Reproducibility of lung volume measurements in hyperpolarized 3-Helium MRI of children with Cystic Fibrosis

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Introduction

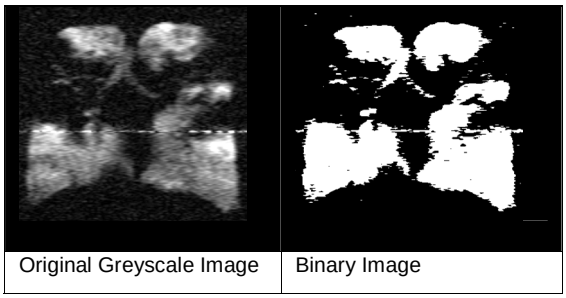
Cystic fibrosis (CF) is a genetic disease affecting about 30,000 people in the United States and about 70,000 people worldwide. Patients with CF typically suffer from chronic respiratory infections, causing gradual destruction of lung tissue. This leads to progressive lung disease, a reduction in ventilated volume and eventually, respiratory failure. An accurate, non invasive and non-ionising method of patient follow up is highly desirable. 3-Helium (3-He) MRI of the lungs is a powerful tool for assessing gas distribution in the lungs and ventilation defects in CF have been previously demonstrated [1,2]. In any longitudinal assessment of lung function reliability is paramount; we examined the reproducibility of ventilated volume measurements obtained with hyperpolarized 3-Helium MRI.

Methods

5 Children with CF were recruited (mean age 11, Range 6-15 years). Each was imaged twice within 30mins. MR images were acquired on a 1.5 T Eclipse system, *(Philips Medical Systems*). 24x 9mm slices were produced in 20s using a 3D gradient recalled echo sequence [2] after inhaling a dose of 5ml/Kg body weight of hyperpolarized 3-He diluted with an equal quantity of N_2, followed by room air to fully inflate the lungs. 3-He (*Spectra Gases)* was hyperpolarized to approximately 30% on site using a spin exchange polarizer (*GE-Health)*. The vital signs of all patients were monitored throughout the examination. The images from the 3-He scans were systematically thresholded to produce a binary image (Fig. 1) and the pixels counted to calculate a volume. The total ventilated volumes were compared.

Results

All children tolerated the procedure well and all vital signs remained stable; no desaturation of blood oxygen levels was observed. All sets of images were diagnostic with good signal to noise ratio. The Pearson correlation coefficient for the ventilated lung volumes was 0.99. Slice by slice regression analysis produced a good fit for each patient, an example is displayed below (Fig. 2) The mean % difference between the two examinations was 5%, 95% C.I. (3, 7). The mean difference in calculated volume was 90.84ml, 95% C.I. (56.08, 125.6). The volumetric results are summarized in Table 1.



Original Greyscale Image | Binary Image

Fig 1. Thresholding to produce binary image

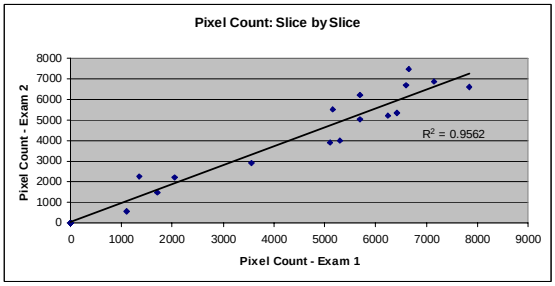


Fig 2. Slice by Slice Regression Analysis (Patient 1)

	Volume 1 (L)	Volume 2 (L)	% Difference	Difference in volume (ml)
Patient 1	1.86	1.74	-7%	-125.57
Patient 2	1.17	1.10	-6%	-70.27
Patient 3	2.40	2.26	+6%	+141.18
Patient 4	2.50	2.43	-3%	-63.44
Patient 5	1.45	1.50	+4%	+53.74

Table 1. Ventilated Lung Volumes

Discussion

The ventilated volume measurements obtained from this difficult patient group appear to be relatively reproducible within the time frame of this experiment. The differences in volumes between examinations (although small) are not unexpected, and could be attributable to a number of factors, such as slight variations in the breath-hold manoeuvres, patient movement between acquisitions, shifting of mucus plugs caused by the breath-hold manoeuvre, and variation in the signal to noise ratio in the data sets which would affect the pixel count returned by the threshold algorithm. The results are encouraging considering the severity of disease and age range of the sample and suggest that 3-Helium MRI could play a role in the long term evaluation of chronic lung disease, especially in children where ionizing radiation is to be avoided.

[1] Donnelly LF, Mac Fall JR, McAdams HP et al, *Cystic Fibrosis: combined hyperpolarized 3He enhanced and conventional proton MR imaging in the lung – preliminary observation.* Radiology 1999; 212:885-9

[2] van Beek EJ, Hill C, Woodhouse N et al, *Assessment of cystic fibrosis in children using hyperpolarized 3-Helium MRI: comparison with Shwachman score, Chrispin-Norman score and spirometry.* Proc. Intl. Soc. Mag. Reson. Med. 11 (2004); 761

[3] Wild JM, Woodhouse N, Paley MN et al. *Comparison between 2D and 3D gradient-echo sequences for MRI of human lung ventilation with hyperpolarized 3He.* Magn Reson Med. 2004 Sep;52(3):673-8