Using esophageal electrodes for increased sensitivity to cardiac-frequency impedance changes

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Abstract: We use EIT measurements made on an 4 electrodes placed in the esophagus to improve the sensitivity of the impedance image to central changes. Results across 3 subjects in an ovine model show increased sensitivity to cardiac-frequency impedance changes.

1 Introduction

Electrical Impedance Tomography (EIT) is most sensitive to changes in impedance near the electrodes and typically has limited sensitivity in the center-most regions of the model. 3D configurations of external electrodes help to give a more uniform sensitivity distribution and limit the effect of off-plane impedance changes compared to a single ring of electrodes [1].

EIT has been used as a tool to continuously monitor mechanical ventilation in critical care patients. but has limited sensitivity near the heart and central regions of the lungs. For many of these patients nasogastric tubes may already be in place and could be used in conjunction with internal electrodes to significantly increase internal EIT sensitivity without additional invasiveness. Previous work has shown that 4 internal electrodes can greatly improve sensitivity near to the internal probe [2], but can be sensitive to motion. EIT has been proposed for use as a blood pressure monitoring tool using pulse wave velocity [3], but external configurations have limited sensitivity to changes in the descending aorta. Internal electrodes present the opportunity to obtain a significantly higher sensitivity and with motion correction may be used to give a more accurate estimate of arterial pressure. This abstract presents a method of using internal electrodes while correcting for motion of the internal probe to yield high internal sensitivity.

2 Methods

The forward model was constructed using EIDORS version 3.10 [4] using `mk_library_model` [5] the internal electrode was added as an extra structure. This model was also used to identify the heart and lung regions. The sensitivity of the lamb model was calculated from the Jacobian using the method from [2]. Sensitivity profiles using 32 electrodes with and without 4 internal electrodes are shown in fig. 1.

Data were collected in 3 ewes during ventilation under general anesthetic using the SenTec EIT Pioneer Set. 30 second recordings were made during regular ventilation with a volume of 400 ±50 ml, frequency of 0.2 ±0.05 Hz, and peep of 6. Recordings were repeated for several ventilation scenarios including: high volume (+100 ml), low volume (-100 ml), high frequency (+0.17 Hz), low frequency (0.07 Hz), high peep (10) and low peep (4).

All breaths in each 30 second segment were ensemble averaged to give one representative breath for each scenario.

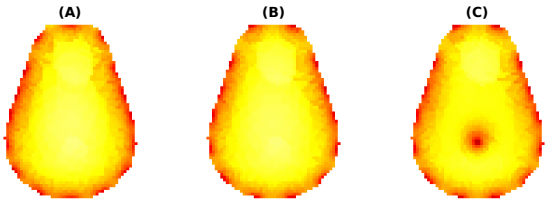

Figure 1: Sensitivity distribution averaged across 10 evenly spaced layers between the electrode planes in the lamb model for: A) 32 external electrodes B) 28 external electrodes c) 28 external electrodes and 4 internal electrodes

Images of one averaged breath per recording were reconstructed using the 3D GREIT algorithm [1] which minimizes the effect of electrode motion on the resulting image. Results were compared for both external only and internal electrode configurations using the same recording. To obtain results with only external electrodes all injections and measurements using internal electrodes were removed prior to reconstruction. Measurements on injecting electrodes were always removed. Images from one subject during regular ventilation are shown below in fig. 2. With internal electrodes, impedance changes at the cardiac frequency had an amplitude of 6.4% ±0.8% of the ventilation frequency and without internal electrodes the amplitude of the cardiac frequency was 0.8% ±0.2% of the ventilation frequency.

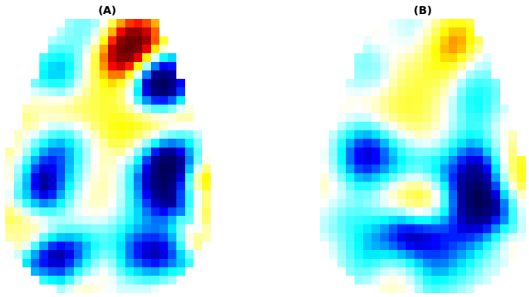

Figure 2: A single breath imaged with: A) no current injections or measurements on internal electrodes b) internal electrodes

3 Conclusions

The use of an internal probe yeilded higher sensitivity near the descending aorta. Reconstructions using the GREIT algorithm with internal electrodes on an esophageal probe were able to give increased sensitivity to cardiac-frequency impedance changes and may allow for better measures of blood pressure and pulse wave velocity.

References

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