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

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INTRODUCTION X-ray computed tomography (CT) is powerful in estimating the structural abnormalities of chronic obstructive pulmonary disease (COPD), while dynamic oxygen-enhanced (OE-) MRI enables assessment of regional oxygen delivery and uptake by using oxygen as a contrast agent. Recently a physiological model has been proposed to extract pulmonary ventilation/perfusion (V/Q) maps directly from dynamic OE-MRI data [1,2]. The aim of this study is: 1) to compare the V/Q maps in COPD patients with or without emphysema identified in 2D CT slices; 2) to explore the local relationship between CT measured emphysema and OE-MRI measured ventilation-perfusion imbalance in COPD patients.

METHODS Dynamic OE-MRI and multislice CT were carried out on 24 COPD patients and 12 healthy volunteers. Dynamic OE-MRI: Baseline T_1 mapping was performed while subjects breathed medical air (21% O_2) using an inversion-recovery half Fourier acquisition single shot turbo spin echo sequence (IR-HASTE) with a range of TI (50, 300, 1100, 2000 and 5000 ms). This was followed by a T_1-weighted dynamic acquisition to monitor the change in T_1 during gas switchover from medical air to 100% O_2 using the same HASTE sequence but with a single TI=1100ms. A single coronal slice was acquired. All images were registered to the end expiration position and fitted pixel-by-pixel by a physiological model to generate V/Q maps [1,2]. Other parameters were: TR/TE 5500 ms/3 ms, 68 phase-encoding steps to reconstruct a 128 x 128 matrix, 10 m m thickness, free breathing, no respiratory or cardiac triggering. Quantitative CT: Multislice CT was performed in COPD patients. A single slice which best-matched the MRI image was selected for each subject. The proportion of lung area with an attenuation value below -950 Hounsfield units (LAA%) was calculated to denote the fraction of emphysema. According to the 2D LAA%, COPD subjects were structurally classified in to 2 subgroups: LAA%<2.5%--non-emphysema type (8 patients), LAA%≥2.5%--emphysema type (16 patients).

RESULTS As can be seen in figure1, a healthy lung shows a homogeneous V/Q map, in which the areas without enhancement (in dark blue) seem to correspond to vessel structure. However, in the COPD lung, whether or not emphysema is present, the V/Q maps become heterogeneous with some areas of decreased V/Q (green and blue), and some areas of increased V/Q (orange and red). The distribution of V/Q in the entire lung can also be illustrated by histograms. In the healthy lung, V/Q distributes in a narrow range with a sharp peak, while in the COPD lung, the histogram becomes broader with longer tails. Although the LAA% are quite different for the 2 COPD subgroups, the V/Q maps and histograms look similar. Figure2 shows a significantly increased inter quartile range of $\log_{10}$ V/Q (IQR-V/Q, denoting the width of the histogram) in COPD subjects when compared with healthy subjects. However there is no significant difference between the COPD groups with and without emphysema. In addition, median $\log_{10}$ V/Q was not significantly different between any of the three subgroups. Figure3 shows a significant positive correlation between LAA% and IQR-V/Q in emphysematous COPD (r=0.449, p=0.017), while there is no significant correlation in non-emphysematous COPD. In addition, there is no significant correlation between median $\log_{10}$ V/Q and LAA% in either COPD group.

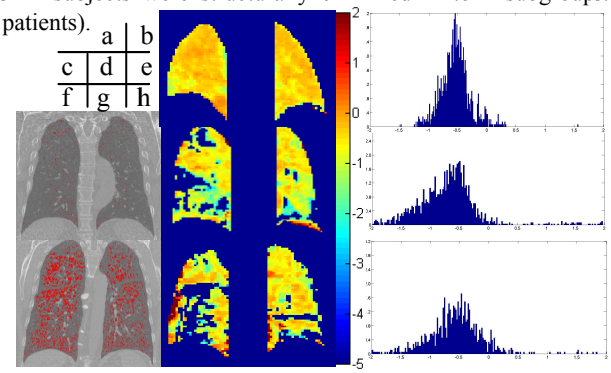

Fig1: a, b) $\log_{10}$V/Q map and $\log_{10}$V/Q histogram of a male healthy subject (58yrs, FEV_1%=129%); c, d, e) LAA% map, $\log_{10}$V/Q map and $\log_{10}$V/Q histogram of a male COPD patient without emphysema (63yrs, FEV_1% =72%, LAA%=0.53%); f, g, h) LAA% map, $\log_{10}$V/Q map and $\log_{10}$V/Q histogram of a male COPD patient with emphysema (62yrs, FEV_1%=67%, LAA%=8.30%). The low attenuation areas in LAA% maps are showed in red.

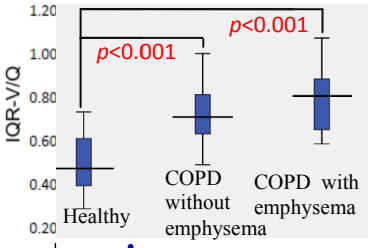

Fig2: The box plot illustrates the significant difference of IQR-V/Q between healthy group and 2 COPD structural subgroups.

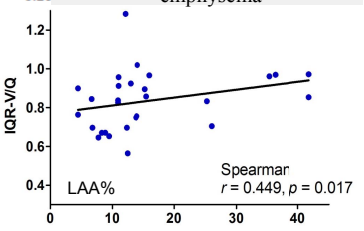

Fig3: The graph shows the significant positive correlation between LAA% and the inter quartile range of $\log_{10}$ V/Q in emphysematous COPD.

DISCUSSION COPD has regional V/Q mismatch whether or not emphysema is present. Within the slice, V/Q distribution becomes more heterogeneous with increasing emphysema, while in non-emphysematous COPD, other factors, possibly including airway blockage and inflammation, maybe responsible for V/Q change.

CONCLUSION Considerably heterogeneous V/Q distribution presents in both emphysematous and non-emphysematous COPD. However, the correlation between OE-MRI estimated V/Q heterogeneity and CT measured emphysema does vary between these two COPD subtypes. The added physiological information available from dynamic OE-MRI using a non-ionising source of contrast makes it an attractive option in the assessment of COPD.

REFERENCES 1) Naish, J.& Parker, G. *Proc 18th Intl Soc Mag Reson Med* 2010; p.2516. 2) Hubbard, P, *et al. Proc 18th Intl Soc Mag Reson Med* 2010; p.2515.
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