Reproducibility Assessment of High Resolution Imaging of Alveolar Oxygen Tension in Human Subjects

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INTRODUCTION: Pulmonary alveolar partial pressure of oxygen (P\textsubscript{AO2}) is closely related to the regional ventilation-perfusion ratio and therefore to alveolar gas exchange. Thus, a reproducible and noninvasive measurement of regional P\textsubscript{AO2} can be of significant investigational and diagnostic value, especially since no other probe of localized alveolar oxygen tension information is currently available in clinical practice. Several techniques based on hyperpolarized helium-3 (HP\textsuperscript{3}He) MRI have been developed for this purpose in animals, as well as in humans. Reproducibility studies, however, are rare. The handful of reported experiments on human subjects also suffer from low spatial resolution. For the first time, we present the short-term reproducibility results of a longitudinal study of high-resolution P\textsubscript{AO2} measurements in human subjects.

METHODS: A total of 21 measurements on seven volunteers were performed. Four healthy non-smokers (50-60 yrs, 2M, 2F), two asymptomatic smokers (47 yr M, 64 yr F), and one level-2 COPD subject (65 yr M) underwent P\textsubscript{AO2} imaging, repeated three times within 15 days. The experiments were performed under IRB-approved protocols for HP\textsuperscript{3}He MRI after obtaining subjects’ informed written consent prior to each experiment. All the human data and their demographics were anonymized. The volunteers’ Body Mass Index (BMI), total smoking pack/years and Total Lung Capacity (TLC) are listed in Table 1. For each measurement, subjects inhaled a mixture of \textsuperscript{3}He:N\textsubscript{2} (FiO\textsubscript{2} = 21%), with the total volume of 12%TLC. P\textsubscript{AO2} imaging was performed using an improved high-resolution interleaved technique (as described in Hamedani, H. et al. in this conference) during a 12-sec breath-hold. Four images of the entire lungs (consisting of 12 coronal slices in supine position) were acquired with an inter-slice time delay of [0.00, 0.24, 0.579, 6.03] sec, with an approximately 2-sec pre-acquisition delay. The end-expiratory O\textsubscript{2} concentration was measured for technique validation. Images were acquired using a multi-slice gradient echo imaging pulse sequence with the following imaging parameters: TR/TE = 6.7/3.2ms, FOV = 300×400mm\textsuperscript{2}, NS = 12, ST = 13 mm, α = 5° and a matrix size = 48×36 (L–R phase encode). The overall mean and standard deviation of P\textsubscript{AO2} distribution within each lung were calculated and the variation δ of mean P\textsubscript{AO2} among each three measurements was calculated according to: δ = (max – min)/mean.

RESULTS AND DISCUSSION: Figure 1 shows four P\textsubscript{AO2} maps from representative healthy #2 and COPD subjects. The P\textsubscript{AO2} distribution is significantly more heterogeneous in the COPD subject. Table 1 lists the overall mean±standard deviation values for all subjects, as well as the variation δ of mean P\textsubscript{AO2}. The reproducibility of P\textsubscript{AO2} was lower than those in smokers and COPD subjects. The P\textsubscript{AO2} distribution in healthy subjects were generally smaller than those in smokers and COPD subjects. Figure 2 (top) shows the variation of peak P\textsubscript{AO2} as a function of vertical position in the lungs of three representative subjects. Also shown in Figure 2 (bottom) is the results summary for the entire study in box-plot format (centerlines are the P\textsubscript{AO2} medians). As can be seen, the P\textsubscript{AO2} distribution in healthy lungs has a smaller intraindividual variability as well as a smaller lung-position dependence compared to the smoker and COPD counterparts.

CONCLUSIONS: Results show that our improved interleaved P\textsubscript{AO2} imaging technique provides a well-reproducible estimate of regional oxygen tension in healthy and diseased subjects. With its unprecedented spatial resolution it can serve as a potentially sensitive marker for diagnosis and assessment of pulmonary diseases.