Pulmonary Functional MRI to Phenotype COPD and Evaluate Treatment Efficacy: Intermediate Endpoints and Predictors of Efficacy when Conventional endpoints fail?

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**Target Audience:** Scientists and clinicians interested in pulmonary functional magnetic resonance imaging (MRI) to phenotype and evaluate therapy in respiratory disease.

**Purpose:** In all mammals, the respiratory system is relatively over-engineered for most every-day tasks and it is not until respiratory disease is well-advanced that symptoms are recognized and conventional clinical measurements such as the forced expiratory volume in 1 s (FEV1) detect abnormalities. In part because diagnosis is typically made when disease is advanced, for patients with chronic obstructive lung disease, (COPD), non-invasive imaging measurements including those provided by computed tomography (CT) and MRI are not used for disease diagnosis or for monitoring disease progression. Moreover, symptoms and FEV1 measurements and not imaging biomarkers or phenotypes are used to guide therapy and patient management decisions. Unfortunately however, airflow and lung volume measurements cannot provide a way to quantify changes in parenchymal tissue abnormalities (emphysema) or airways abnormalities including airway morphologies, and mucus plugging (chronic bronchitis). We think that non-invasive imaging measurements of the direct anatomical and functional contributions to symptoms and airflow limitation can be used as intermediate endpoints in clinical trials of new therapies. Therefore, the objective of this proof-of-concept study was to evaluate hyperpolarized 3He MRI measurements of emphysema and airways disease in a study of the 4-week treatment efficacy of a handheld airflow clearance device for mobilizing mucous secretions and clearing airways in COPD patients with well-advanced disease. We hypothesized that there would be 3He MRI improvements following airway clearance therapy in COPD and that MRI measurements of underlying phenotypes would provide a way to stratify patients based on airways disease/emphysema and based on imaging response.

**Methods:** Subjects with a diagnosis of COPD provided written informed consent to an 8-week randomized controlled cross-over study protocol approved by the local research ethics board and Health Canada evaluating the efficacy of an Oscillatory Positive Expiratory Pressure (oPEP) therapy system. All patients underwent spirometry, plethysmography, six-minute walk test (6MWT), the St. George’s Respiratory (SGRQ) and Patient Evaluation Questionnaires (PEQ) at each of 5 visits and hyperpolarized 3He MRI at baseline, week 4 and week 8. Imaging was performed on a whole body 3.0 Tesla Discovery 750MR (General Electric Health Care, Milwaukee, WI) with broadband imaging capability as previously described. Subjects were instructed to inhale a gas mixture from a 1.0L Tedlar bag (Jensen Inert Products, NJ, USA) from functional residual capacity and image acquisition was performed in 8-15s under breath-hold conditions. Conventional 1H MRI was performed prior to hyperpolarized 3He MRI as previously described. MRI measurements of underlying phenotypes would provide a way to stratify patients based on airways disease/emphysema and based on imaging response. 1

**Results:** Fourteen non-phenotyped COPD subjects with well-advanced disease (6 males, mean age:73±5yrs) completed the study. For all subjects, there was improved dyspnea and ease in bringing up sputum on oPEP therapy. The SDD for 3He MRI VDP was determined based on the reproducibility of repeated measurements and was 2%. Six subjects (3 males, mean age:73±5yrs) were classified as having an improvement in VDP that was greater than the SDD on oPEP therapy (Imaging Improvement Group; off VDP=20±11, on VDP=15±11, p=0.04) and eight subjects (5 males, mean age:72±7yrs) were classified as not having an improvement in VDP while on oPEP therapy (No Imaging Improvement Group: off VDP=19±11, on VDP=23±10, p=0.02). Figure 1 shows a representative subject from the imaging improvement group and no imaging improvement group, the improvement in 3He gas distribution while on oPEP is apparent (white arrows) in the subject classified as having imaging improvement. As shown in Table 1, the imaging improvement group also had improved 6MWD, FVC% pred, and symptoms; compared with the no imaging improvement group, subjects with an imaging improvement had a significantly different smoking history (p<0.02) and there was a trend towards lower 3He MRI ADC (p=0.17) and lower CT RA950 (p=0.26).

**Discussion:** Following therapy, 6/14 subjects were classified as having improved 3He gas distribution, and in this sub-group improvements in standard measurements of pulmonary function and exercise capacity were also observed. Representative analysis of those subjects with imaging improvement suggests that airway clearance therapy may be more effective in COPD subjects with less smoking history and parenchymal tissue abnormalities (emphysema).

**Conclusions:** In a small group of COPD subjects, improvements in objective measurements of pulmonary function and exercise capacity following airway clearance therapy were only observed in a sub-group of subjects with imaging improvement.

**Table 1. Pulmonary function tests, 6MWD, SGRQ, PEQ, and hyperpolarized 3He MRI measurements on and off oPEP therapy for the imaging improvement and no imaging improvement groups.**

**Figure 1.** Hyperpolarized 3He MRI (in blue) registered to the corresponding thoracic 1H MRI for representative subjects with and without imaging improvement. Improved 3He gas distribution on oPEP therapy is apparent (white arrows) for the representative imaging improvement subject.


**SD=Standard Deviation; FEV1=Forced Expiratory Volume in 1 s; %pred=Percent Predicted; FVC=Forced Vital Capacity; RV=Reserve Volume; TLC=Total Lung Capacity; 6MWD=6-minute walk distance; VDP=Ventilation Defect Percent; ADC=Apparent Diffusion Coefficient; No Ch=No Change; Slight Improvement=Slight Improvement; sd=significance of difference. *(p<0.05) determined using repeated measures ANOVA.**