Monitoring Ventilation and Perfusion in the liquid-ventilated lung

Étienne Fortin-Pellerin[1], Michaël Sage[1], Philippe Micheau[2], Julien Mousseau[2], Jonathan Vandamme[2], Mathieu Nadeau[2], Jean-Paul Praud[1], Andy Adler[3]

[1]Dept. of Pediatrics, Université de Sherbrooke, Canada, Etienne.Fortin-Pellerin@usherbrooke.ca
[2]Dept. of Engineering, Université de Sherbrooke, Canada
[3]Systems and Computer Engineering, Carleton University, Ottawa, Canada

Abstract: Total liquid ventilation (TLV) of the lungs provides lung lavage and gentle ventilation. EIT could provide real-time monitoring and allow precise control of TLV parameters. We report a preliminary EIT study in lambs of ventilation and perfusion during TLV perflubron filling. Results suggest more homogeneous ventilation with TLV and rapid blood flow redistribution to limits ventilation-perfusion anomalies.

1 Introduction

Total liquid ventilation (TLV) uses liquid perflubron instead of air for gas exchange. Since perflubron is dense ($\rho \approx 2$) it helps keep open dependent lung regions which would otherwise be collapsed (atelectatic) in pathologic conditions such as ARDS (adults) or hyaline membrane disease (neonates)[3]. Transition from air to liquid ventilation has many potential pitfalls. As Ventilated lung regions change from non-dependent to dependent, there is a risk of acute lung distention from the combined presence of air and liquid and blood redistribution to the ventilated area must occur.

We are motivated by the vision that EIT-based monitoring can identify and help avoid risks in the use of TLV. Our objective is to study the distribution of the volumes of air, perflubron and blood perfusion within the lungs using EIT. Our previous report studied EIT measurements of air and liquid volumes in one animal during the induction phase[1].

2 Methods and Results

Eight lambs (aged 2.4 ± 0.4 days, 3.2 ± 0.8 kg) were anesthetized and ventilated in a supine position using pressure controlled gaseous ventilation. Sixteen EIT electrodes were attached around the thorax and data acquired at 4.7 frames/s using the Sigmatome II EIT device. TLV was introduced using the Inolivent liquid ventilator prototype[2]. Perfusion was measured by a venous injection of a bolus of 7.9% saline solution during an apnea (Fig. 1).

Results were analysed to study the rate at which tidal ventilation and perfusion redistribute after the instillation of TLV. Representitive Ventilation (gas and TLV) and perfusion images from one lamb are shown in Fig. 2. Waveforms of global and vertical slices of ventilation are shown, along with images of tidal ventilation (V) and perfusion (P).

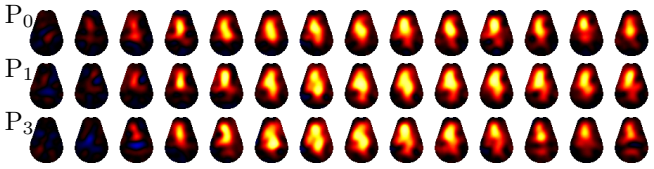

Figure 1: Time sequence of images of perfusion bolus through heart and lungs. Time progresses left to right with 400 ms between images.

3 Discussion

The distribution of ventilation/perfusion may be seen from these images by comparing images V_0/P_0 (gaseous ventilation), V_1/P_1 and V_3/P_3 (for liquid ventilation). Ventilation/perfusion matching is good and happens immediately after filling. However, the risk of overdistention was confirmed by this data and a slower filling protocol is now being used avoid this problem.

References

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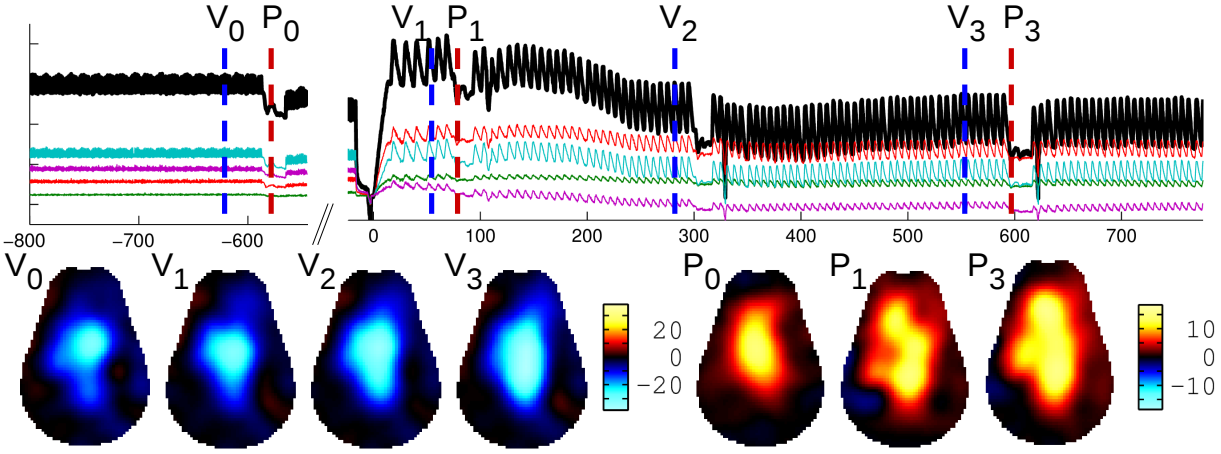

Figure 2: Example EIT waveforms and functional images showing the distribution of ventilation and perfusion in a slice of the thorax. Waveforms (vs. time (s) after the start of liquid ventilation) show global amplitude (black), and layers: green (ventral), red, blue, purple (dorsal). Images (blue, $\downarrow \sigma$, and red, $\uparrow \sigma$) show tidal ventilation (V) and perfusion (P) at the time instants shown.