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Noninvasive Cardiopulmonary Monitoring of Hemodynamic and Respiratory Parameters using Electrical Impedance Tomography (EIT)

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Noninvasive cardiopulmonary monitoring would ideally include real-time measurements of stroke volume (SV), heart rate (HR) and cardiac output (CO) as basic hemodynamic parameters, and tidal volume (TV), respiration rate (RR) and minute ventilation (MV) as basic respiratory parameters. Such a noninvasive cardiopulmonary monitoring device could be useful for cardioprotective hemodialysis as well as other clinical applications in OR, ICU, and ER. Electrical impedance tomography (EIT) has emerged recently as a new tool for simultaneous measurements of beat-to-beat SV and breath-by-breath TV. The objectives of this presentation are to (1) introduce the EIT technology to clinician users and (2) show the results of multiple animal and clinical studies to evaluate its potential usefulness in noninvasive cardiopulmonary monitoring.

EIT has been developed for functional imaging of electrical conductivity distributions inside the human body. In EIT, electrical currents are injected, and the induced voltages are measured through multiple surface electrodes attached around the chest. Afterwards, a cross-sectional conductivity distribution image inside the chest is reconstructed from the measured boundary voltage data using a reconstruction algorithm. This process is repeated at a fast rate, e.g., 50 or 100 times per second. In addition to its successful clinical application in the regional lung ventilation imaging of mechanically-ventilated patients in OR and ICU, EIT could be potentially useful as a cardiopulmonary monitoring tool.

Lately, we developed a new source separation algorithm to extract cardiogenic and respiratory components in measured EIT data. Using an EIT device with this source separation algorithm, the following animal studies were conducted to evaluate its performance in simultaneously measuring TV and SV:

- (1) Measurements of TV and SV using the EIT device and comparison with those from a mechanical ventilator and an invasive hemodynamic monitor (VolumeView and FloTrac)
- (2) Measurements of SV during repeated mini-fluid challenges using the EIT device and an invasive hemodynamic monitor (FloTrac)
- (3) Measurements of CO and stroke volume variation (SVV) using the EIT device and



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comparison with those simultaneously measured by two invasive hemodynamic monitors (Swan-Ganz CCO and FloTrac)

In addition, the following clinical studies were conducted to assess the potential of cardiopulmonary monitoring using the EIT device:

- (1) Measurements of TV and SV during overnight polysomnography (PSG)
- (2) Measurements of TV and SV in PACU
- (3) Measurements of TV and SV during hemodialysis

Summarizing the results of these animal and clinical studies, future development of an integrated cardiopulmonary monitor including EIT, ECG, blood pressure, and SpO₂ will be discussed. Research collaborations using a clinical EIT device will be suggested to explore numerous clinical applications including noninvasive intradialytic cardiopulmonary monitoring.