Electrical Impedance Tomography for Perfusion Imaging and Monitoring

A Summary of PhD Work

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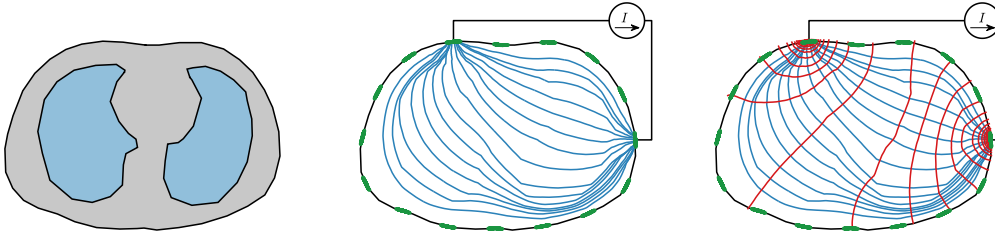
September 17, 2021

Overview

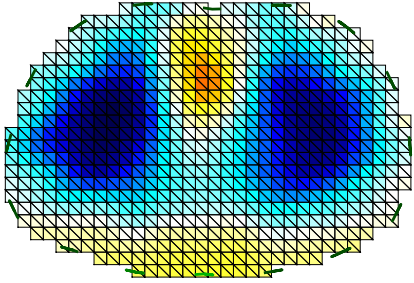
EIT



Electrodes on the body surface are used to inject current and measure the resulting voltages.

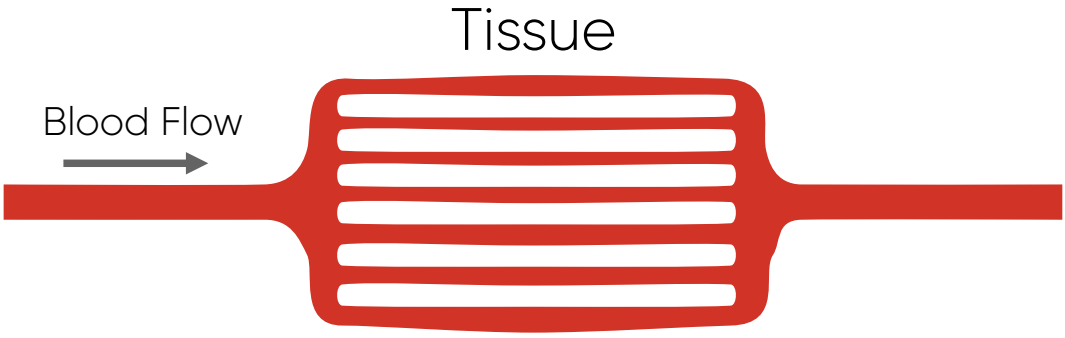
Thoracic EIT typically images impedance changes due to the movement of fluid in the chest.

Electrical impedance tomography (EIT)



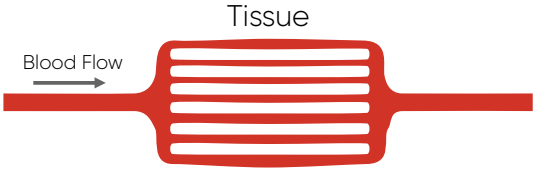
Voltage measurements are reconstructed into images

What is perfusion?



EIT Measures of Perfusion

Blood perfuses into the tissue.



The perfusion signal can come from:

- Change in blood volume in the tissue
- Change in blood volume in vessels
- Physical deformation of structures due to movement
- Ballistic forces in the body
- The orientation of red blood cells (very small change)

EIT Perfusion Imaging

Compared to other techniques used to image perfusion EIT is:

- Fast
- Does not use ionizing radiation
- Can be used continuously
- Cost efficient

Challenges of perfusion imaging with EIT:

- Unclear source of cardiac-frequency (cardiosynchronous) signal
- Low amplitude of cardiac-frequency signal
- Low sensitivity in the centre of a subject

Challenges of EIT Perfusion Imaging

Not all perfusion results in a cardiac-frequency change

- e.g. Continuous flow

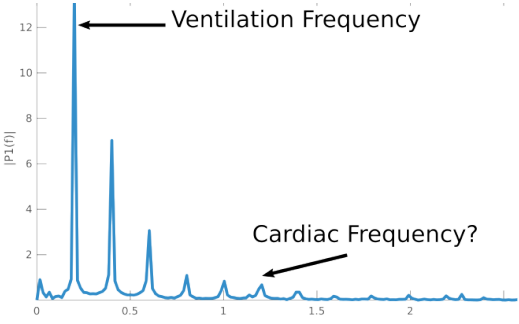
Non-perfusion effects can result in heart-frequency EIT signals

- e.g. Movement

Challenges of perfusion imaging with EIT:

- **Unclear source of cardiac-frequency (cardiosynchronous) signal**
- Low amplitude of cardiac-frequency signal
- Low sensitivity in the centre of a subject

EIT Perfusion Imaging



Example FFT of an EIT signal with only external electrodes (frequency in Hz).

Challenges of perfusion imaging with EIT:

- Unclear source of cardiac-frequency (cardiosynchronous) signal
- **Low amplitude of cardiac-frequency signal**
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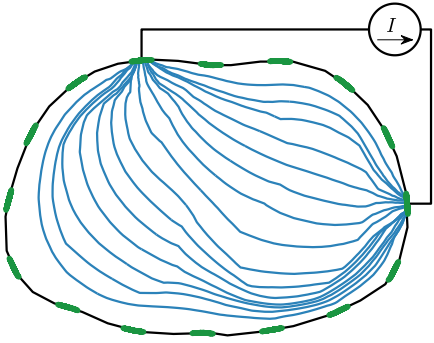
EIT Perfusion Imaging



Sensitivity is proportional to current density.

Challenges of perfusion imaging with EIT:

- Unclear source of cardiac-frequency (cardiosynchronous) signal
- Low amplitude of cardiac-frequency signal
- **Low sensitivity in the centre of a subject**

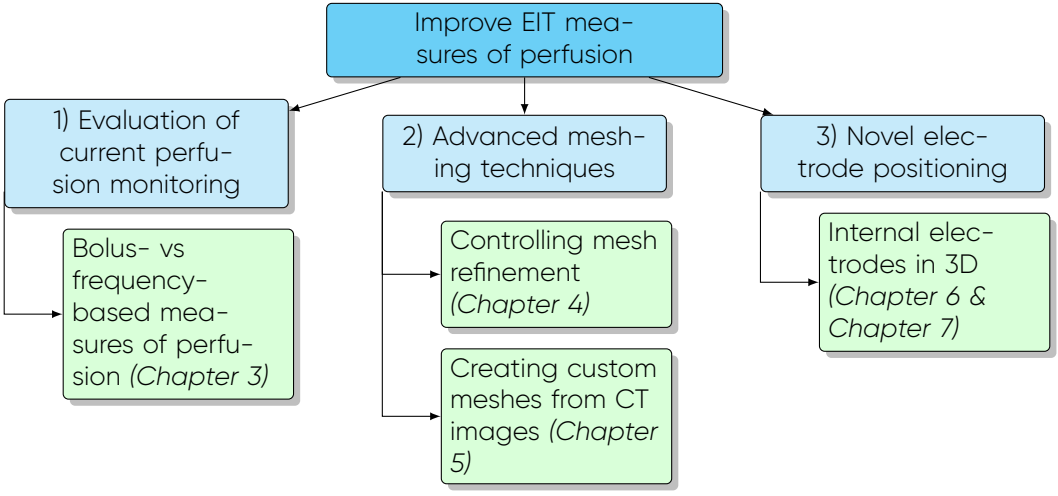
Shortcomings of EIT Perfusion Measures

- Bolus-based measures cannot be used continuously and are invasive
- Filtering-based methods have low sensitivity to cardiosynchronous activity
- Low internal sensitivity

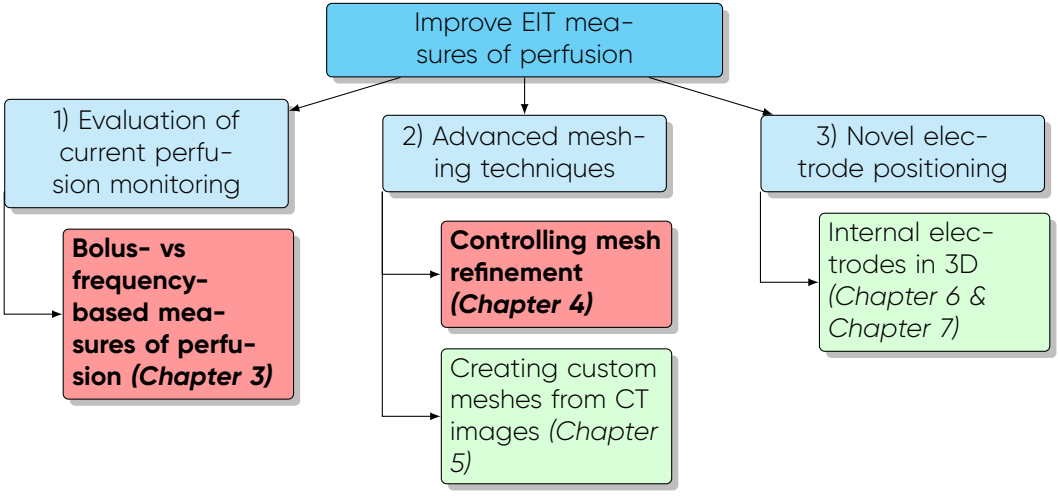
How can measures of perfusion be improved?

1. Investigate the source of perfusion and cardiosynchronous EIT signals
2. Increase sensitivity near where perfusion is measured

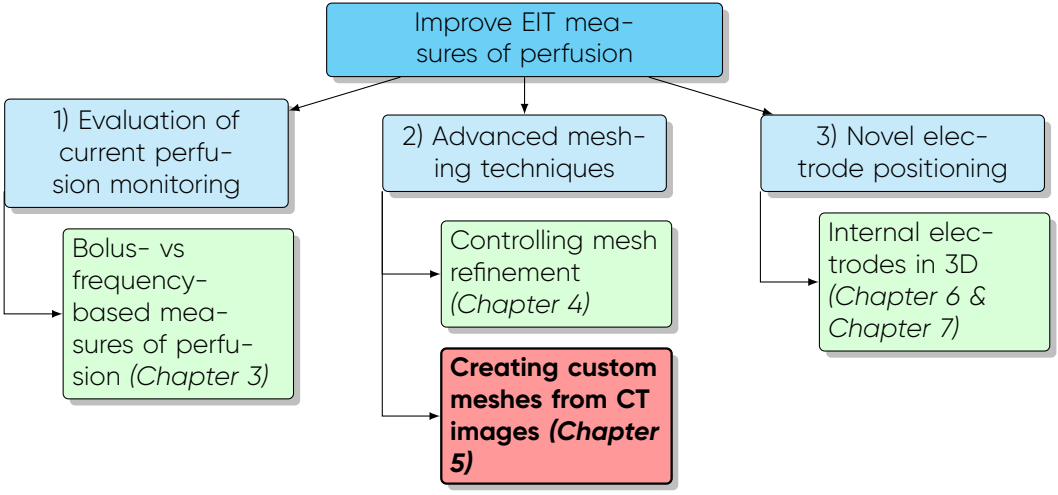
Thesis Goals



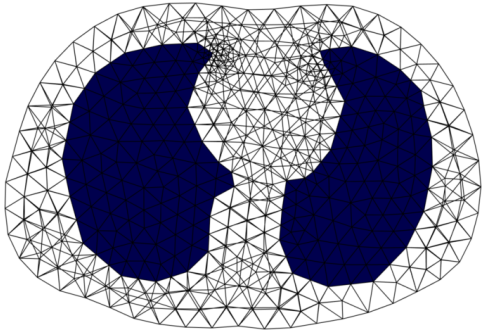
Thesis Goals



Chapter 5: Custom EIT Meshes



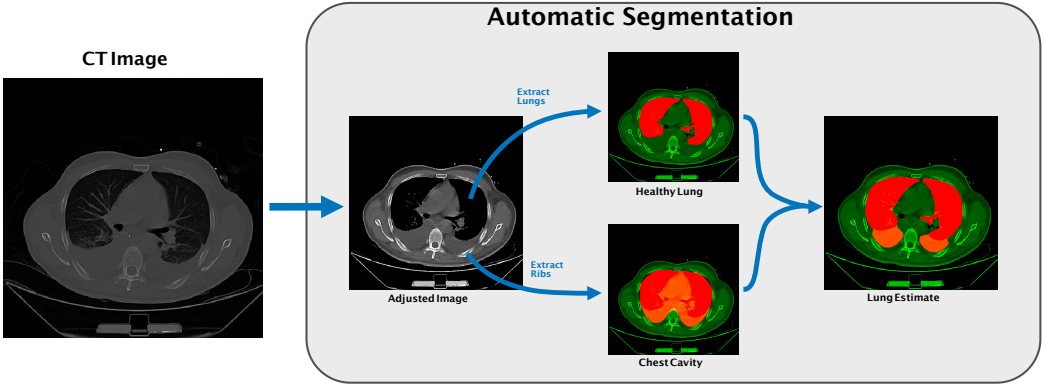
Introduction



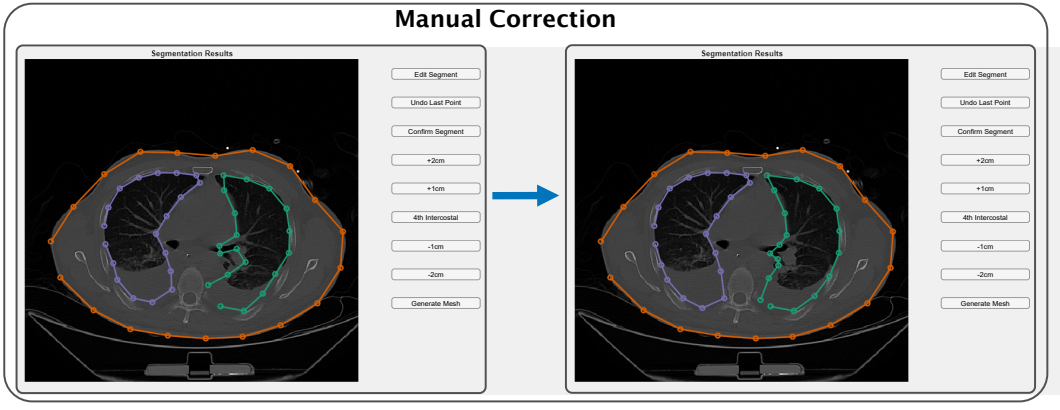
- A finite element model is required to reconstruct voltages into images
- The more accurate the FEM, the better the reconstruction
- More prior information regarding the body conductivity
- For some patients (ARDS) we have diagnostic CT images

Can we use this to improve EIT image reconstruction and monitoring of patients?

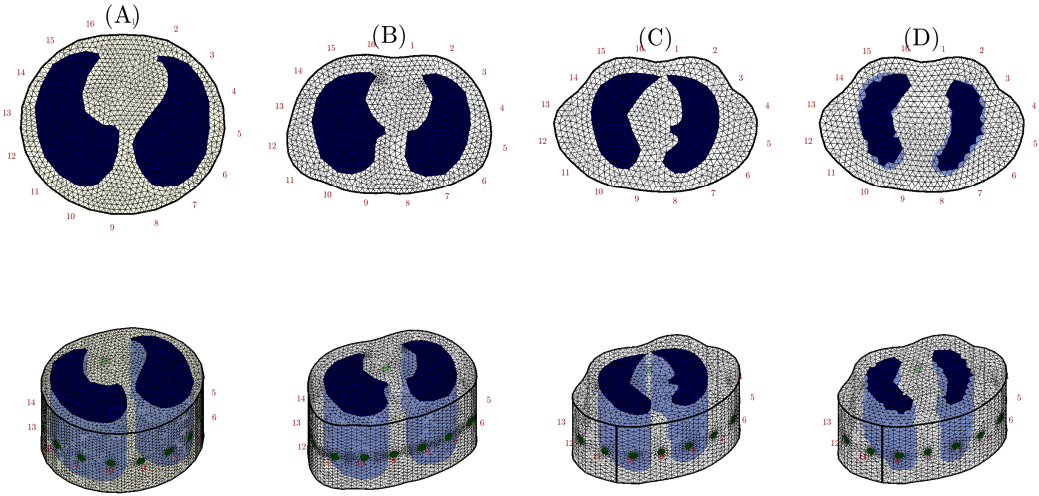
Methods: Automatic Segmentation



Methods: Manual Correction

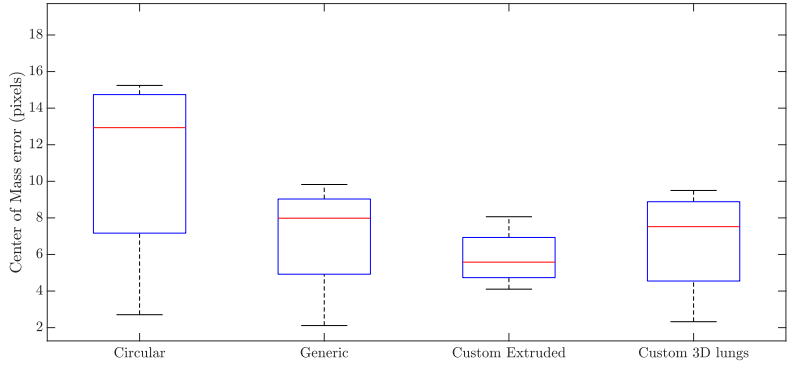


Methods: Meshing



Results

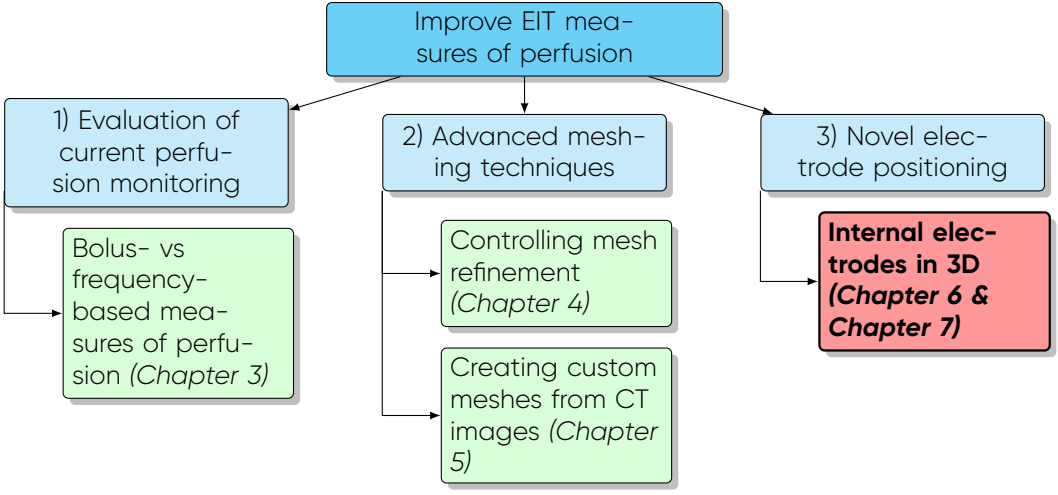
Center of ventilation error relative to the CT centre of ventilation.



Custom model is lower, but not consistently.

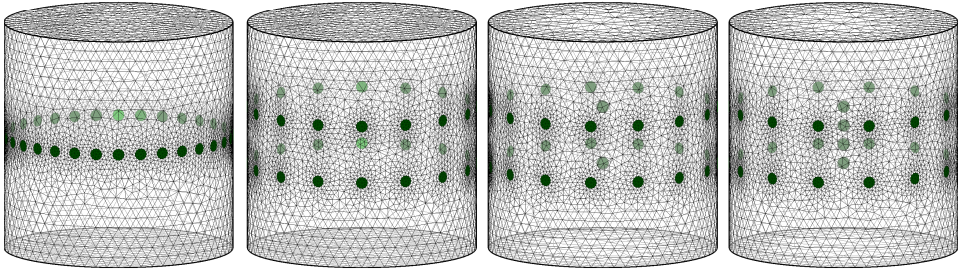
Electrode locations are still unknown...

Chapter 6: Internal Electrode Sensitivity



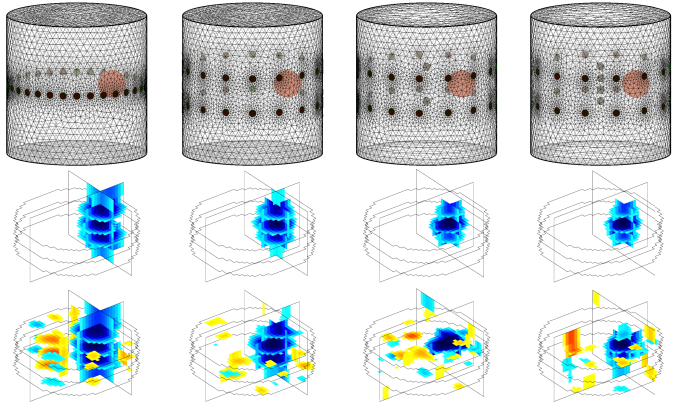
Introduction

To increase sensitivity in the centre of a model internal electrodes are added.



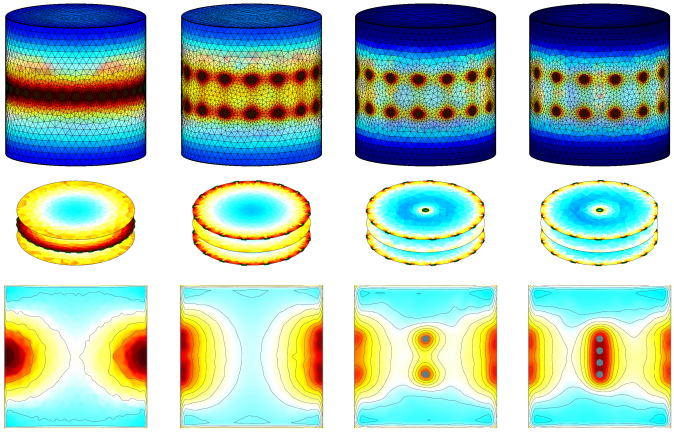
Typical 2D and 3D configurations are compared to internal electrode configurations.

Results



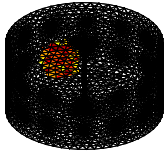
Internal electrodes were used to reconstruct the target closer to actual size.

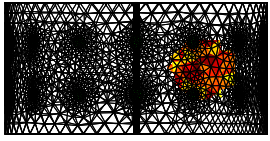
Results

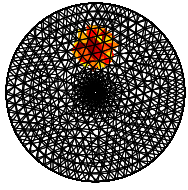


With high sensitivity near the internal electrodes, small internal errors can produce large artefacts.

Introduction



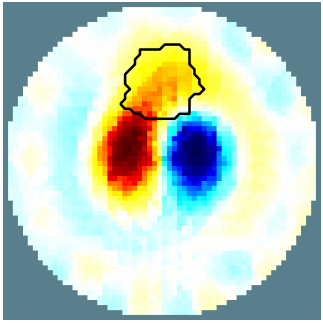




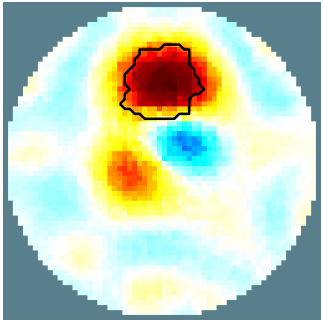
- High sensitivity near the internal probe
- A small amount of movement produces a large artefact

Methods

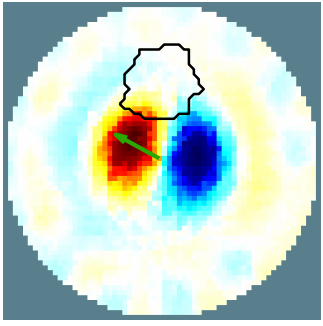
For a probe is moved 5% of the tank radius:



Regular reconstruction



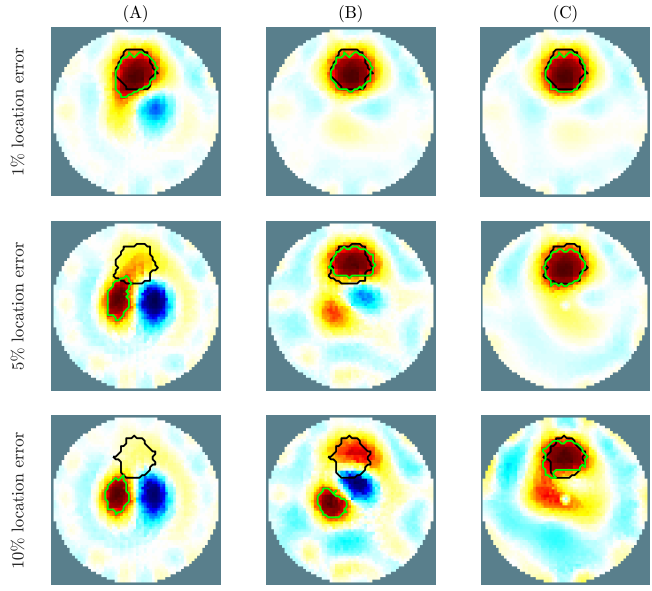
Reconstruction with original motion correction



Reconstructing the effect of motion only

This direction is used to generate a new model for reconstruction

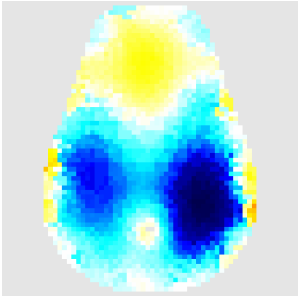
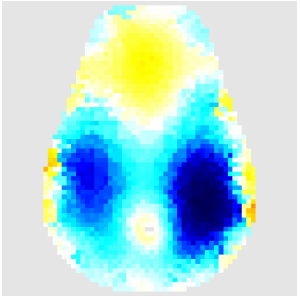
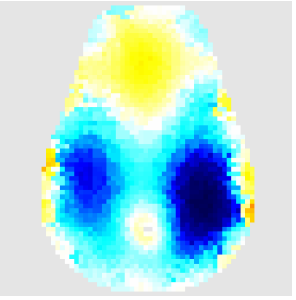
Results



- **A** – No motion correction
- **B** – Regular motion correction
- **C** – Probe position correction

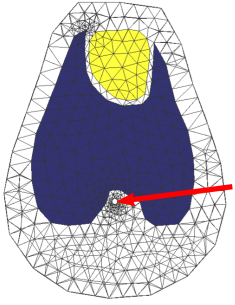
Actual (black) vs. reconstructed (green) target location.

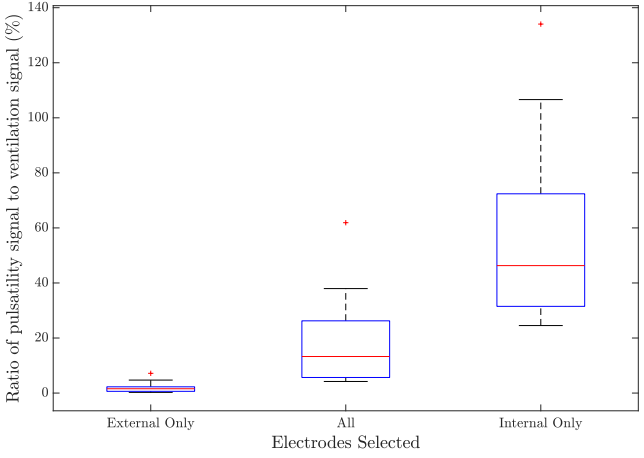
Results

Increased separability of the lungs with regular motion correction (column 2) and probe position correction (column 3)

Results




Ratio of pulsatility signal to ventilation signal (%)
140
120
100
80
60
40
20
0
External Only
All
Internal Only
Electrodes Selected

Summary

This thesis presents:

- Potential for filtering based measures of perfusion imaging
  - limited sensitivity to cardiac frequency
  - challenging to identify the lung regions
- Advanced modelling techniques to improve ventilation and lung localization
- A reconstruction technique used *in-vivo* that was able to correct for probe motion
  - Motion up to 5% of the tank radius in simulation

Current Work

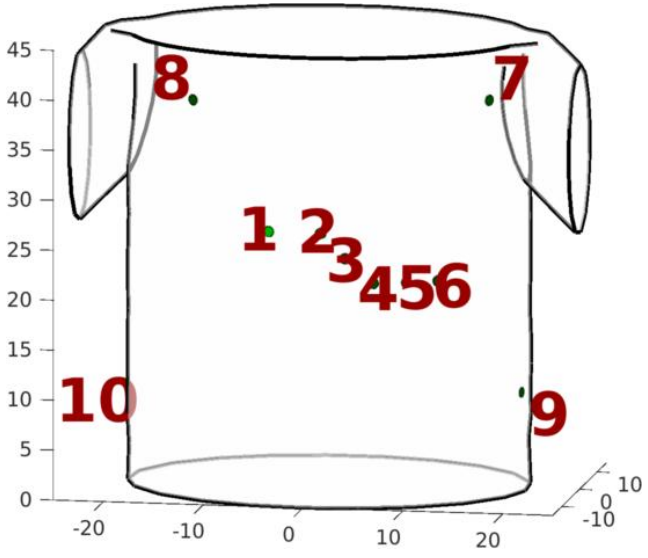
ECG and Bioimpedance

- Many patients have ECG recordings as an assessment of cardiac health
- Electrodes are already in place for ECG recordings
- Bioimpedance measures are also used as a diagnostic tool and imaging modality
- Measure or quantifying blood flow using impedance measurements

What additional insight can bioimpedance measures taken on the ECG electrodes provide?

Current Work
System

Modelling and Simulation



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