Hyperpolarized ^{3}He Image Feature Analysis in Asthmatics

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Purpose

To investigate the discriminatory capabilities of quantitative features generated from hyperpolarized ^{3}He ventilation images specifically with respect to diagnosed asthmatic and normal subjects. Both extracted hyperpolarized ^{3}He image and spirometric features were ranked based on their ability to characterize clinical diagnosis using a mutual information based feature subset selection algorithm [1].

Methods

Axial MRI data were acquired on a 1.5 T whole body MRI scanner (Siemens Sonata, Siemens Medical Solutions, Malvern, PA) with broadband capabilities and a flexible ^{3}He chest radiofrequency coil (IGC Medical Advances, Milwaukee, Wis; or Clinical MR Solutions, Brookfield, Wis.). During a 10-20 s breath hold following the inhalation of approximately 300 mL of hyper polarized ^{3}He mixed with approximately 700 mL of nitrogen a set of 19-28 contiguous axial sections were collected. Parameters of the fast low angle shot sequence for ^{3}He MR imaging were as follows: repetition time msec/ echo time msec, 7/3; flip angle, 10°; matrix, 80 × 128; field of view, 26 × 42 cm; section thickness, 10 mm; and intersection gap, none. These data consisted of 110 image scans from 55 patients subjects (47 asthmatic and 8 healthy) before and after respiratory provocation (exercise or methacholine-induced).

For each of the 110 images, a total of 533 features were calculated over whole lung and sub-regions from the following categories:

- first order statistics derived from the intensity histogram of the bias-corrected ^{3}He image in the calculated regions,
- first order statistics derived from the stochastic fractal dimension (SFD) image in the calculated regions, and
- second order statistics, or texture-based measurements, using the cooccurrence (CM) and run-length matrices (RLM) of the calculated regions in both the bias-corrected ^{3}He image and SFD image, and
- ventilation ratios quantifying the volume of the ventilated regions to the total lung volume.

Each subject also underwent pulmonary function testing which generated an additional 27 spirometric features, e.g. forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and peak expiratory flow (PEF). For each subject we combined the pre and post respiratory challenge images in addition to their difference values for a total of 1599 features. These were combined with the 27 × 2 = 54 spirometric values for a total of 1653 features per subject.

Maximal relevance, minimal redundancy ranking of spirometric and imaging features using the mRMR feature classification algorithm.

Rank	Feature	Pre/Post/Diff	Region
1	ventilation ratio	pre respiratory challenge	left lung
2	RLM_5	post respiratory challenge	outer rind, left lung
3	ventilation ratio	post respiratory challenge	left lung
4	RLM_{10}	difference	right lung
5	CM_2	post respiratory challenge	inferior left lung
6	RLM_8	post respiratory challenge	inferior left lung
7†	% Predicted FEV_1	—	—
8	RLM_5	post respiratory challenge	inferior left lung
9	CM_6	post respiratory challenge	outer rind, left lung
10	CM_2	post respiratory challenge	outer rind, whole lung
:	:	:	:
34	FEV_1	—	—

'†' denotes a spirometric value. Subscript refers to specific 'texture' measurement.

Results

Both the image and 27 spirometric features were ranked based on their ability to characterize clinical diagnosis using a mutual information based feature subset selection algorithm [1]. It was found that the top image features perform much better compared with the current clinical gold-standard spirometric values when considered individually. Interestingly, it was also found that spirometric values are relatively orthogonal to these image feature values in terms of informational content.

Conclusions

Considered as a global assessment, individual image features performed much better in characterizing clinical diagnosis compared with the spirometry values for this particular study. These results demonstrate the potential importance of image-based assessment of asthma. However, the best performing spirometric features from Table 1 show limited redundancy with respect to the image features. It is also interesting that the most discriminating image features was the ventilation ratio which is analogous to commonly used human reader scoring of the ventilation defects.

References

[1] Peng H, Long F, Ding C. Feature selection based on mutual information: Criteria of max-dependency, max-relevance, and min-redundancy. IEEE Trans Pattern Anal Mach Intell 2005;27(8):1226–1238.