Electrical Impedance Tomography for Perfusion Imaging and Monitoring

Thesis Defence Presentation

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Overview

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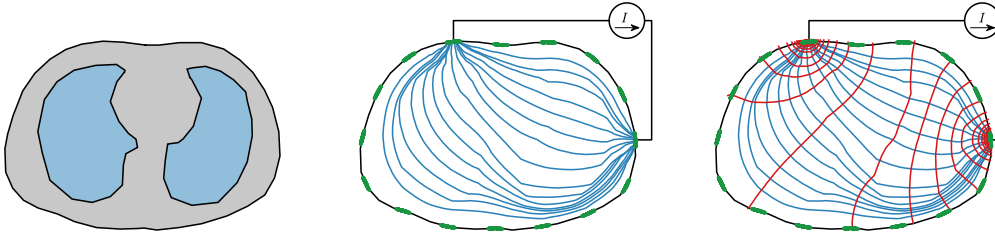
1. Background
2. Thesis Goals
3. Contributions
4. Methods and Results
5. Conclusions
6. Future Work

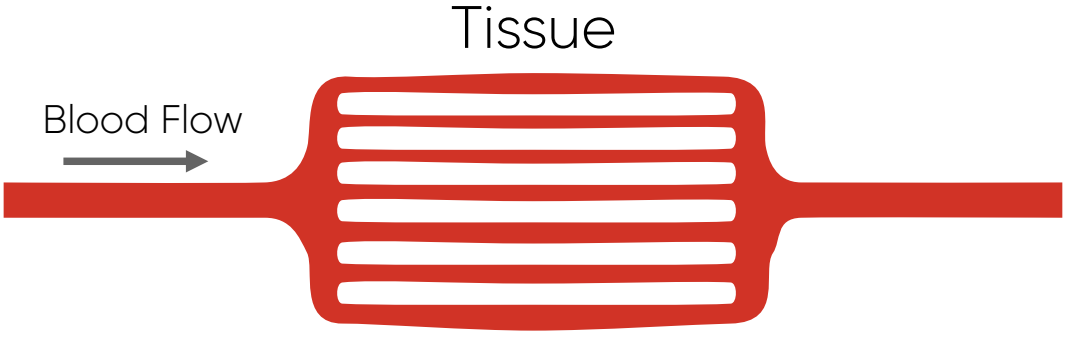
EIT



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

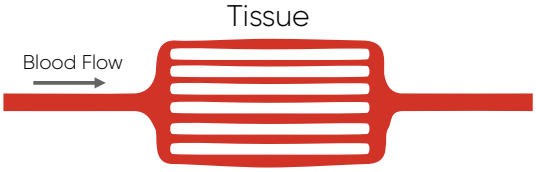
Thoracic EIT typically images impedance changes due to the movement of fluid in the chest.

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
- Pysical 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 or cardiosynchronous signal
- Low amplitude of cardiac-frequency signal
- Low sensitivitiy in the center of a subject

Challenges of EIT Perfusion Imaging

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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:

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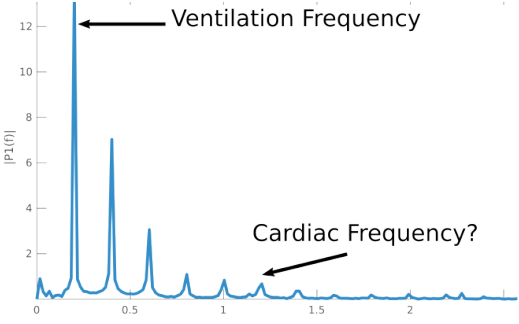
EIT Perfusion Imaging



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

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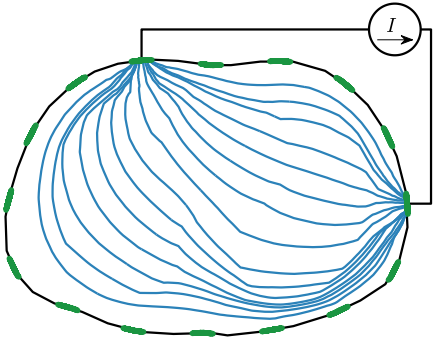
EIT Perfusion Imaging



Sensitivity is proportional to current density.

Challenges of perfusion imaging with EIT:

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Current State of EIT Perfusion Imaging

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Bolus Injection

- A conductive contrast agent is injected
- The transit of the conductive contrast agent is imaged
- Occurs during apnoea
- Saline solution is typically used

Frequency Filtering

- The signal at the cardiac frequency is isolated
- An image of activity at the cardiac frequency is generated
- Can be done during either ventilation or apnoea

Ensemble Averaging

- Many heartbeats are averaged together
- An image of the impedance change over the averaged heartbeat is generated
- Can be done during either ventilation or apnoea

Shortcomings of EIT Perfusion Measures

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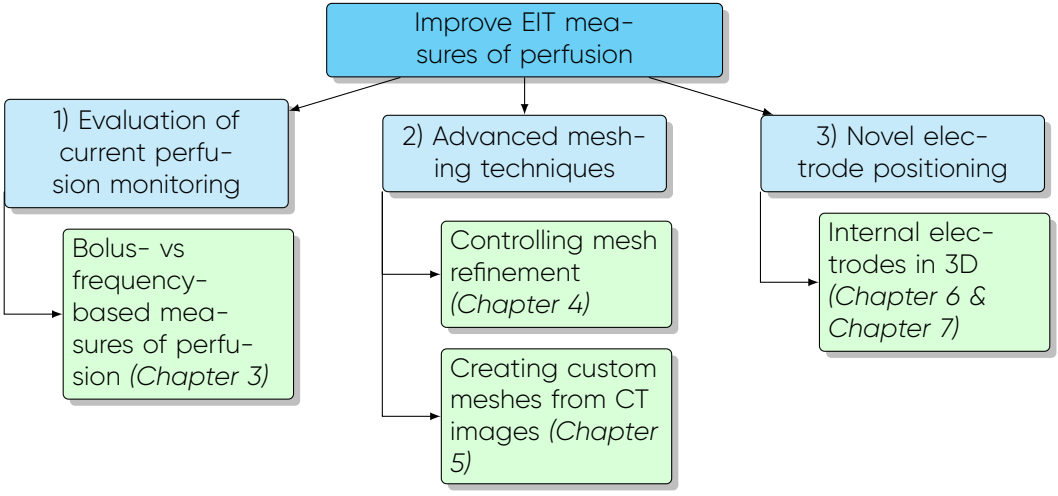
1. Bolus-based measures cannot be used continuously and are invasive
2. Filtering-based methods have low sensitivity to cardiosynchronous activity
3. Low internal sensitivity

How can measures of perfusion be improved?

- Investigate the source of perfusion and cardiosynchronous EIT signals
- Increase sensitivity near where perfusion is measured

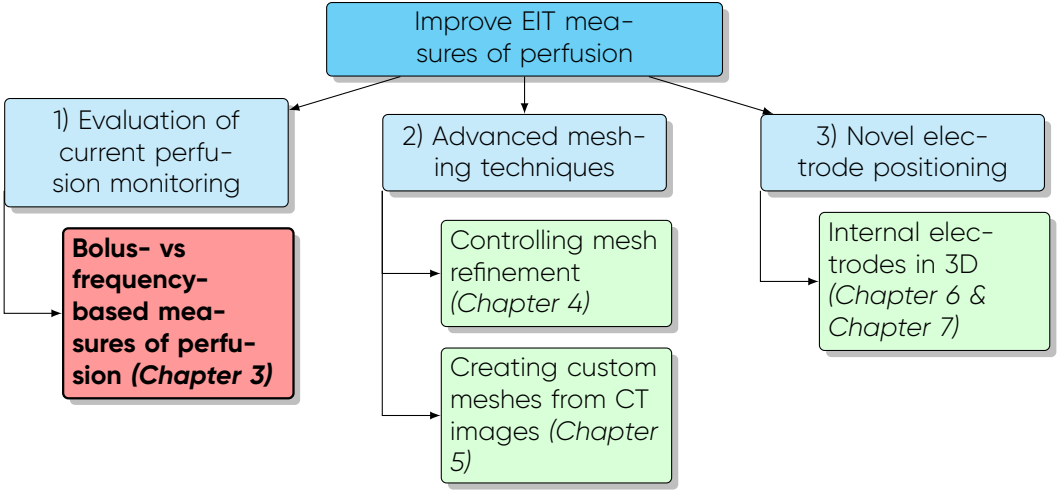
Thesis Goals



Contributions

1. A mesh analysis technique to reduce error in sensitivity calculations on cylindrical meshes (Chapter 4).
2. A tool to generate custom meshes of exterior and lung boundaries from CT images (Chapter 5).
3. An analysis of 3D electrode placements with internal electrodes on internal sensitivity (Chapter 6).
4. A method to reconstruct images using internal electrode measurements in the presence of movement (Chapter 7).

Chapter 3: Bolus- and Frequency-Based Perfusion



Introduction

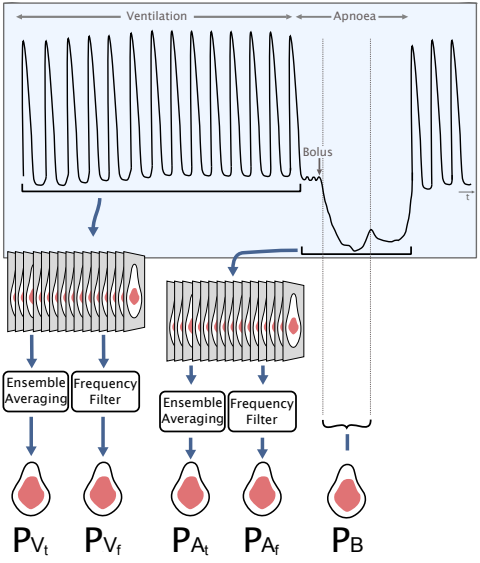
There are three common techniques to measure perfusion with EIT.

1. Bolus injection
2. Frequency filtering
3. Ensemble averaging

Goals

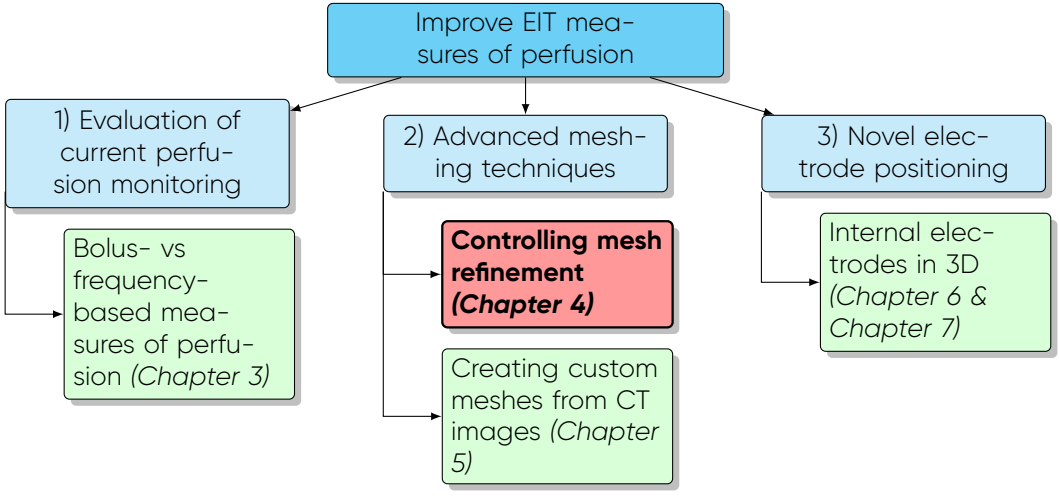
- Compare different measures of perfusion.
- Investigate the source of cardiosynchronous EIT signals.

Chapter 3: Bolus- and Frequency-Based Perfusion Methods

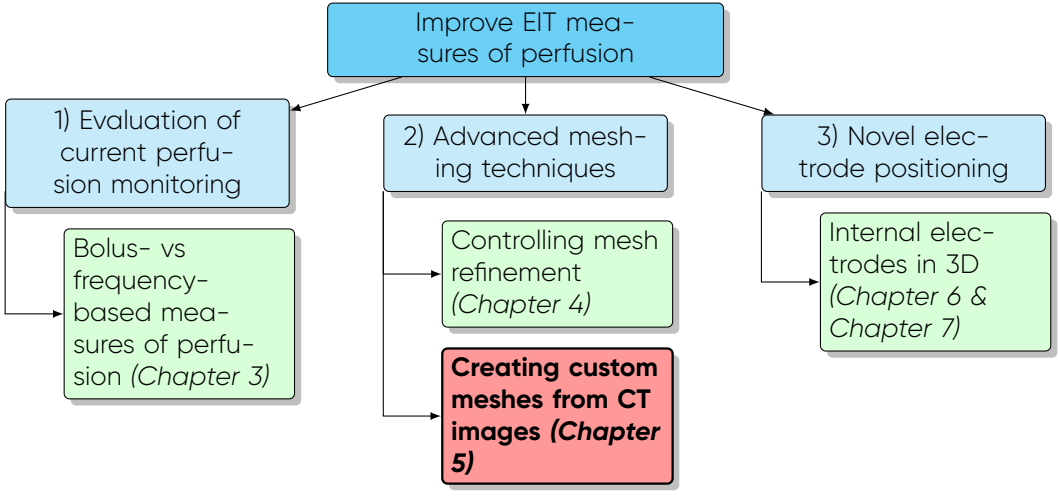


- 7 animals, 4 postures (suppine, left side, right side, prone)
- Frequency filtering (P_V) and ensemble averaging (P_A) methods used during both ventilation and apnoea
- Compated to a bolus injection during apnoea

Chapter 4: FEM Mesh Refinement for 3D EIT



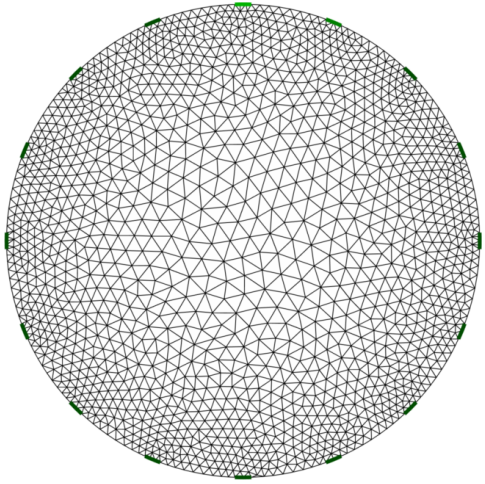
Chapter 5: Custom EIT Meshes



ARDS - Acute Respiratory Distress Syndrome

- Widespread inflammation in the lungs
- Reduces the lungs' ability to exchange oxygen and carbon dioxide
- Can be diagnosed with chest x-ray
- Treated with mechanical ventilation

Finitie Element Models (FEMs) in EIT



- 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 is better

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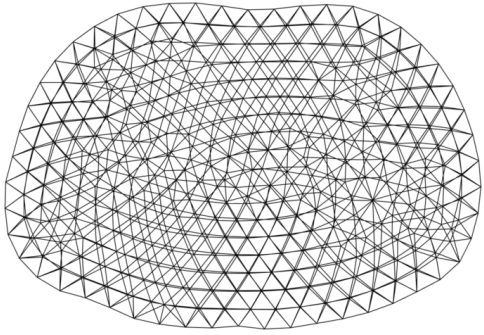

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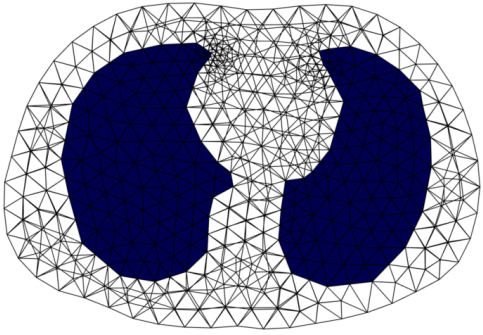

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Motivation

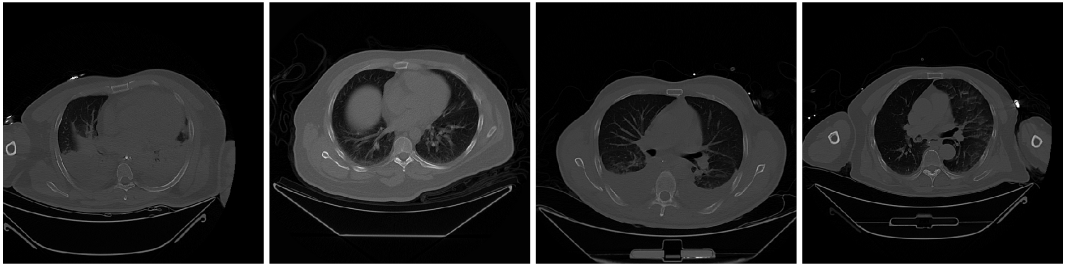
- Often a generic model is used for reconstructions
- True electrode locations and internal geometry is unknown
- With ARDS patients we have information from diagnostic CT images
- More prior information

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

Overview

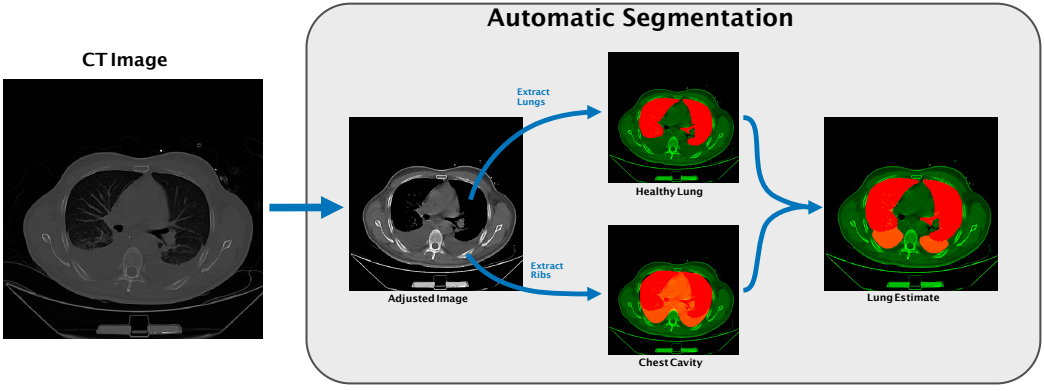
1. Obtain CT images
2. Automatically identify lung regions
3. Present in a GUI for correction by doctors or technicians
4. Generate a FEM based on the corrected segmentation
5. Reconstruct EIT data

CT images

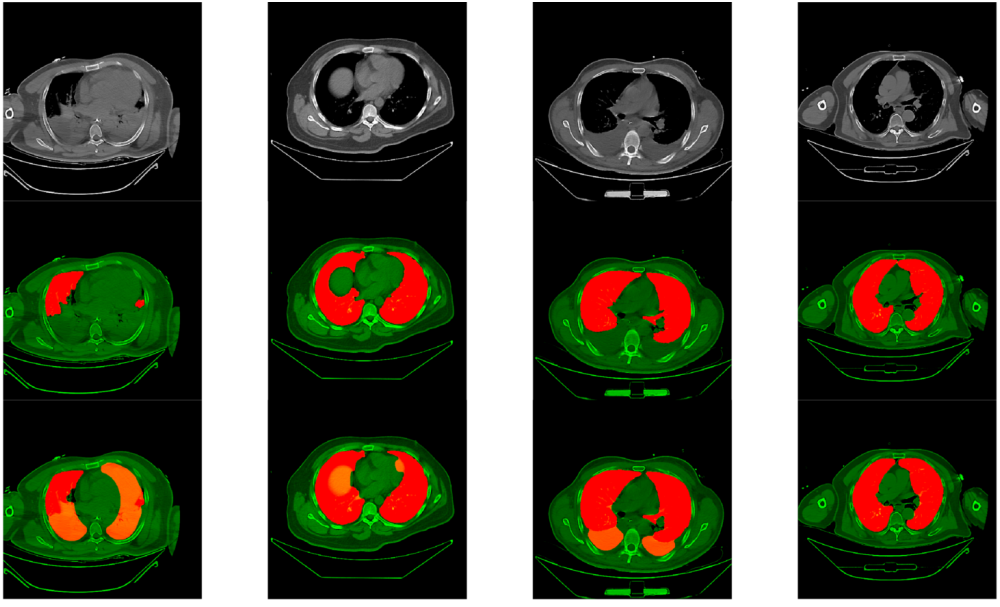


Example images taken from the 4th intercostal space for each subject

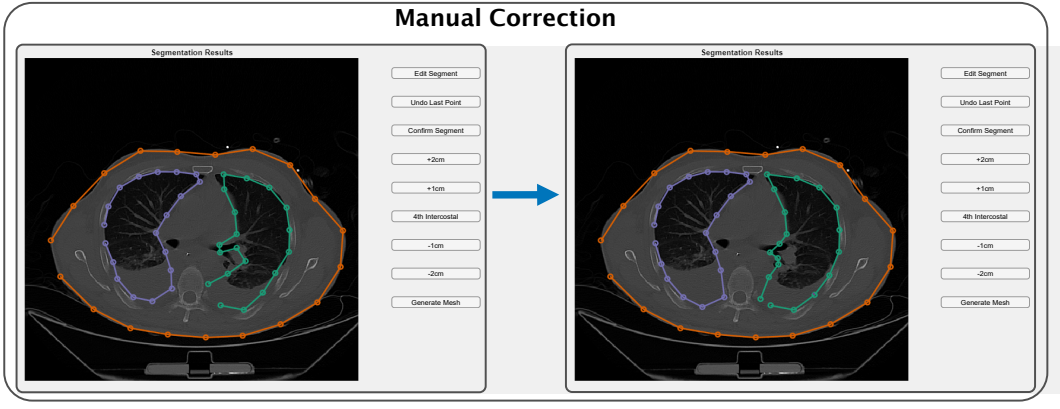
Methods


CT Image
Automatic Segmentation
Extract Lungs
Extract Ribs
Adjusted Image
Healthy Lung
Chest Cavity
Lung Estimate

Segmentation Results

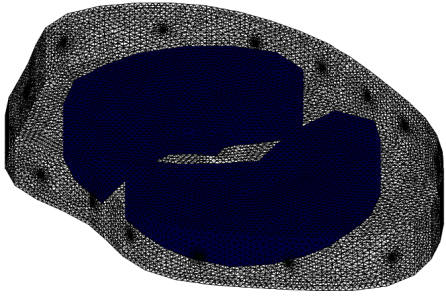


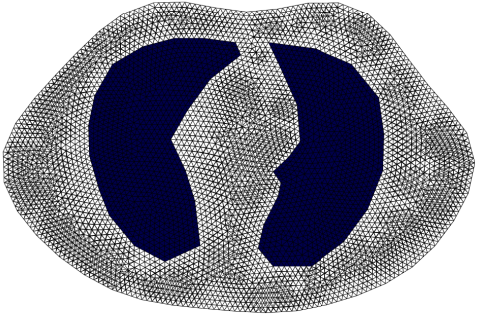
Methods


Manual Correction
Segmentation Results
Edit Segment
Undo Last Point
Confirm Segment
+2cm
+1cm
4th Intercostal
-1cm
-2cm
Generate Mesh
Segmentation Results
Edit Segment
Undo Last Point
Confirm Segment
+2cm
+1cm
4th Intercostal
-1cm
-2cm
Generate Mesh

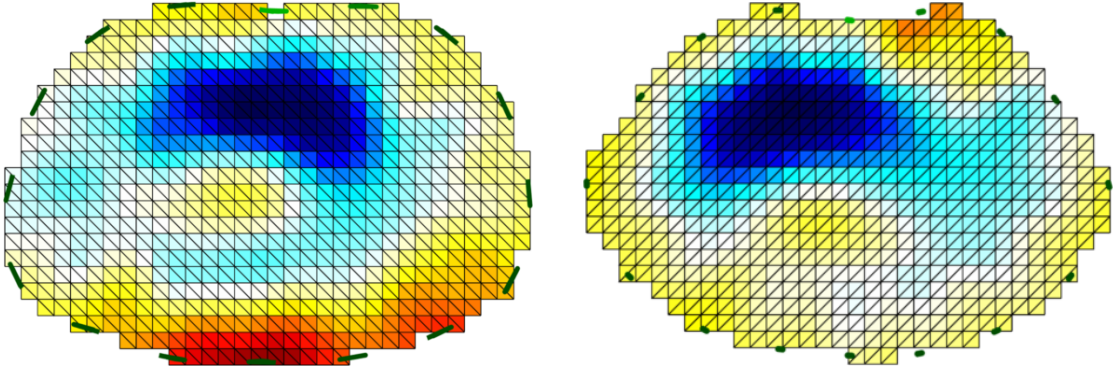
Methods

Mesh Generation



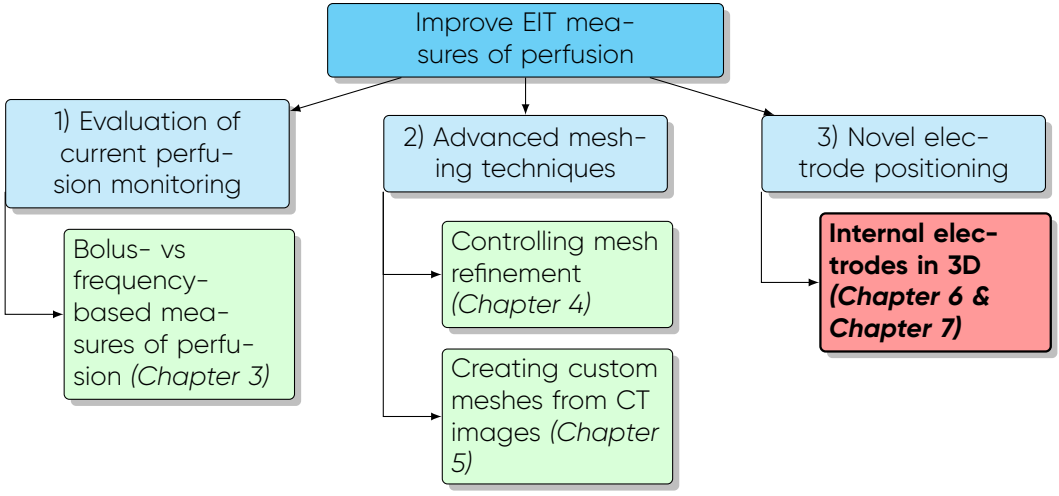


Preliminary Results

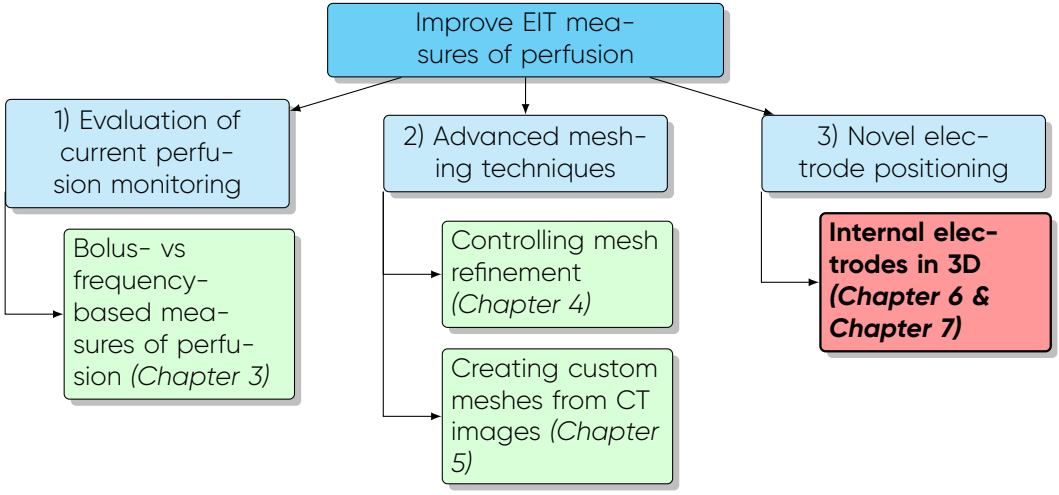


An average breath imaged for two FEMs

Chapter 6: Internal Electrode Sensitivity



Chapter 7: Internal Electrode Motion



Current Work

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Improvement

- Apply the segmentation to larger numbers of patients
- Create a more user friendly editing pgoram to accelerate segmentation and meshing
- Create a database of meshes that can be applied to additional subjects

Validate the use of custom meshes for ARDS monitoring

Do patient specific meshes:

- improve on generic meshes for ARDS monitoring?
- give increased accuracy in measures of lung collapse and fluid movement?
- Improve detection of collapse and overdistention

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