

Assessment of Pulmonary Capillary Blood Pulsation in Severe COPD Using Hyperpolarized ^{129}Xe CSSR

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Target Audience: MR scientists and physicians interested in hyperpolarized-gas MRI and the assessment of pulmonary function.

Purpose: Chronic obstructive pulmonary disease (COPD) is commonly considered a lung illness that, particularly in severe cases, can lead to death due to lung failure. However, a recent, autopsy-based study found surprisingly that most of these deaths may actually be due to cardiovascular causes (1). Using hyperpolarized xenon-129 (HXe) “Chemical Shift Saturation Recovery” (CSSR) MR spectroscopy (2-6), we sought to investigate what, if any, blood flow abnormalities might be detectable in subjects suffering from severe COPD. CSSR is usually performed by acquiring HXe MR spectra following a variable delay time τ after RF saturation pulses destroy the signal from all HXe currently residing in the lung tissue (“dissolved phase” HXe). However, by holding τ fixed, it has been demonstrated that it is also feasible to characterize the pulsatile blood flow in the pulmonary capillary bed in the form of periodic changes in the spectral peak amplitudes (7). The purpose of our studies was an initial assessment of pulsatile blood flow in subjects with severe COPD using CSSR spectroscopy.

Methods: As described in (7), Gaussian RF pulses (2-ms duration) were applied to saturate the tissue/plasma (TP; 198 ppm) and red blood cell (RBC; 218 ppm) dissolved-phase resonances. Following a delay time τ of 100 ms, a 1.2-ms Gaussian RF excitation pulse was used to generate a free induction decay. This sequence was repeated 32 times during a single breath hold. The signal was sampled for 30.72 ms with 1024 sampling points, apodized by a squared cosine function, zero-filled to 2048 points, Fourier transformed and phased. Each of the two dissolved-phase resonances was integrated numerically. To account for T1 and RF-pulse induced magnetization decay, both sets of peak integrals were corrected with an exponential decay function fitted to the TP peak integrals. HXe ventilation images were also collected, using a gradient echo pulse sequence. All MR studies were performed at 1.5T (Avanto; Siemens), using a flexible Xe129 chest RF coil (Clinical MR Solutions), under a physician’s IND for HXe MRI. Informed consent was obtained in all cases and a physician supervised each study. Enriched xenon gas (87% Xe129) was polarized using a prototype commercial system (XeBox-E10, Xemed). The study group included 2 smoking COPD subjects (gold stage 3; FEV1 46% and 39% predicted; 58 and 55 years old, respectively) and one age-matched, clinically healthy subject with a history of heavy second-hand smoke exposure (FEV1 101% predicted; 50 years old). All subjects inhaled 0.5L of HXe starting from residual volume, then continued inhalation of room air and held their breath at total lung capacity (TLC).

Results and Discussion: Figure 1 depicts the pulsations in the RBC and TP dissolved-phase peak integrals over time for the three subjects. In the clinically healthy second-hand smoker (SHS), a rhythmic pulsation in both dissolved-phase peaks, with a frequency of approximately 1 Hz, is clearly discernible (Fig. 1A). The amplitude of the RBC pulsation is about six times higher than the TP pulsation. In neither of the two COPD subjects is a rhythmic TP pulsation apparent (Fig. 1B and C). Also, the RBC oscillations are at least partially absent and lack the periodicity seen in the age-matched SHS. In a separate study of healthy, albeit younger, subjects for the same delay time τ of 100 ms, a pulsation of the TP and RBC signals was also visible in all cases (7). In the ventilation images (not shown), the three subjects exhibited ventilation defects ranging from mild (SHS) to severe (COPD subjects). In healthy subjects, the observed pulsations reflect differences in gas uptake by the blood plasma and RBCs throughout the cardiac cycle. However, since the spectroscopic measurements are global in nature, this pulsatile blood flow in the pulmonary capillaries has to be sufficiently in phase throughout the pulmonary volume to minimize cancellation effects of the temporal fluctuations. A possible explanation for the disappearance of the global peak pulsations might therefore be that emphysematous lung tissue destruction, or regional pulmonary hypertension, in subjects with severe COPD reduces the coherence of the various regional pulsations. Nevertheless, given the small number of COPD patients investigated, additional subjects will need to be studied before more concrete conclusions can be drawn.

Conclusion: We demonstrated that the pulsatile flow of the pulmonary capillary blood as detected by global CSSR spectroscopy is abnormal in subjects with severe COPD, possibly due to pathological changes in the cardiovascular system.

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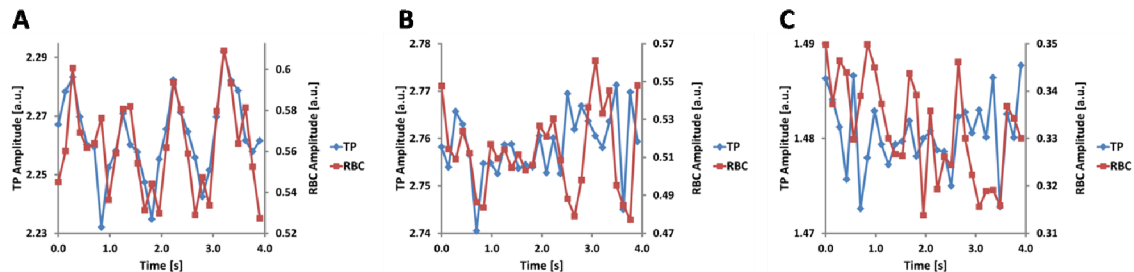


Figure 1. RBC (red) and TP (blue) amplitude fluctuations at TLC in a clinically healthy SHS (A) and two gold stage 3 COPD subjects (B,C).