Measures of lung fluid via posture-change fEIT

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Abstract: There is significant interest in possible monitoring of pulmonary oedema with EIT. One novel idea is to observe the short-term redistribution of lung fluid in patients following posture changes. We report on initial results in human subjects and a novel fEIT measure.

1 Introduction

Pulmonary oedema is the accumulation of extra-vascular fluid in the lungs. It impairs gas exchange and lung function, and can occur due to left-ventricular insufficiency or lung tissue injury. There would be considerable clinical benefit to a non-invasive ability to monitor the amount and location of oedema, and EIT has been proposed for this application by several studies (e.g. [1]). Results have been mixed, largely because it is difficult to distinguish slow changes in lung fluid from slow changes in FRC or drift in the electronics.

Recently a novel functional approach to monitor lung fluid [2] has been validated in pigs; lavage-injured animals were laterally tilted (roll) to each side. With increasing oedema, fluid filled the dependent spaces and ventilation moved more to the non-dependent lung.

The goal of this study is to examine whether these results can be reproduced in patients, and to develop relevant EIT-analysis methods.

2 Methods and Results

Subjects were adults diagnosed with ARDS, and were monitored with an invasive Pulse-Induced Contour Cardiac Output (PiCCO) which can be used as a gold-standard measure of lung water content (although not reported here).

The experimental protocol involves posture changes, as shown in fig. 1, and analysis of the EIT signal in the ten minutes following the posture change from which functional EIT parameters are calculated. On each day of the experiments (normally three days), patients are positioned at 45° to the left, 45° to the right and supine. Slow EIT changes after posture change were analysed, based on our assumption that extra-vascular fluid will slowly redistribute, followed by gas volumes.

We define two new fEIT measures based on the EIT image sequence after posture change: 1) redistribution of ventilation, RoV=$\frac{b-a}{V_T}$, and 2) redistribution of fluid, RoF=$\frac{c}{V_T}$, where tidal volume, $V_T = \sum a_i$, for each pixel i.

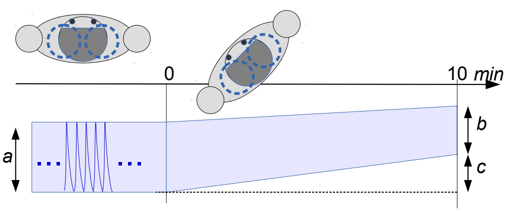

Figure 1: Block diagram of functional data analysis. After posture change, the envelope of tidal breathing (after rejecting outliers) of each EIT pixel waveform is analysed (↑ corresponds to ↑ ρ)

Fig. 2 shows representative results for a patient on day 3 of treatment. On day 1, the left tilt image was similar, but no change was seen for the right tilt.

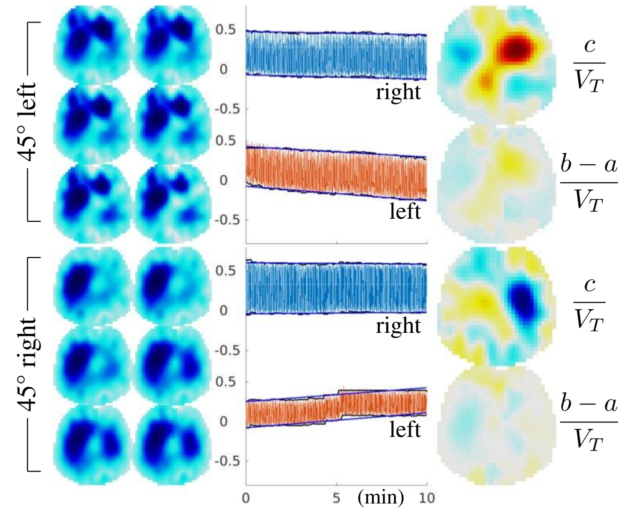

Figure 2: Left and right tilt results, for 10 min following each posture change. *Left:* end-inspiratory images (→ then ↓) at 0, 2, 4, 6, 8 and 10 minutes. *Middle:* time course of left and right image half and fitted trend. *Right:* fEIT images, RoF (top) and RoV (bottom).

This patient had severe left-lung oedema (fig. 3), which is consistent with the observed EIT results. With either tilt, there is little change in the right lung, which is more healthy. When tilting left, the left lung loses gas volume, especially in the non-dependent areas. When tilting right, the left lung loses fluid or gains gas volume.

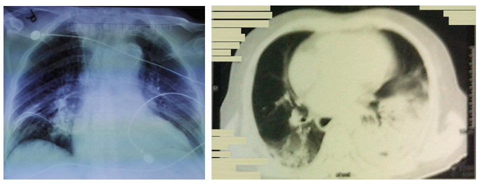

Figure 3: X-ray (*left*) and Transverse CT image (*right*) of patient in a supine position. Note severe left-lung oedema.

3 Discussion

We investigate EIT-measures of lung fluid, based on posture change-induced EIT signals. The idea is to supplement the assumptions of symmetry in the methodology of [2], since oedema is typically heterogeneous.

We develop two new fEIT measures which can be calculated from a patient in the minutes after a posture change. In this patient and others, the pattern of changes appears consistent with the distribution of oedema. In future work, we will focus on validating our calculations against PiCCO measures in these patients.

References

[1] Victorino JA *et al*, *Am J RCCM* 169:791–800, 2004.
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