EIT measurement of heart and lung perfusion

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1. Introduction

Electrical Impedance Tomography (EIT) shows promise for monitoring a patient's heart and lungs through the movement of conductivity contrasting blood and air. We are interested in using EIT to measure blood flow, which is useful for monitoring changes in cardiac output and ventilation / perfusion matching in the lungs. The goal of this research is to determine the accuracy of EIT measurements of blood flow in the heart and lungs.

2. Methodology

The data collection protocol was reviewed and approved by the institutional research ethics board. All patients underwent electrocardiogram-gated contrast enhanced Cardiac Computed Tomography (CT) scans at the University of Ottawa Heart Institute. Radio-opaque contrast agent (Omnipaque 350) was given to the patients and CT data was acquired (CT image as in Figure 1(a)). This CT data serve as a control for comparison against the EIT data. Three EIT electrodes were placed on each candidate before the CT scan, to serve as markers for the later placement of a total of sixteen electrodes.

EIT data was acquired immediately following the CT scan with a Goe-MF II EIT system (Viasys Healthcare, Höchberg, Germany) at a rate of 25 frames per second, during a 15 second breath-hold with the subject in a supine position.

A Finite Element Model (FEM) was designed based on the geometry acquired from CT data using Distmesh (http://www-math.mit.edu/~persson/mesh/). Images were reconstructed of a cross section of the thorax using several reconstruction algorithms, including a generic chest model and a model based upon the CT images (Figure 1 (b), (c)). The time profile of perfusion in the regions of interest for the heart and lungs is currently being extracted from the CT data for comparison against the EIT results. Lung perfusion is analyzed by segmenting the left and right lungs into four vertical slices and determining the perfusion time course in each. These measurements will enable one to quantify the accuracy of the perfusion measurement with EIT.

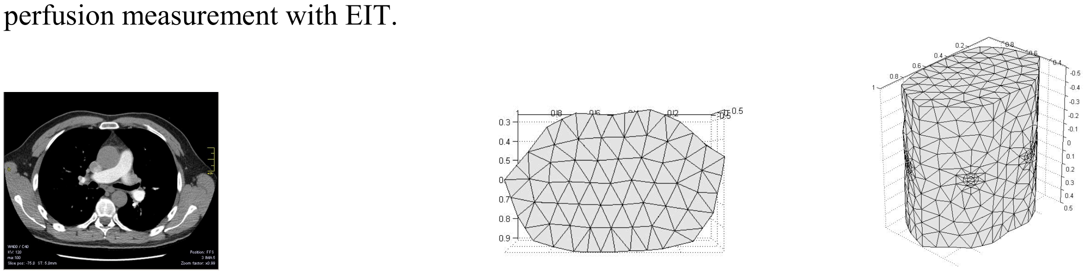

Figure 1: (a)Cross section of CT Image (b)2D CT Derived FEM (c)3D CT Derived FEM

3. Results

EIT and CT data have been acquired, and preliminary EIT results have been analyzed using EIDORS (www.eidors.org). Figure 2(a) shows the EIT measurements over one complete breathing/breath hold cycle using a two-dimensional Finite Element Tank model. The heart and lung regions of interest can clearly be seen when the sections for the breathing cycle are overlapped as illustrated in Figure 2(b).

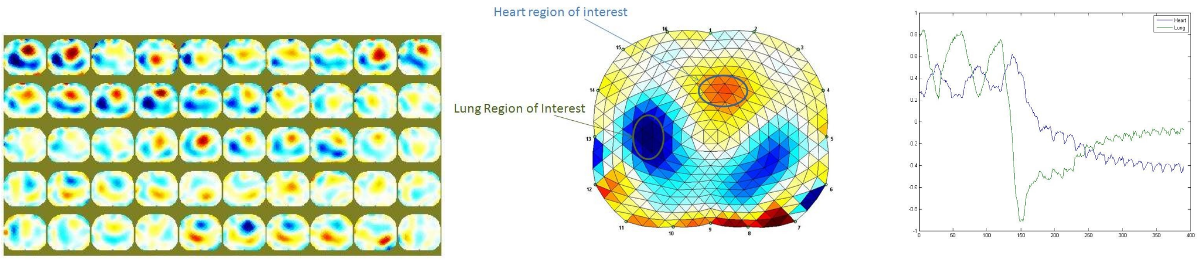

Figure 2: (a)One breathing/breath hold cycle (b)2D FEM with heart/lung region (c)heart and lung signal

Figure 2(c) shows the average impedance in the regions of interest as a function of time (sample). Both the heart and the lungs produce a periodic signal. The subject is breathing normally until sample 140. In this region, the impedance change is dominated by the lungs. After sample 140 the subject begins to hold their breath, and as a result, the data is dominated by the heartbeat leading to an increase in frequency. There appears to be no phase delay between the heart and lung signal as negative heart peaks correspond to positive lung peaks. This preliminary EIT data shows promise in its capability to determine perfusion in the heart and lung regions upon completion of the prescribed methodology described earlier.

4. Discussion

Significant work is still in progress. Locating cardiac blood flow on EIT scans has proven problematic, as there were significant inconsistencies between patients. Two possible causes of these issues will be analyzed: inaccurate electrode placement, and inadequate measuring equipment. It is postulated that inaccurate electrode placement may be contributing to the difficulty in determining the heart perfusion. During the initial measurements, the nipple line was used for electrode positioning. This positioning works well on healthy patients but can provide inconsistent results on patients with loose skin and/or excess weight. A new technique, based on counting ribs as a guide for positioning, will be tested to see if this will improve electrode placement and make EIT readings more consistent. While collection of EIT/CT data continues the calculation of perfusion from the CT data, and calculating additional EIT images using new CT derived FEM will also be completed.

Based on our results, EIT in this configuration appears to be able to measure cardiac blood flow and ventilation of the lungs. Both the heart and the lung regions have been identified for several subjects. It is expected that the use of a representative FEM will lead to better EIT images. The accuracy of these measurements is still unknown, but will be determined using the available CT data.

5. Acknowledgment

This work was sponsored by a grant from Natural Sciences and Engineering Research Council of Canada (NSERC).