Exploring the Potential of Electrical Impedance Tomography (EIT) for Monitoring the Human Cardiovascular System

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The demand for devices to assess human cardiovascular function in ambulatory conditions is continuously increasing: while reducing the need for long hospitalization periods, ambulatory monitors reduce healthcare costs and improve patient comfort. In recent years, portable electrocardiograms, blood pressure monitors and pulse oximeters have been successfully released into the market paving the way towards the monitoring of cardiac and vascular parameters in out-patients. Unfortunately, these parameters still provide an incomplete picture of health status of the patient and do not fully fulfill clinical demand. The goal of this research is to explore the use of the emerging Electrical Impedance Tomography (EIT) technology for a novel application: the non-invasive and continuous monitoring of human cardiovascular function. In this report, CSEM illustrates the potential of this technology by providing in vivo measurements of arterial blood flow performed in a pig model.

From an electrical perspective, the thoracic cavity can be viewed as a complex distribution of impedance volumes. While the lungs (filled with air cavities) form high impedance volumes, the heart (filled with blood) forms a compact low impedance volume.

Electrical impedance tomography (EIT) creates tomographic reconstructions of the distribution of impedances within the thoracic cavity. As input signals, EIT requires a set of impedance measurements performed around the chest (see Figure 1). Basic *a-priori* knowledge about chest anatomy allows estimation of the most likely impedance distribution given the set of measurements, and determination of specific regions of interest, such as the heart and the lungs. With the help of EIT technology, fast *in-vivo* images of the thoracic cavity (up to 50 images/second) have been obtained simply requiring the placement of several electrodes around the thorax (e.g., in a simple chest belt or in more sophisticated anatomy-adjusted configurations).

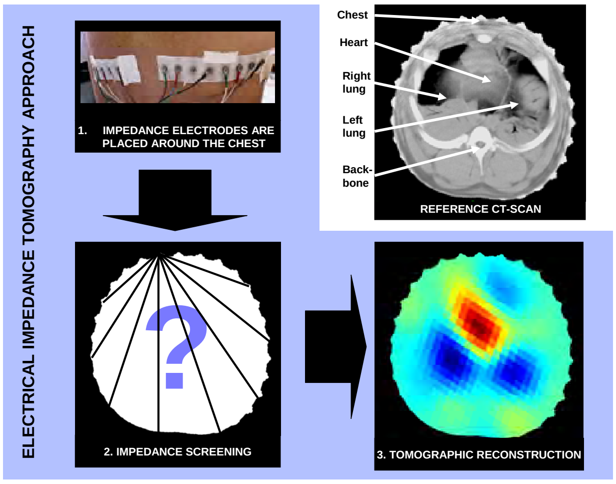

Figure 1: Estimation of chest perfusion images by electrical impedance tomography. After placing several impedance electrodes around the chest (1), impedance measurements are performed for each electrode pair (2). Tomographic images are then constructed (3). By analyzing a series of images obtained during a complete cardiac cycle, one obtains information on the movement of arterial blood within the chest. A CT-scan of pig chest is provided as anatomical reference.

During each cardiac cycle any vascularised structure within the chest receives fresh and highly conductive blood which decreases its local impedance. Hence, when comparing a sequence of EIT images acquired during a complete cycle, one is able to track the flow of blood through the different organs represented in the EIT plane. This fact is exploited to analyze the temporal distribution of blood within the capacitive reservoirs such as the different heart cavities and the vascular bed of the lungs. The EIT-based visualization of blood flow from the heart to the lungs of an anesthetized pig is illustrated in Figure 2.

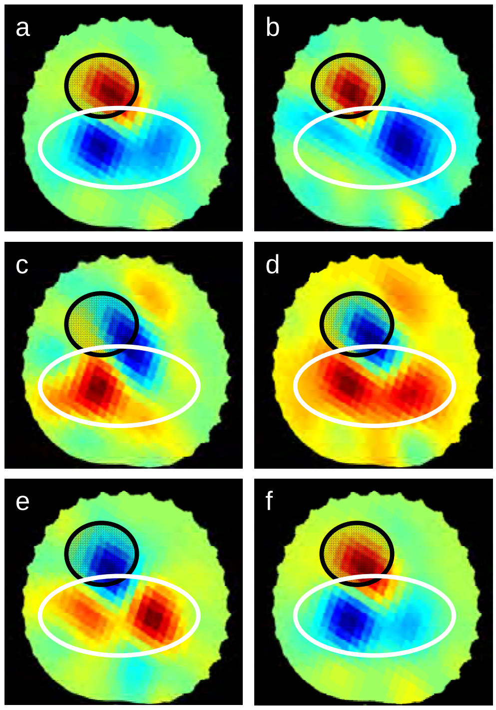

Figure 2: Tracking of blood as it moves through the heart and lungs during a cardiac cycle. EIT images show the local filling of blood in red and emptying in blue. The heart region has been delineated in black and the lung regions in white. In a) and b) one observes the filling of the heart. In c) the heart empties while the right lung (here on the left hand side) is starting to be perfused. In d) and e) both lungs are perfused. Finally, in f) the cardiac cycle starts again.

Because of its non-invasive and non-obtrusive nature, EIT appears to be a good candidate for the continuous monitoring of cardiovascular function in out-patients. Together with the universities of Hamburg and Madrid, CSEM is currently performing inter-disciplinary research work to assess the potential of this technology.

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