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Principal Component Analysis of Computer Tomography Histogram In Early Cystic Fibrosis

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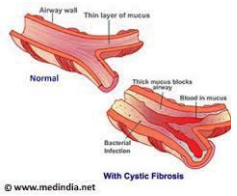
Background

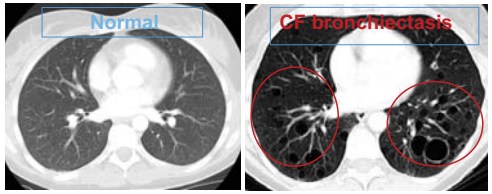
Cystic fibrosis (CF), a genetic condition characterised by progressive obstructive lung disease is a major life threatening disorder in the western world [1].

Traditional lung diagnostic tests such as pulmonary function tests (PFTs) are insensitive to early structural damage occurring in CF, especially in pre-school children who cannot always perform PFTs.

Currently, CF is diagnosed by subjective assessment of computed tomography (CT) images (radiological scoring). This is time consuming and is not always reproducible or sensitive enough to assess CF disease over time.



The image on the left shows typical airway changes in CF. Below are CT slices in normal and CF lungs. In CF significant changes in structure can be seen.



Aims and objectives

The evaluation of an automated statistical analysis (principal compenent analysis – PCA) on CT histograms of 24 children diagnosed with mild cystic fibrosis was performed to provide rapid, automated tool to assess CF progression.

Radiological assessment

A subjective radiological assessment was performed by an expert radiologist based on the Brody method [2]. This method assesses presence and severity of abnormalities such as bronchiectasis, bronchial wall thickening, mucous plugging and air trapping in each lobe. The average ratio of airway lumen to vessel diameter (LD/VD) in each subject was also quantified using digital calipers.

Methods

Four steps were employed to analyse images: image de-noising, image segmentation, histogram calculation and PCA feature extraction. The correlation between PCs and quantitative measures of CF diseases was assessed using student t-tests.

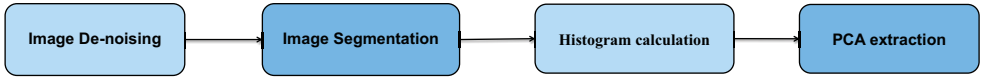


Image de-noising

Different levels of noise occur between CT images due to different CT scan settings so de-noising is essential prior to image analysis. The following algorithm based on dual tree complex discrete wavelet transform (DTCDW) was applied to all images as a novel method.

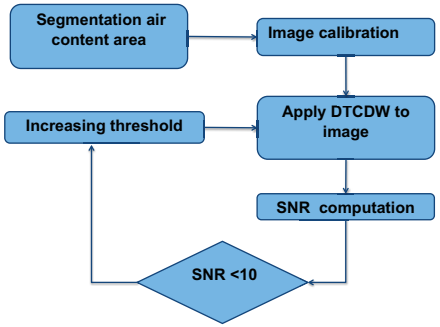
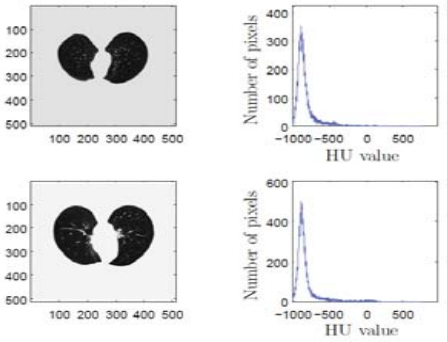


Image segmentations and histograms

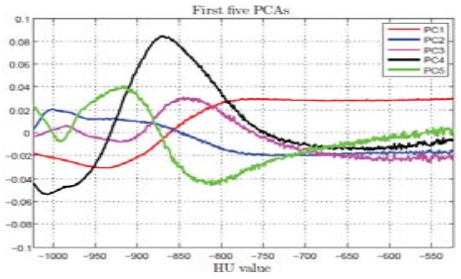
Lung segmentation was performed using a custom written function in Matlab. Optimal thresholding based on Otsu method was used [3]. For each slice, a relative frequency histogram for the segmented area was computed. At total lung histogram was obtained by accumulation of histogram of each slice.



Features selection and principal component calculations

Seven features were extracted from the histogram:

1. Area under the histogram curve between -1024 and -975 HU (the amount of air).
2. The area under the curve between -950 and -850 HU (low tissue density).
3. The area under the curve between -850 and 500 HU (high tissue density).
4. The density at the peak of histogram.
5. The maximum density value in the lung.
6. Kurtosis.
7. Skewness.

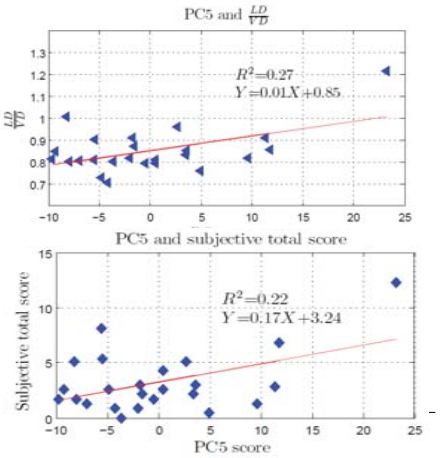


Principal component analysis of histogram was conducted. The first 5 principal component scores for each subject were computed. Then correlations between PCAs scores, computed features and radiological scores were assessed.

Summary

The results show

- A significant correlation between the fifth principal component score and a quatitative measure of bronchiectasis (LD/VD). LD/VD represents ratio of airway lumen to blood vessel diameter calculated from imaging using digital calipers.
- A significant correlation between the fifth principal component and the subjective total disease score, which reflects overall level of disease.
- PCA scores provide a rapid way to assess CF progression and better reflect structural disease than each of the 7 histogram features tested.



References

1. Bobadilla, J.L., Macek, M., Fine, J.P., Farrell, P.M.: Cystic fibrosis: a worldwide analysis of mutations correlation with incidence data and application to screening. Human mutation 19(6), 575(606), (2002).
2. Brody, A.S., Klein, J.S., Molina, P.L., Quan, J., Bean, J.A., Wilmott, R.W.: High-resolution computed tomography in young patients with cystic fibrosis: distribution of abnormalities and correlation with pulmonary function tests. The Journal of paediatrics 145(1), 32(38), (2004).
3. Otsu, N.: A threshold selection method from grey-level histograms. Automatic 11(285-296), 23(27), (1975).

Acknowledgement

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