235. Imaging in COPD

Pathologically altered lung mechanical properties are difficult to assess regionally. A method has been developed utilising structural proton MRI in conjunction with post-processing and image registration techniques to provide measures of relative regional lung compliance [1]. This method was applied in 23 COPD patients and 11 healthy controls. Each subject had two supine scans, 1 week apart. Compliance maps were found to be reproducible, with increased spatial heterogeneity seen in patients compared to controls (Figure 1).

Figure 1. Relative regional compliance maps for healthy controls and COPD patients (mapped on log scale).

The gradient of relative compliance from lung apex to diaphragm was calculated. An increased compliance gradient was seen in moderate COPD (p < 0.05), with a more significant increase in severe COPD (p < 0.001) (Figure 2).

Figure 2. Box plot of relative compliance gradients (found using regional relative compliance and position as fraction of lung length).

The method shows significant differences between COPD patients and healthy controls with areas of altered relative regional compliance indicating likely regions of disease.

Reference:

1880 Novel ventilation-perfusion ratio measurements in COPD using MRI

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We present a novel analysis of oxygen-enhanced (OE) MRI data in COPD that allows quantitative ventilation-perfusion ratio (V/Q) maps to be determined. Representative V/Q maps of: A healthy, B moderate & C severe COPD subjects reveal homogeneous maps for A and considerable heterogeneity in B/C.

We investigated the reproducibility of the derived V/Q ratio maps in 23 COPD patients and 11 healthy controls. Each group had 12 subjects, data averaged over 2 scans. Using a single slice, minimum group sizes to detect a 50% difference of the healthy group window are 27 (EF) & 14 (IQR V/Q). Power calculations are specific to this implementation of the methods, we envisage improvements with further development.

Conclusions: Overall, the proposed imaging protocol is feasible and applicable in significantly ill COPD patients. The protocol is easy to use and shows a high repeatability in the key aspects for assessment of morphological and functional disease components.

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Ventilation-perfusion mismatch in COPD with or without emphysema:
Comparison of structural CT and functional OE-MRI

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Single-slice coronal oxygen-enhanced MRI (OE-MRI) images were acquired in 24 patients with chronic obstructive pulmonary disease (COPD) and 12 healthy subjects, from which color-coded V/Q maps were extracted by pixelwise model fitting. COPD were structurally classified by percentage of low attenuation areas under -950 HU (LAA%) in matched single-slice CT images: LAA%≤10%—non-emphysematous COPD than in emphysematous COPD, which demonstrates that comparative V/Q mismatch exists in COPD even if there is no emphysema. To explore potentially different structure-function relationship in two COPD types, correlation between CT and OE-MRI parameters were measured. Median V/Q did not correlate with LLA% in COPD. However, inter-quartile range of V/Q, representing the extent of heterogeneity, was fairly correlated with LLA% in emphysematous COPD (r=0.449, p<0.017), indicating V/Q mismatch in COPD gets worse as emphysema increases. However, the correlation was not found in non-emphysematous COPD.

Results:
Data were analysed for all subjects throughout the study although censored after they changed their smoking habit. At study entry, 1075 subjects did not have AFO and 843 subjects had AFO based on GOLD spirometry criteria. For the reference group, PD15 was (mean±SE) 72.4±0.8 g/L, and was higher in women (17.6±0.6 g/L); and in active smokers (10.5±0.7 g/L), and lower in subjects with AFO (-3.4±0.6 g/L). Annual decline in PD15 for the reference group was -0.38±0.08 g/L/yr and was higher in women, with additional (0.30±0.07 g/L/yr), current smokers with additional (0.53±0.08 g/L/yr) and for subjects with AFO with additional (0.34±0.07 g/L/yr).

Conclusion: Active smoking, female sex and the presence of airflow obstruction are associated with accelerated decline in lung density.

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Decline in lung density is accelerated in active smokers

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Background: Small airways disease and emphysema are the main components of airflow limitation in COPD. The independent contribution of quantitative CT measurements of these components to airflow limitation in COPD is yet unknown.

Purpose: To determine to what extent the combination of quantitative CT measurements of air trapping and emphysema can explain the variance in lung function in a population that covers the total spectrum of airflow limitation.

Methods: We studied 248 subjects (50 without airflow limitation; 50 GOLD 1; 50 GOLD 2; 50 GOLD 3; 48 GOLD 4) with paired inspiratory and expiratory CT scans and pulmonary function tests. We calculated CT emphysema (2 methods) and CT air trapping (4 methods), and used univariate and multivariate linear regression analysis to relate the quantitative CT measurements to lung function parameters (FEV1, FEV1/FVC, RV/TLC and Kco).

Results: Quantitative CT measurements were strongly related to airflow limitation, the best univariate R-square value was 0.72 (p<0.001) for percentage of voxels ≤-850 Hounsfield units (EXP,430) and FEV1/FVC. In multivariate analysis (corrected for sex, age and height) the combination of CT emphysema and CT air trapping explained 68% to 83% (p<0.001) of the variance in lung function parameters of airflow limitation (FEV1, and FEV1/FVC).

Conclusion: Quantitative CT air trapping and CT emphysema measurements are strongly associated with lung function impairment, and when combined they explain a large part of the variance in airflow limitation. Our results may prove useful in automated detection and phenotyping of COPD cases.

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The relationship between airflow limitation and quantitative computed
tomographic assessment of air trapping and emphysema

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Computer modelling and visualisation of the microscopic
distributions of hyperpolarized gas diffusivity in models of acinar airways

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Diffusion MRI using hyperpolarized gases is sensitive to lung microstructure. Computer simulations used to investigate the relationship between diffusivity (ADC) and airway dimensions are generally limited by non-realistic geometric assumptions (e.g. infinite cylindrical airways). In this work, we use histology sections to generate realistic models of acinar airways that are used in finite element computer simulations of 3He and 129Xe gas diffusion and 129Xe exchange between gas and tissue.

Results:

Figure 1. The different diffusivities of 3He (A) and 129Xe (B) result in different ADC (in cm²/s) distributions.

For 3He, the distribution over the largest airway is nearly uniform due to motional averaging. For 129Xe, its reduced diffusivity limits the mixing between intra- and extra-alveolar gas resulting in a non-uniform distribution, which can be described with a two-compartment analytical model.

These results suggest that 129Xe MRI may be more sensitive to alveolar structure than 3He, while being less sensitive to branching and localized diffusion effects.
Conclusion: Computer simulation and visualization of maps of microscopic diffusivity distributions in realistic acinar geometries have helped provide a better understanding of the length scales and diffusion regimes relevant to hyperpolarized gas lung MRI and may help simplify the development of $^{129}\text{Xe}$-based MR lung morphometry techniques.