Distribution of Pulmonary Pulse Arrival in the Healthy Human Lung

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Abstract: The pulmonary artery pressure (PAP) can be noninvasively assessent using the EIT-derived pulmonary pulse arrival time (PAT). However, the spatial distribution of PAT is poorly understood. We analyzed the spatial distribution of PAT in healthy human lungs using cardiac-gated 3D EIT data. Results show PAT varies laterally (and is more than 20 ms lower in the middle) but has little cradio-caudal variation.

1 Introduction

Cardiac-gated EIT can be used to image the pulsatile component; this has been used in several applications, including monitoring of pulmonary arterial pressure [1]. However, the characteristics of the spatial distribution and timing of this signal are poorly understood.

In this study we seek to understand the spatial distribution of the pulmonary pulsatility signal in more detail, in particular the pulse arrival time (PAT) in healthy human lungs.

2 Methods

In our analysis we used previously-measured cardiac-gated EIT data [2], in which healthy volunteers had 32 EIT electrodes placed on the chest in two vertical bands and 3D EIT and synchronized ECG data were acquired, as described in [3].

From these data we analyzed one-minute averages of 3D cardio-synchronous EIT images recorded in supine position during recovery after bicycle exercise. These images were reconstructed using GREIT [4] on five different planes (L1 to L5), with L2 and L4 corresponding to the level of the upper and lower electrode bands [3].

For each of the nine available subjects we calculated the pulmonary PAT for each voxel as detailed in [1]. In a next step we analyzed the inter-subject spatial distribution of pulmonary PAT in two ways: (a) from right to left, i.e. in five vertical segments (see Figure 2) on L2, the EIT plane with strongest pulmonary activity; and (b) along the craniocaudal axis, i.e. EIT planes L1 to L5.

3 Results and Discussion

Figure 1a shows the horizontal distribution of PAT between the five different vertical segments. We can observe a lower PAT in the middle which increases towards the side. On the left the PAT is lower than on the right, probably due to the fact that the left lung lobes are closer to the pulmonary valve, resulting in a lower PAT.

In contrast, over the three uppermost EIT planes (L1 to L3) the PAT does not seem to change remarkably as shown in Figure 1b. The unexpected earlier PATs on L4 are hypothesized to be not due to a reduction of the real PAT but more due to interference with heart-related EIT signals leading to a diminution of the EIT-based PATs.

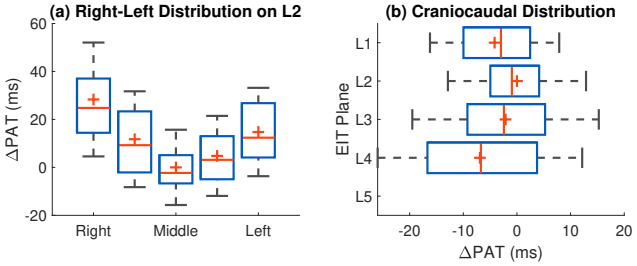

Figure 1: Distribution of the differences in EIT-derived pulmonary PAT from all nine subjects on (a) the five different vertical segments (see Figure 2) on the EIT plane L2 and (b) the five different EIT planes. Note that differences in PAT were calculated for each subject individually by subtracting the mean of (a) the middle segment and (b) the EIT plane L2. The whiskers represent ± one standard-deviation, + the mean, and − the median.

In summary, we could show via ECG-gated 3D EIT that in healthy volunteers the EIT-derived pulmonary PAT is (a) varying from left to right, being lowest in the middle, larger on the left and largest to the right; but (b) barely changing in craniocaudal direction. These findings are in line with PAT values derived from a 3D circulatory lung model [5].

References

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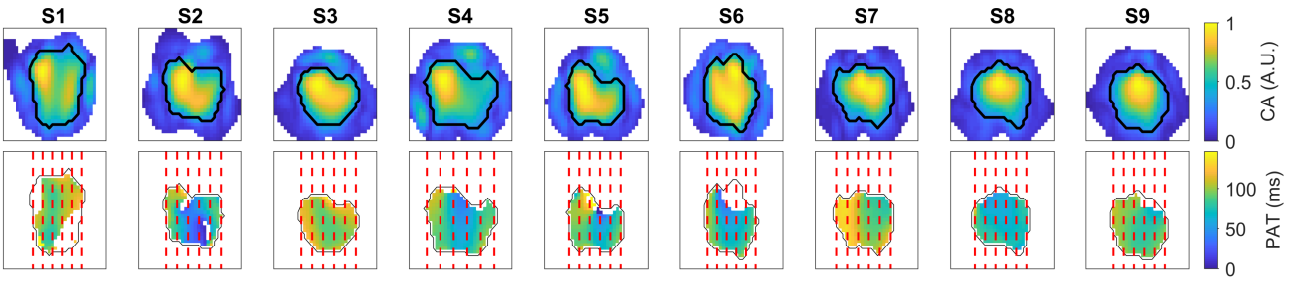

Figure 2: For each of the nine subjects (S1 to S9) we show: (Top) cardio-synchronous activity (CA) image as the pixel-wise temporal standard deviation of the EIT plane L2 with the lung ROI delineated in black. (Bottom) Spatial distribution of the pulmonary PAT in the lung ROI and on the same EIT plane with the five vertical segments separated by dashed red lines.