Simultaneous Multiple Source Electrical Impedance Tomography

What is EIT?

Electrical Impedance Tomography (EIT) is an imaging technology that uses the electrical properties within an anatomic structure derived from measurements made on the structure's surface. EIT is a non-invasive, non-ionizing, real-time, functional imaging technique with no harmful side effects. EIT is suitable for patients of any age and can be performed continuously at the bedside without sedation. EIT can generate images of lung ventilation, perfusion, and V/Q ratio maps in real time – breath to breath and beat to beat.

GE's novel EIT approach

GE Research collaborated with academic partners to develop a novel, simultaneous multi-source EIT. We refer to this as SMS-EIT. GE has built prototype SMS-EIT systems with 32 independent channels. Each channel consists of individual current source and voltage measurement circuits for driving and measuring signals operating at 10 kHz operating frequency. Data is acquired at about 20 frames per second with 16-bit accuracy.

While other EIT commercial systems exist, they use an inferior approach and multiplex a single (or bipolar) current source about their electrode array. A single source approach affords significantly less capability to detect small inhomogeneities than an SMS-EIT systems in which the number of current sources is equal to the number of skin electrodes. GE's SMS-EIT design provides higher signal-to-noise ratio and greater sensitivity to image pulmonary perfusion in addition to ventilation.

Helping trauma patients

Real-time lung monitoring and assessment is an unmet need for the many high acuity care conditions:

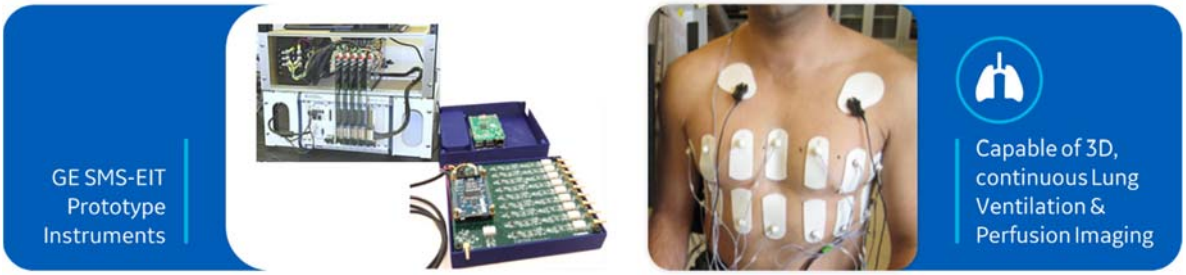
- Differentiate pneumothorax and hemothorax and track its progression for combat casualty care
- Monitor lung function for ventilated patients during aeromedical evacuation
- Enable successful weaning with continuous lung function monitoring following ventilator disconnect
- Monitor lung function and therapy response for premature neonates and pediatric patients

Lung function assessment with EIT presents a radiation free alternative for pediatric and neonate patients. EIT can be implemented as a small, battery-operated and portable device to bring continuous lung assessment to the point of injury for civilian or military trauma applications.

Clinical lung V/Q data

Our confidence in SMS-EIT capability is based upon data we've collected with clinical partners from multiple adult and neonate human subjects. The following examples summarize key results collected and published by GE Research.

Thirty-two commercially available ECG electrodes were attached around the chest of a healthy human subject in two circular rings with approximately equal spacing. To correlate to the breathing and cardiac cycles, the subject breathed through a pneumotachograph with a breathing mask and a pulse oximeter was placed on the right hand for PPG measurements. The correlation between the SMS-EIT global conductivity data and the spirometer and PPG data from one subject are shown in the following figure.



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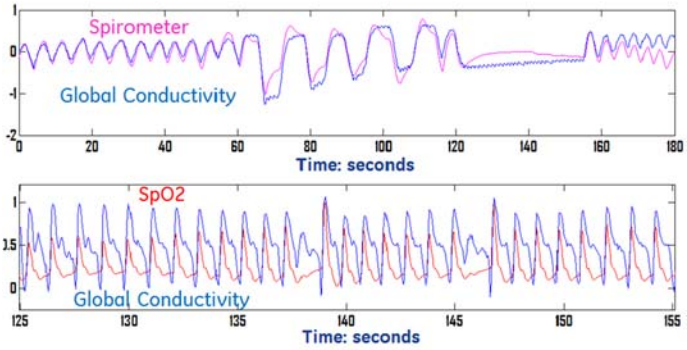
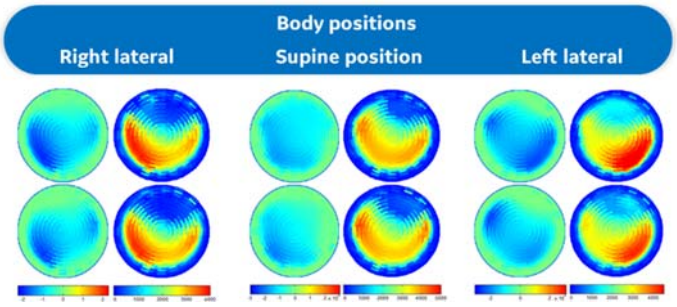
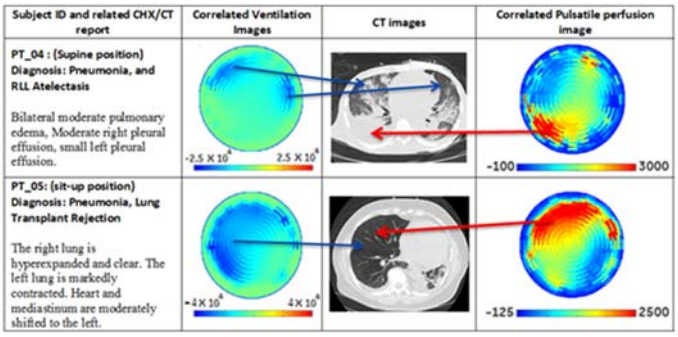
Strong agreement is found between global SMS-EIT conductivity and spirometer waveform as well as PPG (during breath hold only cardiac perfusion signal is changing).



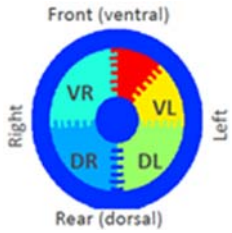
SMS-EIT can show the ***regional changes in time-differenced perfusion and ventilation images*** *(referenced to the start of a breath or cardiac cycle)* with different body postures. Real-time reconstructed perfusion and ventilation images from 3 different body postures are shown below. Each reconstructed image is presented in 2 layers. Top and bottom layers represent the conductivity change in the cephalad and caudal electrode plane, respectively. The perfusion images all use the same color scale, and the ventilation images use another color scale. Red indicates an increase in conductivity from the chosen reference frame to the depicted frame and blue represents a decrease in conductivity. The expected influence of gravity on the lung can be seen from the changes in spatial locations of both air and blood.

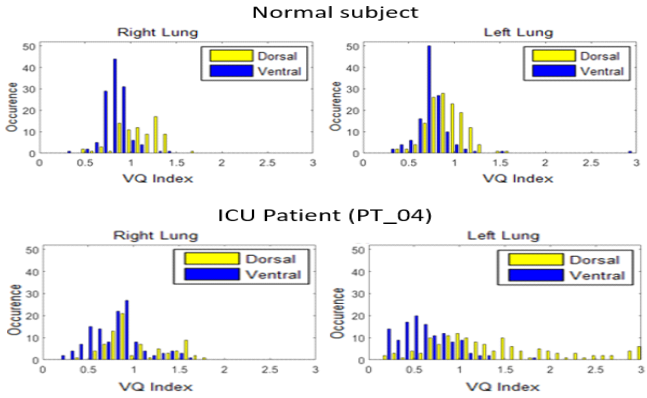


SMS-EIT ventilation and pulsatile perfusion images correlate with CT images and patient pathophysiology. We collected data from 20 ICU patients (10 Male, 10 Females, age: 49. ± 16. years, BMI: 23 ± 5.5, Chest Circumference: 94±13 cm, mean ± std dev).



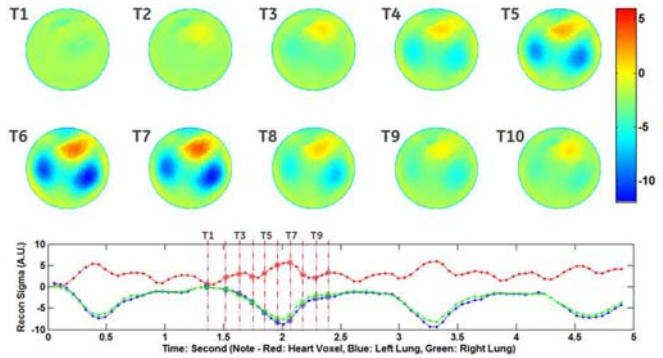
A novel VQ index was calculated from SMS-EIT images by estimating the fractions of air and blood at region allocations in the lungs. ***Regional VQ Index*** is computed by sum of the voxel conductivity in four quadrants of the lungs: Ventral and Dorsal, Left and Right. The cardiac regions (red) and surface / central regions (blue) are not analyzed. The histograms below highlight the regional differences in right and left lung V/Q index for a normal, healthy subject and an ICU patient *(PT_04, CT shown above).*





SMS-EIT allows one to view the ***temporal evolution of ventilation and perfusion*** as a spatial reconstruction or as a temporal waveform of impedance voxels within a specific region. In the examples below the reference point for the reconstruction (time t=0) is the end of exhalation. Below the reconstructions a regional conductivity waveform that shows the time points denotes for each spatial reconstruction image

Ventilation temporal evolution, SMS-EIT



Perfusion temporal evolution, SMS-EIT