

Test-Retest and Inter-Reader Reliability of Hyperpolarized Helium-3 MRI in Patients with Exercise-Induced Bronchoconstriction

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Introduction: Hyperpolarized helium-3 magnetic resonance imaging (HPHe MRI) is a promising tool for evaluation of obstructive lung disorders because it allows regional measurement of ventilation. Despite its promise, the reliability of HPHe MRI has not been thoroughly investigated. Image analysis often involves subjective steps, such as defining boundaries of regions with high or low ventilation. The purpose of this study is to determine the reliability of HPHe MRI measurements between exams taken on separate days and the inter-reader reliability of HPHe MRI measurements when studies are read independently in a blinded fashion.

Methods: Thirteen patients with mild asthma and a history of exercise-induced bronchoconstriction (EIB) were tested on two separate visits. Patients performed a 10-minute treadmill exercise challenge during each visit and showed at least a 15% drop in forced expiratory volume in one second (FEV1) after exercise. HPHe MRI of the lungs was performed three hours prior to exercise (baseline), immediately after exercise (post-challenge), and 35 minutes after exercise (recovery). Exams consisted of 12-16 1.5-cm-thick coronal slices acquired with a fast gradient echo sequence (TR/TE = 7.7ms/4ms, 7° flip angle, 40-48cm FOV, 128 matrix).

The images were independently analyzed by two image scientists using custom software written in MATLAB (The Mathworks, Natick, MA). The total lung volume (V_L), the total volume of unventilated regions (defects; V_D), and the number defects (N_D) were measured by manual segmentation of the HPHe images. The percent ventilated volume of the lung (V_V) was calculated as $V_V = 100\% \times (V_L - V_D) / V_L$.

Test-retest reliability between the two visits was calculated using the intra-class correlation coefficient (ICC). This calculation was performed separately with results from each reader. Inter-reader reliability was assessed by the ICC and a Bland-Altman analysis. ICC calculations were for absolute agreement rather than consistency.

Results and Discussion: Figure 1 shows typical HPHe images for two visits in one patient. Note the similarity of defect size and location between visits (A vs. B rows) and post-challenge (arrows). Segmentation maps (C vs. D rows) show defects defined by two independent reviewers blinded to subject, time point, and visit.

Table 1 shows the test-retest and inter-reader reliability of HPHe MRI measurements as well as the bias and 95% confidence interval from the Bland-Altman analysis. Test-retest ICC values indicate that V_D , V_V , and N_D are highly reproducible between visits. Similar agreement has been reported for V_D in COPD [1], supporting the reproducibility of this measure for obstructive disease in general. The relatively low test-retest reliability for V_L may result from uncertainty in determining the lung boundary in HPHe images with large defects. This can be resolved by using anatomical ¹H MRI images to identify the lung boundary.

The high inter-reader ICC values indicate that all four measurements are reliable for multiple readers. Bias between readers is very small for V_L , V_V and N_D .

Conclusions: This study shows that measurements based on HPHe MRI are robust between separate visits and between independent evaluators. Reliability of V_L can be further improved by using ¹H MRI images in conjunction with ³He to identify the lung boundary when large defects are present.

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References:

1. Mathew et al. *Acad Radiol.* 2008. Oct;15(10):1298-1311.

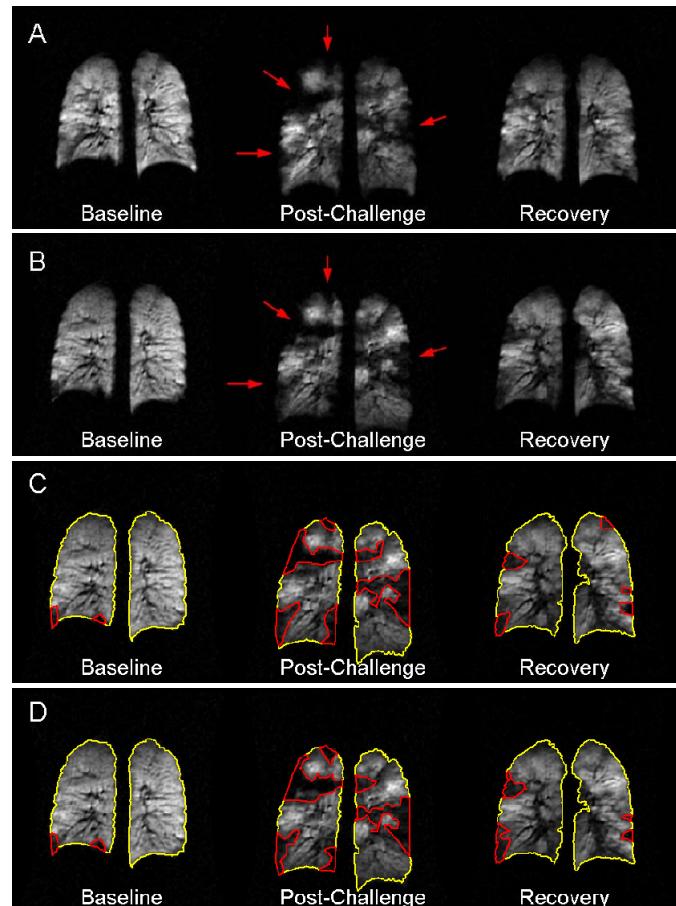


Figure 1. Typical HPHe images showing ventilation defects as dark regions. A and B are from separate visits in a single patient. Note the similar size and position of defects between visits (arrows). C and D show segmentation of the lung boundary (yellow lines) and defects (red lines) for a single visit by two independent readers. Note the similarities between these independent segmentations.

Table 1. Test-Retest and Inter-Reader Reliability Measures.

	Test-Retest Reliability		Inter-Reader Reliability		
	Reader 1 ICC	Reader 2 ICC	Inter-Reader ICC	Bias	95% confidence interval
V_L	0.65	0.61	0.91	-27.5 *	-560 – 505 *
V_D	0.90	0.84	0.92	-38.0 *	-346 - 270 *
V_V	0.89	0.88	0.93	0.80 †	-5.21 – 6.81 †
N_D	0.77	0.82	0.91	1.37	-13.0 – 15.7

* milliliters; † percent