Automated Scoring of Hyperpolarized Helium-3 MR Lung Ventilation Images: Initial Development and Validation

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Abstract

Hyperpolarized helium-3 (H3He) is a new gaseous MR contrast agent that permits MR imaging of lung ventilation. Human reader scoring of the ventilation images is tme consuming and tedious. Five candidate image analysis algorithms were developed and then compared with human reader scoring of 11 H3He MR lung ventilation studies. All algorithms correlated well with the human reader scoring for subjects with severe disease. Only one algorithm, the heirarchical K means, performed well in subjects with mild disease. The heirarchical K means approach is promising for the automated scoring of H3He lung ventilation MRI.

Introduction

Hyperpolarized helium-3 (H3He) MRI of lung ventilation demonstrates focal regions of decreased signal intensity in the lungs of subjects with lung disease and some normal subjects. Human reader scoring of H3He lung ventilation MRI is tedious and time consuming. The purpose of this study was to develop and validate an automated scoring system for H3He ventilation MRI that quantifies ventilation abnormalities. The ideal scoring system would be fully automated, robust, reproducible, similar to human reader scoring and correlated with disease severity.

Methods

Five different classification algorithms were compared with human reader scoring of previously acquired H3He MR studies in 11 subjects with a variety of lung diseases and a spectrum of disease severity.

Image Processing The image processing software was developed in IDL (RSI, Boulder CO, USA). Lung segmention from the surrounding tissue was performed using proton images that had been acquired shortly after the H3He MRI at identical slice positions and at approximately the same level of inspiration. The lungs were segmented using a threshold selected from the pixel intensity histogram.

Five different classification algorithms were developed and evaluated: 1) threshold based, 2) K means with 3 classes, 3) K means with 4 classes, 4) fuzzy-C means with 4 classes, and 5) heirarchical K means (1). The threshold algorithm divided the lung into three classes using thresholds at 20% and 40% of the maximum intensity pixel. The K means and C means clustering algorithms partition the pixel intensity range into a predetermined number of classes containing clusters of similar intensity values with the greatest possible distinction between classes. With the 4 class K means algorithm, the top two classes were merged to yield 3 classes. With the heirarchical K means algorithm, the image was initially segmented into two classes. The bottom class was then segmented into two classes. For all of the algorithms, the class corresponding to the highest image intensity values was called the ventilated class, the middle class hypo-ventilated and the lowest class non-ventilated. The percent of the total lung volume in each of the three classes was calculated.

Reader Analysis A single trained radiologist reader blinded to all clinical information evaluated the 11 H3He studies. The percent non-ventilated lung, hypoventilated lung and ventilated lung was estimated for each image. The results from each image in a study were averaged to yield the percent of lung in each class.

Imaging Breath held MR images were obtained on a Siemens 1.5 T scanner in the coronal orientation immediately after inhalation of spin-exchange polarized H3He gas using a FLASH sequence with typical parameters: TR/TE 7.0/ 2.7ms, FA 9 degrees, FOV 420mm, TH 10mm, 9-15 slice sections. Conventional coronal proton lung images were obtained at the same anatomic locations using a gradient echo sequence.

Results

All five algorithms successfully classified the lungs into ventilated, hypo-ventilated and non-ventilated regions. The classification obtained using the K means algorithm and the fuzzy-C means algorithm were nearly identical. Since the fuzzy-C means algorithm was significantly more computationally intensive, the fuzzy-C means algorithm was not evaluated further. In comparison with the other algorithms, the threshold based algorithm classified more of the lung as non-ventilated , while the 3 class K means emphasized the hypo-ventilated class and the hierarchical K means emphasized the ventilated class as seen in Fig. 1.

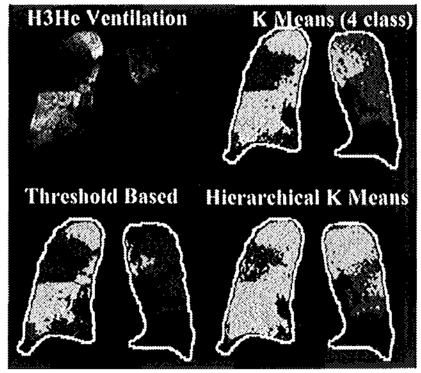

Figure 1. *Comparison of the H3He ventilation image and the classification obtained from three of the algorithms. (The non-ventilated class is black, hypoventilated class dark grey, and ventilated class light grey.) The outline of the lung is obtained by segmenting the lung on the proton images.*

In comparison with the human reader, all four algorithms correlated well with Pearson correlation coefficients for the percent ventilated lung of 0.87, 0.75, 0.83, and 0.91 for the threshold based, 3 class K means, 4 class K means, and hierarchical algorithms respectively (Fig. 2). The hierarchical K means algorithm had a substaintially smaller mean square error than the other algorithms. The threshold based algorithm and the 4 class K means algorithm overestimated disease severity in subjects with mild disease. The hierarchical algorithm underestimated desease severity relative to the reader in two subjects: one with large areas of hypoventilated lung and another with a very heterogeneous ventilation pattern.

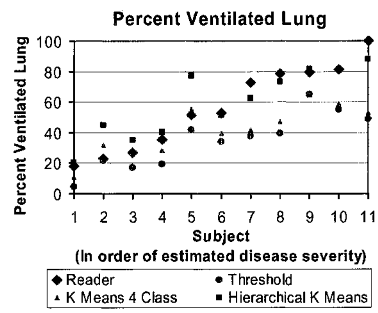

Figure 2. *Comparison of the reader scores and the algorithm classifications. There is excellent agreement between the reader and the hierarchical K means algorithm.*

Discussion

We evaluated 5 potential classification algorithms for the evaluation of H3He ventilation MRI. The hierarchical K means algorithm most closely matched the human reader scoring of the images. All algorithms performed well in subjects with severe disease. Only the hierarchical K means algorithm performed well in subjects with mild disease. In subjects with severe disease, most of the intensity variation in the image was due to lung disease, and thus the reader and the clustering algorithms scored similarly. In subjects with mild disease, much of the intensity variation in the images was due to coil inhomogeneities. The trained reader ignored coils inhomogeneity when scoring the images and only the hierarchical K means algorithm was robust to coil inhomogeneity artifacts. Thus, the hierarchical K means algorithm appears to be a promising candidate for the automated evaluation of H3He lung ventilation MRI.

References

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