Principal Component Analysis of the 3He ADC

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Introduction

With hyperpolarized ^{3}He MRI the distribution of airspace sizes can be studied in detail by calculation of the apparent diffusion coefficient (ADC). Helium-3 ADC maps of the lungs indicate from visual inspection alone that there is variation in ADC between different areas of the lungs [1]. Since registration of images between subjects is problematical, comparison is usually based on the statistical analysis of the average ADC value for the entire lung, which immediately loses all of the obvious spatial heterogeneity. Here we present an entirely new way of analysing the distribution of ADC values to assess changes in the lung that simple analysis of the mean and standard deviation of the histogram fails to highlight.

Methods

MRI: All work was performed on a 1.5T whole body system, (Eclipse –Philips Medical Systems). A flexible twin saddle quadrature T-R coil was used (IGC Medical Advances). The MR sequence was based on an interleaved low flip angle gradient echo acquisition with a reference scan (*b=0*) followed by diffusion-weighted acquisition (*b=1.6 scm^{-2}* - bipolar trapezoids of plateau strength 19.5 mTm^{-1} and duration 460 μs with 500μs ramp time –*direction in-slice*). Phase encoding was centric with 112 views, the remaining sequence parameters were: flip angle 7°, 9 coronal slices, 15 mm slice thickness & 5mm gap, FOV =42 cm, TE=2.5 ms, TR=6.7 ms, 128 samples, BW 16kHz. ^{3}He gas was polarized on site to 30% by optical pumping with rubidium spin exchange apparatus (GE Health). In-vivo imaging was then performed following breath-hold of a 300 ml ^{3}He/800 ml N_2 mixture from a Tedlar bag. Age matched groups of six healthy non-smokers, five healthy smokers and five patients with moderate COPD were studied with approval from the local Research Ethics Committee. Spirometry was performed on all subjects. Diffusion imaging was performed following hyperpolarized 3-Helium gas inhalation to produce regional ADC maps, which were assessed in random order by an observer who was blinded to all the patient data. Figure 1 displays an example ADC colour map.

Statistical Analyses: Firstly, the voxels representing the airways and also any voxels containing background noise were segmented from each image. The statistical analyses are therefore based on the frequency distributions of all voxel values of ADC from the specified ROI from each of the nine images for one subject. Initial analyses concentrate on histograms and kernel density estimates of the distributions. The main analysis is *functional principal component analysis* (FPCA), a multivariate technique aiming to locate the principal sources of variation between the distributions by principal component analysis of the discretized distributions [2]. The resulting principal components (PC) are used to construct an exemplary set of distributions providing the distinct types of variation.

Results

Simple kernel density estimates of these distributions suggest that there is a difference between healthy and diseased lung and FPCA highlights where the differences occur. Figure 3 displays the score plot of the first two PCs from FPCA on an initial study, which shows the discrimination between healthy and diseased lungs. Interpretation of the PCs by inspection of how a typical density is varied from the overall mean reveals that PC 1 reflects a difference in the mean ADC (Figure 2), while PC 2 reflects differences between a diffuse distribution and more peaked ones.

Discussion

Application of FPCA to helium-3 ADC colour maps of the lungs is an entirely novel way of analysing such data. The results from this preliminary study have shown that this analysis is not only detecting the obvious change in mean ADC but other differences too, which is not surprising considering that each image exhibits a great amount of spatial heterogeneity. This method holds promise for all areas of research where the responses are images.

Reference: [1] Fichele, S., et al. (2004). *J Magn Reson Imaging,* **20(2)**:331-335.
[2] Ramsey, J., & Silverman, B. (1997). *Functional Data Analysis*. Springer-Verlag, London.

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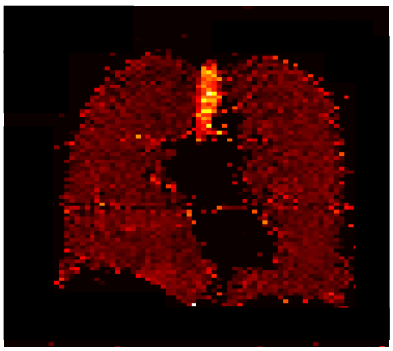

Figure 1: Helium-3 ADC colour map of the lungs

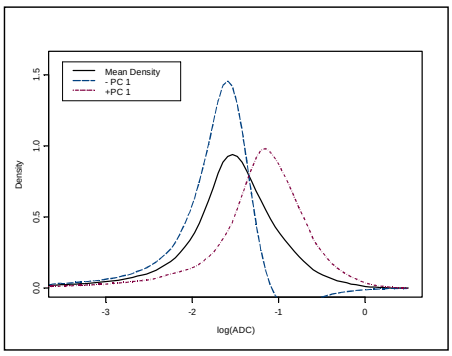

Figure 2: Pictorial representation of PC1 as varied above and below mean

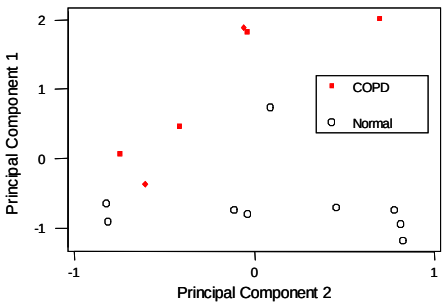

Figure 3: Score plot of normal vs diseased lungs