Blood Pressure Monitoring via EIT: Optimizing the Technology

F. Braun, M. Proença, M. Rapin, M. Lemay, J. Solà i Carós

The pulse transit time principle allows for a new generation of blood pressure measurement devices replacing traditional arm cuffs. The herein presented work describes bio-impedance simulations performed in order to optimize the setup when measuring pulse transit times in the descending aorta via electrical impedance tomography, a non-invasive, safe, and low-cost medical imaging technology.

With a 40% prevalence at a worldwide scale [1], high blood pressure (BP) is the main risk factor for cardiovascular diseases, which accounts for 30% of all deaths [2]. This gives rise to the need for a reliable and non-invasive BP monitoring device. Nowadays, non-invasive BP measurements are routinely performed using a cuff attached around the upper arm. Since these measurements are only performed on an intermittent basis, *e.g.* every 20 minutes, short-term variations in BP cannot be monitored. Furthermore, in case of nocturnal monitoring, the inflation of the cuff can lead to arousal of the patient and therefore falsify the results and increase patient's discomfort. As previously reported [3], CSEM is developing new concepts for continuous BP monitoring (mean arterial BP) which are based on the pulse transit time (PTT) principle: the time the pressure pulse takes to propagate along the aorta.

One way to measure the arterial PTT is via electrical impedance tomography (EIT), a non-invasive and low-cost medical imaging technology allowing the reconstruction of 2D images representing the intra-thoracic impedance distribution. From these images, the signals from the descending aorta are used to determine the aortic PTT [4]. This work aims at finding the most appropriate EIT belt configuration for reliably detecting the low amplitude aortic signals. The research evaluates thus aortic impedance changes at a variety of belt positions and under different hemodynamic conditions.

Based on magnetic resonance (MR) images of a human volunteer a 3D thoracic bio-impedance model was created (Figure 1). While the lungs and the heart were modelled as static structures, the aorta was modelled as a dynamic structure with constant conductivity, composed of thirty cylindrical segments. The radii of these segments were extended individually, thus simulating the aortic distension caused by aortic pressure pulse propagation.

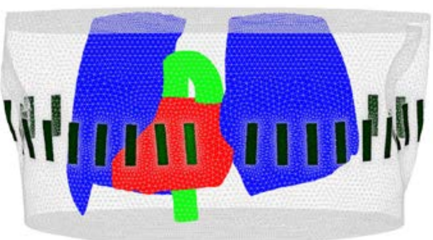

Figure 1: 3D bio-impedance model of the human thorax with the lungs (blue), heart (red) and aorta (green). The dark rectangles depict the electrodes of the EIT belt in transversal placement (TM).

To investigate the influence of belt position, four cases were distinguished: in a transversal plane between the 8th and 9th thoracic vertebra (labeled TM), 5 cm below TM (labeled TL), 5 cm above TM (labeled TH), and by tilting TM by 15° from transverse to coronal to obtain an oblique placement (labeled OM) as recommended for imaging the heart via EIT [5]. One full cardiac cycle was then simulated by modulating conductivities and structures as follows:

- the aortic radii were extended up to 15% according to real aortic BP readings
- the conductivity of the lungs remained unchanged
- the heart conductivity was modulated according to real blood volume readings. The maximal change was varied to achieve different signal-to-noise ratios (SNR): *e.g.* an SNR of 0.1 represents a ten-fold higher overall image amplitude originating from the heart compared to the aorta

To evaluate the performance of the belt positions, each pixel of the simulated EIT images was correlated with the known modulation signals from the aortic radii. The resulting figure of merit shows the percentage of the overall signal which originates from the descending aorta.

Figure 2 shows the best performance over the entire SNR range for the TL position, followed by TM performing half as well as TL on average. Similar simulations were performed with varying conductivities for the lungs instead of the heart, which lead to comparable results.

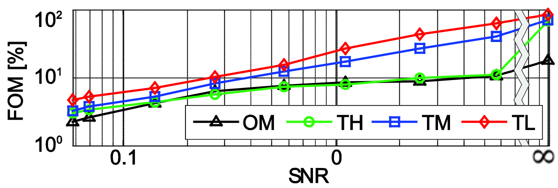

Figure 2: Double logarithmic plot showing the performance of four belt positions (OM, TH, TM and TL) to detect the descending aorta with decreasing influence of the heart (SNR).

These results suggest that among the four EIT-belt positions studied, a transversal low placement (TL) represents the most suitable placement to detect pulsatile signals from the descending aorta. However, the model is limited by the static nature of the lung and heart structures. Currently these simulations are being extended with the heart and the lungs as dynamic structures. Furthermore, comparisons with real EIT recordings will be performed to validate the current results.

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[5] A. Vonk Noordegraaf, *et al.*, Physiol. Meas. 17 (1996) 179