Comparing belt positions for monitoring the descending aorta by EIT

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Abstract: In electrical impedance tomography, the impedance changes stemming from the descending aorta contain valuable information for haemodynamic monitoring. However, the low signal strength necessitates an optimal measurement setup. Among different belt positions investigated in this work, a transversal and low placement is the best choice for detecting signals of the descending aorta.

1 Introduction

The intra-thoracic impedance changes measured by Electrical Impedance Tomography (EIT) are primarily used to monitor ventilation. In contrast, cardiovascular monitoring by EIT is still in its infancy [1]. Nonetheless, recent studies provide experimental evidence that blood pressure [2] and stroke volume variations [3] can be estimated non-invasively and continuously with this low-cost technique. Both of the aforementioned approaches exploit impedance changes originating from the descending aorta.

To the best of our knowledge, little is known about the most appropriate configuration for reliable detection of the low amplitude aortic signals. Therefore, this work aims to answer these questions by evaluating impedance changes of the descending aorta at a variety of belt positions and under different heart and lung conditions.

2 Methods

Based on MR images of a human volunteer [4] a 3D thoracic bio-impedance model was created. 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 the propagation of an aortic pressure pulse.

To investigate the influence of belt position, four cases were distinguished by placing the belt (i) in a transversal plane between vertebra Th8 and Th9 (TM), (ii) 5cm below TM (TL), (iii) 5 cm above TM (TH). Lastly (iv), the TM belt was tilted by 15° from transverse to coronal to obtain an oblique placement (OM) as recommended for cardiac EIT imaging [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 blood pressure 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 one from the aorta.

All simulations were performed using Netgen and the EIDORS toolbox with GREIT for reconstruction [6].

2.1 Performance Evaluation

Each pixel of the simulated EIT images was correlated with the known modulation signals from the aortic radii and heart conductivity. A figure of merit (FOM) was then calculated as the sum of root mean square amplitude (A_{RMS}) of the descending aorta pixels normalized by the total sum of A_{RMS} within the whole image. In other words, this FOM shows how much (in percent) of the overall signal originates from the descending aorta.

3 Results

Figure 1 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.

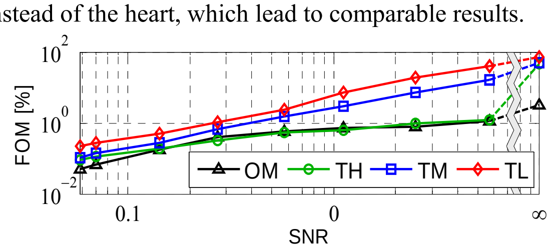

Figure 1: Double logarithmic plot showing the performance (FOM) of four belt positions (OM, TH, TM and TL) to detect the descending aorta with decreasing influence of the heart (SNR).

4 Conclusions and Outlook

These results suggest that a transversal low placement (TL) of the EIT belt is best to detect pulsatility signals from the descending aorta. However, the model is limited by the static nature of the lung and heart structures.

Future simulations with the lungs and heart as dynamic structures and comparisons with real measurements are suggested to validate the current results.

References

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