Dynamic Oxygen-Enhanced Ventilation Imaging in Healthy and Asthmatic Humans

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Introduction

The signal change in oxygen-enhanced ventilation imaging technique results from the increase in concentration of dissolved oxygen in the lung tissue and blood [1-3], and studies have shown that the rate of oxygen-enhanced signal change correlates with pulmonary diffusion capacity [4,5]. In this study, we will simultaneously reconstruct the maps of signal difference, rate of signal enhancement (slope), and the time shift of signal enhancement by fitting the dynamic time course of the signal intensity to tanh, linear, sine, or exponential function.

Materials and Methods

All experiments were performed on a GE CV/i 1.5 T Signa system (GE Medical Systems, Milwaukee, WI). Eight healthy volunteers and four subjects with asthma were imaged. A cardiac-triggered nonselective inversion recovery single-shot fast spin echo sequence was used with a bandwidth of 250 KHz. A slice thickness of 15 mm, a field of view of 450 mm, a matrix of 128 x 256, and a TI of 1200 ms were used. The subject was asked to perform respiratory pacing to ensure that image acquisition occurred at approximately end-expiration. The subject would temporarily hold his/her breath before the acquisition of each image. Once the gradient knocking sounds finished, the subject would breathe in and out once before temporarily performing breathholding again for the next image acquisition. A series of 100 images were acquired with the subject alternatively inhaling room air and 100% oxygen. The subject was breathing room air for the first 25 or 30 images, and at which time, oxygen flowing at a rate of 15 l/min through a non-rebreathing ventilatory mask was initiated for the next 40 images. After which oxygen flow was stopped for the remaining 35 or 30 images. The data were then transferred off-line for image reconstruction on both the up-ramp (oxygen on) and down-ramp (oxygen off) of the signal time courses. The fitting algorithms were written in MATLAB (The Mathworks Inc., Natick, MA).

Results and Discussion

The maps were successfully reconstructed from all volunteers. Shown in Fig. 1 are pixel-by-pixel maps of the signal difference, slopes, and shift of a subject with severe asthma. All the maps obtained from tanh, linear, sine, and exponential fittings consistently exhibit similar pulmonary anatomical features and a reduced signal intensity difference and rate of enhancement (slope), but an increase in the time shift in the lower left lung. Figure 2 shows the plots of the time course of the signal intensity measured from a region of interest in the normal, upper right lung and the resulting good fits for tanh, linear, sine, and exponential functions. Although further studies are needed to validate these preliminary findings, they strongly suggest that the proposed method can provide a comprehensive tool for the diagnosis of pulmonary diseases such as asthma.

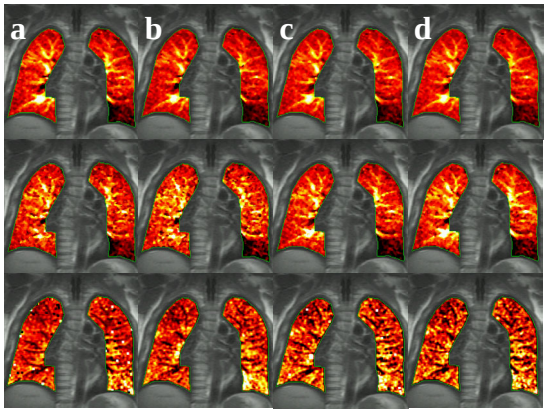

Figure 1. *Pulmonary oxygen-enhanced ventilation maps of the signal difference (top row), slope (middle), and signal difference (bottom) of a subject with asthma. The maps result from fitting to (a) hyperbolic tangent, (b) linear, (c) sine, and (d) exponential functions.*

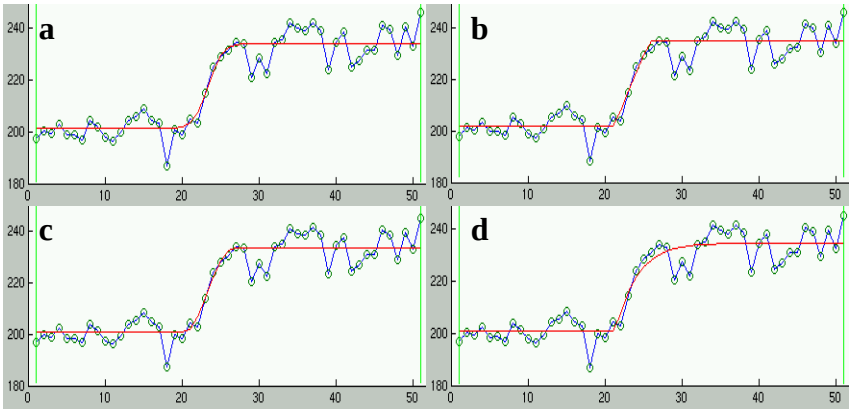

Figure 2. *Time courses of dynamic oxygen-enhanced ventilation signal intensities (open circles and blue lines) of a normal, upper-right lung region along with the resulting mathematically fitted lines (red) of (a) hyperbolic tangent, (b) linear, (c) sine, and (d) exponential functions of the up-ramp of the signal time course.*

References (1) Edelman RR et al. *Nature Med*. 1996;2:1236-1239. (2) Chen Q. et al. *MAGMA* 1998;7:153-161. (3) Mai VM et al. *MRM* 1999;43:913-916. (4) Muller CJ et al. *Radiology* 2002;222:499-506. (5) Ohno Y et al. *MRM* 2002;47:1139-1144.

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