-based imaging and a custom-built ^{3}He-tuned single-channel birdcage coil (Rapid Biomedical, Columbus OH) for the ventilation imaging.

Analysis: Two cardiothoracic radiologists (6 and 7 yrs experience) independently scored each acquisition in a randomized, blinded fashion, recording the volume % of diseased lung on a continuous scale with a subjective 95% confidence interval. CT and UTE images also received a volume percent air-trapping sub-score because air trapping is thought to represent one of the earliest signs of CF lung disease and has been difficult to detect by MRI. Image quality was assessed as poor, suboptimal, good, and excellent, with "good" and "excellent" considered clinically useful. Scores were compared using paired t-test and Fisher's exact test. Linear regression and correlation of each modality with the CT air-trapping score was also performed.

Results: The readers rated CXR, CT, ^{3}He MRI, perfusion MRI, and UTE MRI image quality as good to excellent and therefore suitable for clinical use in assessing the extent of CF lung disease, while SSFSE and bSSFP were not. There were strong correlations between CT air trapping and ^{3}He MRI, perfusion MRI, and UTE MRI (Table), with slope > 1. There were modest but statistically significant biases between readers in the estimates of % lung disease for CT, bSSFP, SPGR, and UTE, but the subjective 95% confidence intervals for the readers overlapped. Contrast-enhanced perfusion, and ^{3}He MRI were the strongest performers when considering both minimization of reader bias and correlation with CT.

Discussion: There has been growing recognition in the CF community that CT "air trapping" may be the earliest sign of CF lung disease. Historically, MRI has had difficulty detecting air trapping. In this small study, we have shown that ^{3}He ventilation MRI, contrast enhanced perfusion MRI, and UTE MRI all show promise in overcoming this limitation.

Conclusion: ^{3}He ventilation MRI, contrast enhanced perfusion MRI and UTE MRI may be useful as non-irradiating alternatives to CT in the setting of cystic fibrosis.

Metric	Notes BH=breath-held FB=free breathing	Deemed suitable for clinical use in CF	Difference in % diseased volume between readers *Mean [95% CI]*	p-value	Correlation coefficient wrt CT air trapping *Mean [95% CI]*	Linear regression slope	p-value
CXR		**Yes**	3% [-9%, 14%]	0.590	0.21 [-0.73, 0.87]	0.2	0.692
CT – Total	BH, Insp/Exp	**Yes**	**-11% [-21%, -1%]**	**0.041**	**0.88 [0.25, 0.99]**	**1.2**	**0.020**
CT – Air trapping			3% [-9%, 15%]	0.533	--	--	--
^{3}He	2D, BH, axial	**Yes**	5% [-8%, 17%]	0.399	**0.83 [0.06, 0.98]**	**1.1**	**0.041**
SSFSE	2D, BH, coronal	No	**15% [4%, 25%]**	**0.018**	0.02 [-0.81, 0.82]	0.0	0.973
bSSFP	2D, BH, coronal	No	**34% [28%, 39%]**	**< 0.001**	0.57 [-0.45, 0.94]	0.2	0.239
Perfusion	3D, BH	**Yes**	9% [-2%, 19%]	0.083	0.76 [-0.13, 0.97]	1.1	0.079
SPGR	3D, post-contrast, BH	Maybe	**20% [8%, 32%]**	**0.007**	-0.16 [-0.86, 0.75]	-0.1	0.761
UTE – Total	3D, post-contrast, FB	**Yes**	**18% [11%, 25%]**	**0.001**	**0.91 [0.35, 0.99]**	**1.2**	**0.020**
UTE – Air trapping			**21% [6%, 35%]**	**0.014**	**0.91 [0.35, 0.99]**	**1.3**	**0.013**

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References: [1] Wang K, et al JMRI 38:751-756 (2013); [2] Johnson KM, et al MRM 70:1241-1250 (2013)