Challenges of prolonged continuous monitoring of mechanically ventilated pediatric patients using electrical impedance tomography

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Several studies have compared images of ventilation produced by electrical impedance tomography (EIT) with other medical imaging techniques providing information on lung ventilation. Most of these studies were however performed in controlled environments where data acquisition was performed over relatively short periods of time. Monitoring of mechanically ventilated patients in pediatric intensive care units (PICU) to optimize ventilation settings and prevent ventilator induced lung injury require continuous EIT monitoring over long periods of time. Prolonged comparisons of EIT measurements against reference techniques over several hours or days have never been performed with current EIT systems [1].

The main goal of this project is to validate EIT measurements against ventilator data over prolonged continuous monitoring of PICU patients. Specific goals are: 1) to study long term drift effects leading to slow variations in EIT images over time that may be as large as or larger than those expected at the onset of pulmonary edema, atelectasis, or pneumothorax; 2) to study clinical events that may cause large artifacts in EIT images during regular staff interventions due to patient movement, electrode disconnection, drying of electrode gel, *etc*.

We have recently developed an acquisition system to simultaneously acquire EIT and ventilator data by interfacing a SERVO-I (Maquet, Solna, Sweden) ventilator with the EIT system developed by our group [2]. This combined acquisition system is capable of acquiring all ventilator data from its built-in serial port in real time. Such data include volume, pressure and flow curves, as well as alarms, settings, and physiological information provided by the ventilator at every breath and every minute. All ventilator and EIT data are time stamped with microsecond resolution to enable reconstructing an accurate timeline of all events. The temperature inside the EIT system is also similarly recorded to account for any temperature related measurement drift.

After obtaining approval from relevant ethic committees, we started performing simultaneous recordings of ventilator and EIT data using the unique set-up we have developed on a few PICU patients. These recordings were performed without using any recruitment protocol while PICU personnel were performing regular patient care. The personnel were simply instructed to reconnect any electrode that became disconnected. Preliminary assessment of acquired data shows that some interventions on the patient result in electrode disconnections or change of posture that may require resetting some of the electrodes or resetting the reference frame used for the time-difference imaging algorithm we use. Other medical instruments used on the patient or large bandages covering wounds also sometimes interfere with the desired electrode placement. The next phase of analysis is a statistical study to find any correlation that may exist between all acquired ventilator and EIT data. Each correlation found will be further investigated for its relevance as a diagnostic tool or its use as a model parameter to account for unwanted measurement drift.

Expected outcomes from this project are: 1) a model to account for measurement drift based on the ventilator data and the temperature sensor inside the EIT system; 2) an algorithm to automatically validate the quality of EIT images and inform the clinical staff of any possible action that may improve image quality; 3) an algorithm to automatically select the reference frame that is used for time-difference imaging since it has to be reset whenever the patient's position changes; 4) more robust reconstruction algorithms that incorporate *a priori* real-time information provided by the ventilator such as breathing frequency, tidal volume, *etc*.

[1] A Adler, M B Amato, J H Arnold, R Bayford, M Bodenstein, S H Böhm, B H Brown, I Frerichs, O Stenqvist, N Weiler, and G K Wolf, "Whiter lung EIT: Where are we, where do we want to go and what do we need to get there?", *Physiol. Meas.*, 33:679-694, 2012.

[2] H Gagnon, J C Gervais, O Fléchelles, P Jouvet, and A Adler, "Acquisition system for correlating electrical impedance tomography and ventilator data during prolonged continuous monitoring of mechanically ventilated patients", *100 Years of Electrical Imaging*, Presses des Mines, Paris, 2012.