Towards a better Understanding of Helium-3 MRI Manual Segmentation Error Using Fuzzy C-mean Methods

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Introduction: Hyperpolarized ^{3}He MRI provides a way to visualize and quantify lung function based on segmentation of lung ^{3}He ventilation. Manual segmentation of ventilation defect volume and ventilation volume is currently used in our laboratory but is time consuming. Inter- and intra-observer variability, measured using the coefficient of variation, ranges from 2-20% which is likely too high for clinical trials where small changes in ventilation might be expected. Therefore, one of our overarching goals is to develop a fully automated method for segmenting ventilation volumes. The aim of this work is to evaluate the potential for Fuzzy c-mean (FCM) methods as a way to: 1) automatically segment 3He ventilation images, 2) to compare different observer manual segmentations, and, 3) to provide a better understanding of observer-slice interactions and the types of error that dominate measurement precision.

Methods: Hyperpolarized ^{3}He MRI was performed with slice thickness of 15mm, matrix 128x128 and field of view of 40x40cm. Images were reconstructed to 512x512 and the trachea was removed manually. Images were then segmented manually by three trained observers to derive ventilation volume. In addition, a fully automated fuzzy c-mean method (1) was applied to segment each slice into four clusters. We applied additional rules to refine the result of FCM in order to deal with non-removed background in the original input data and with some inappropriate clustering in the first and the last MRI slices of each subject. Finally a comparison between our method and the manual method was performed to find the correlation between the methods.

Results: Figures 1 and 2 show significant correlation between the automated and manual segmentation methods (fcm-obsv1: 0.974, $p<0.001$; fcm-obsv2: 0.983, $p<0.001$; fcm-obsv3: 0.978, $p<0.001$) using a paired t-test. By comparing the number of pixels segmented by FCM to the number of pixels selected by the three observers (Table 1), the mean differences between the selected regions were 2214, 2912, and 2116 pixels for observers 1, 2, and 3, respectively. In addition, the mean difference between the second observer and the first and third observers was 2638 and 2476 pixels, respectively, which shows more difference than between the FCM method. The smallest difference was between the first and third observers, which was 1224 pixels. Observers 1 and 3 segmented a ventilation area greater than the FCM method at the first and last slices of each subject and segmented a ventilation area smaller than FCM at the center slices of each subject (peaks). Both observers segmented an area close to the FCM result in the remaining slices. Figure 2 shows that, for most of the slices, the second observer underestimated the ventilation area as compared to the FCM result.

Conclusion: FCM showed that the first and the third observers overestimated the end slices and underestimated center slices, and this is typical of bias or error predicted by psycho-optical research and stemming from the human eye's contrast sensitivity to volume since the ventilated regions are relatively small in start/end slices and larger in center slices. The second observer consistently underestimated ventilated regions compared to FCM. FCM is reproducible and does not show observer bias such as that typical of human decision making in optical tasks. FCM is also much faster than manual segmentation and provides a fully automated, efficient method to compare observer results and determine estimation error and bias.

1. A. Hassanien, *et al.*, An Overview of Fuzzy C-Means Based Image Clustering Algorithms, Studies in Computational Intelligence, Vol. 2, SCI 202, pp. 295-310, 2009.

Table 1: Average and standard deviation of difference (per slice in pixel size) between results of FCM and manual segmentation by three observers.

Methods	Observer1		Observer2		Observer3	
	mean	SD	mean	SD	mean	SD
FCM	2214	2039	2912	1967	2116	1878
Observer1			2638	1987	1224	1072
Observer2					2476	1814
Observer3						

SD=standard deviation

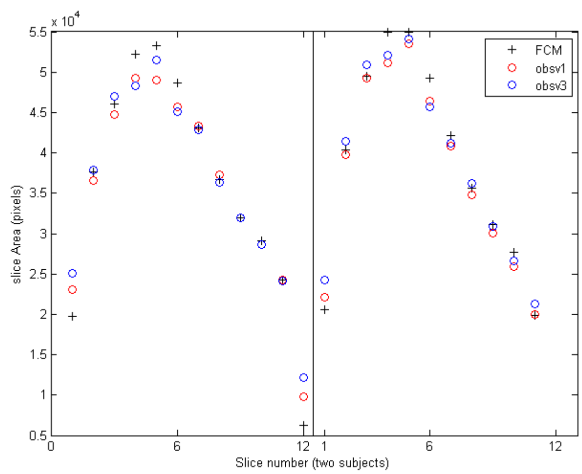

Figure 1: Ventilation area measurement based on Fuzzy c-mean (FCM) and manual segmentation by first and third observers (obsv1 and obsv3) for two subjects.

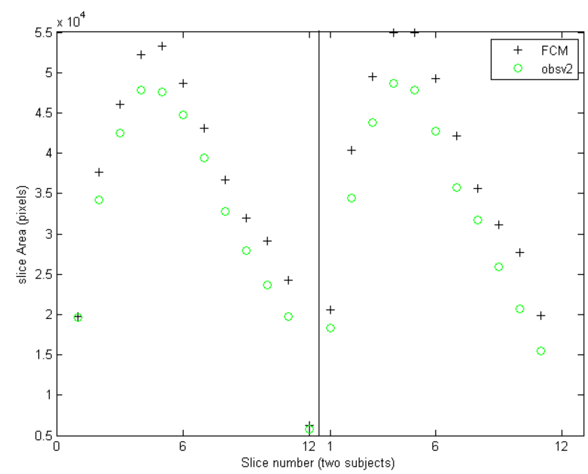

Figure 2: Ventilation area measurement based on Fuzzy c-mean (FCM) and manual segmentation by second observer (obsv2) for two subjects.