GERMAN
CANCER RESEARCH CENTER

Carleton UNIVERSITY

Asymmetries in EIT Lung Images

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Introduction

The clinical reality:

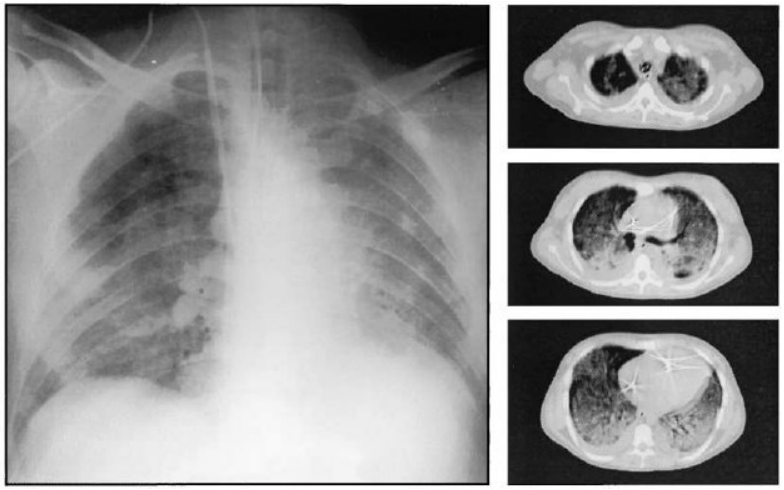

Figure: A patient with ARDS [3]

- Lungs are non-conductive and heterogeneous
- Heart is conductive and off-centre
- Ventilation is preferential to central and ventral regions

Introduction

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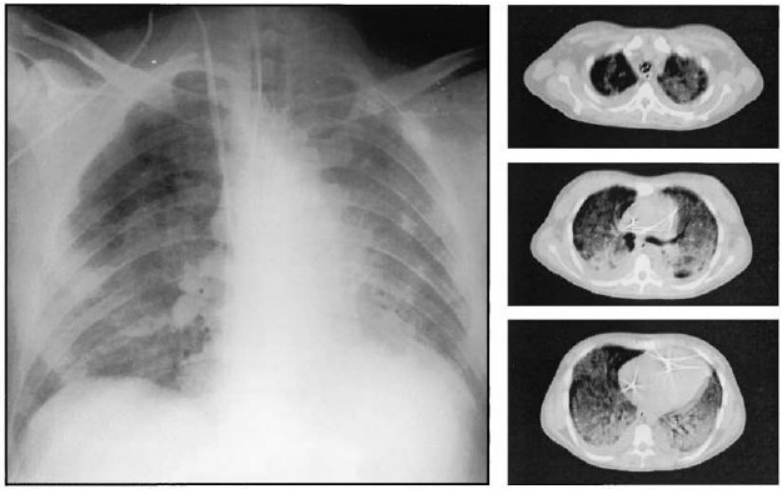

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- Ventilation is preferential to central and ventral regions

EIT simplification:

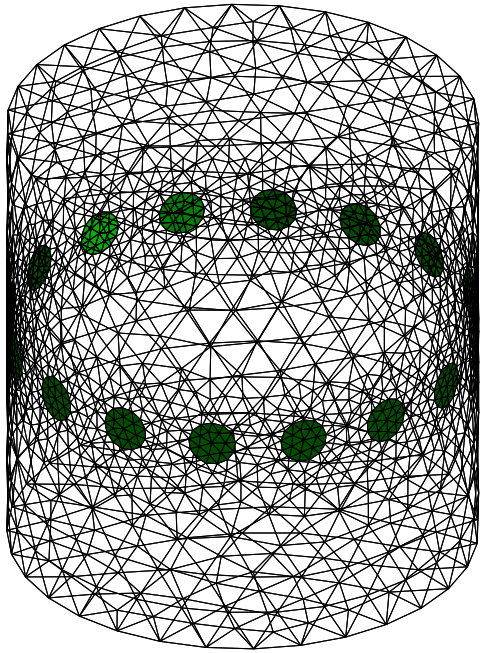


Figure: A typical FEM used for forward modelling

- A homogeneous cylinder

Falsely asymmetric lung images

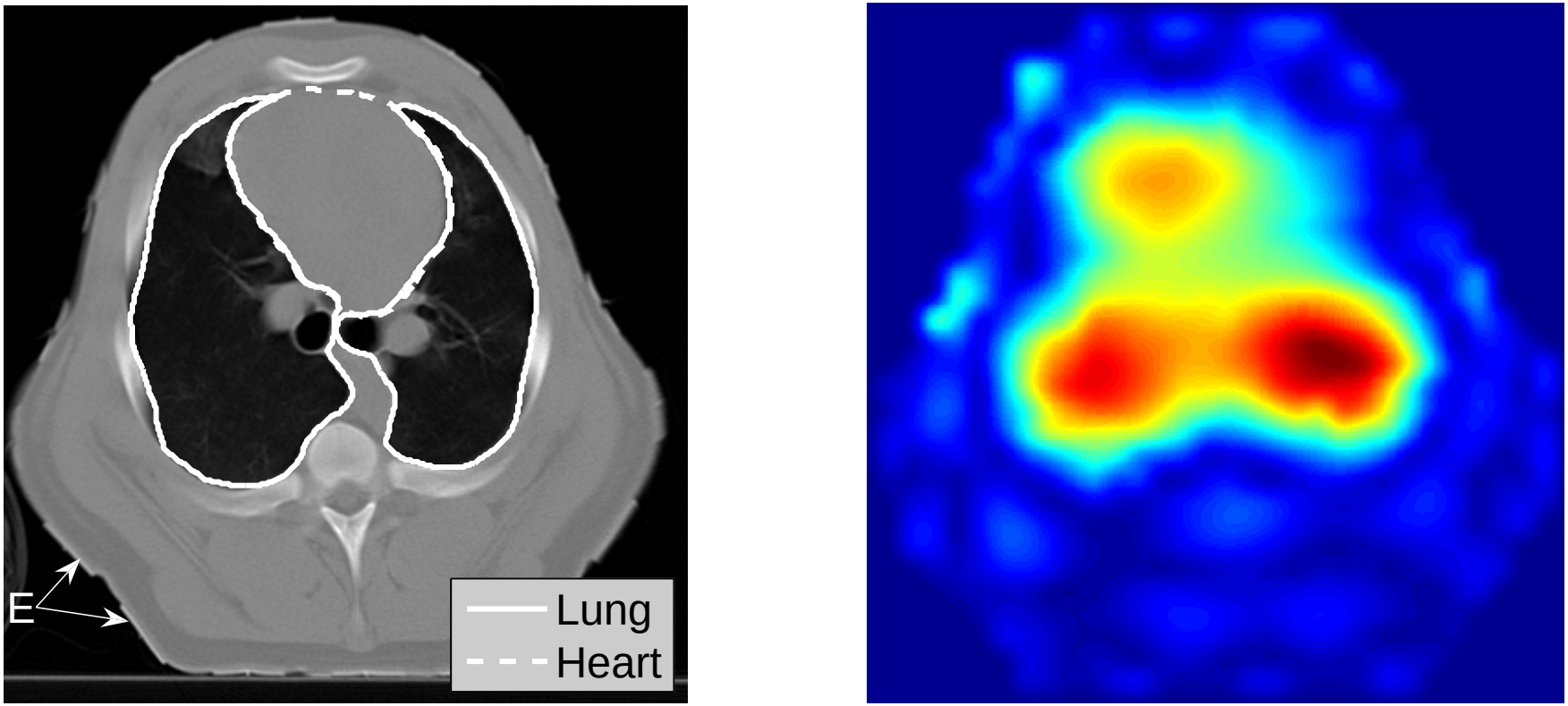
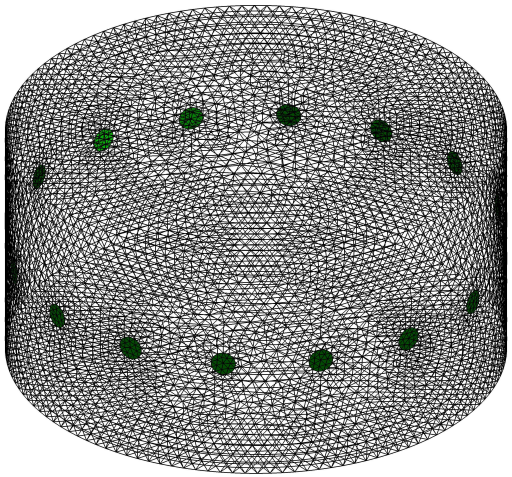


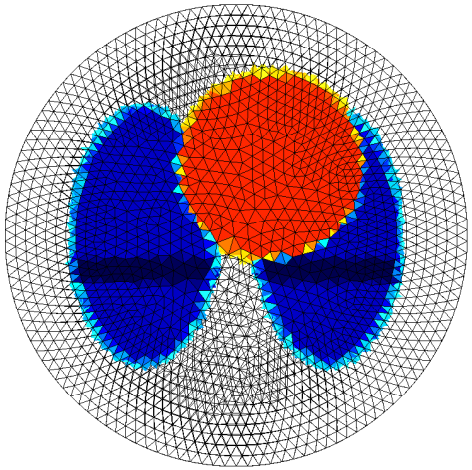
Figure: EIT reconstruction of ventilation in a healthy swine [2]

- Why is ventilation stronger in the left lung?

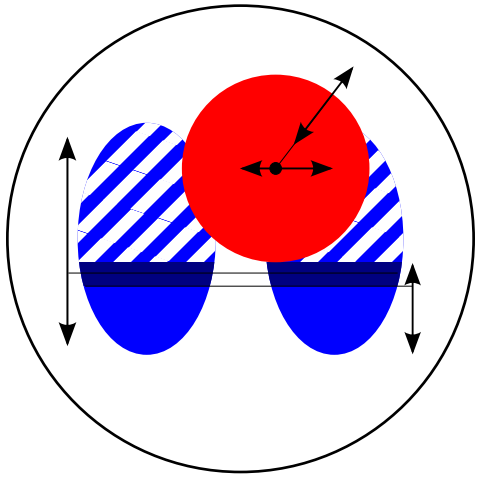
Methods



(a)



(b)



(c)

Figure: Simulation models:(a) FEM used for simulations; (b) FEM with tissue conductivity values (top view); (c) parameters varied in the experiments.

- Cylindrical model with 16 electrodes
- Difference EIT (GREIT [1])
- EIDORS 3.5

Reference setup

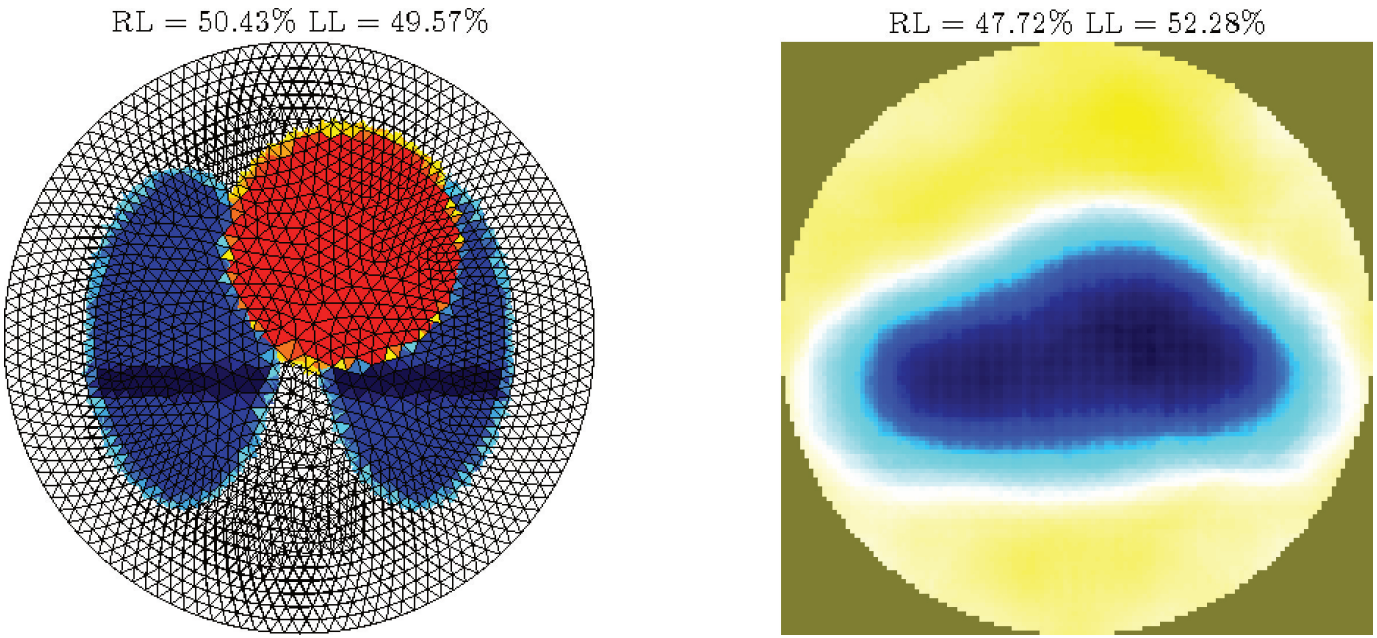
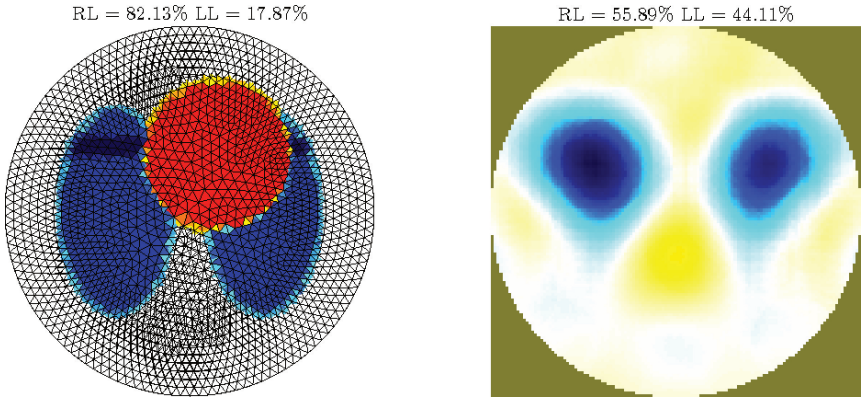


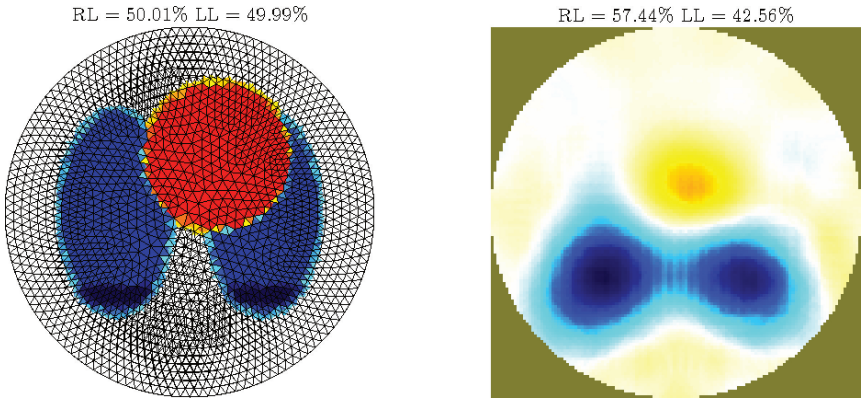
Figure: Reconstruction of a symmetric ventilation distribution.

$$\Delta = \frac{L_{\text{sol}} - R_{\text{sol}}}{L_{\text{sol}} + R_{\text{sol}}} - \frac{L_{\text{sim}} - R_{\text{sim}}}{L_{\text{sim}} + R_{\text{sim}}} = 4.44\%$$

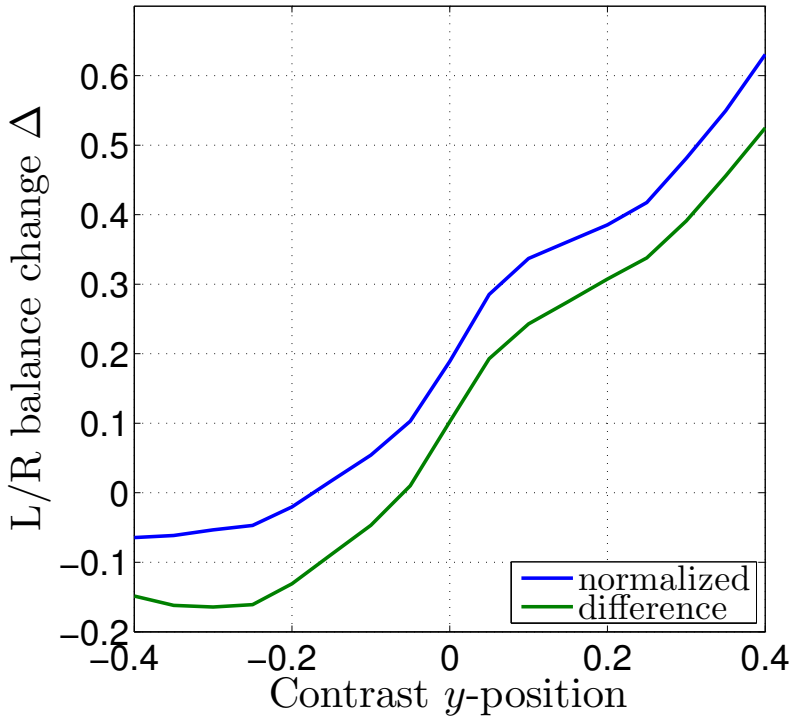
Selected tests: Contrast location



(a) $\Delta = 52.48\%$



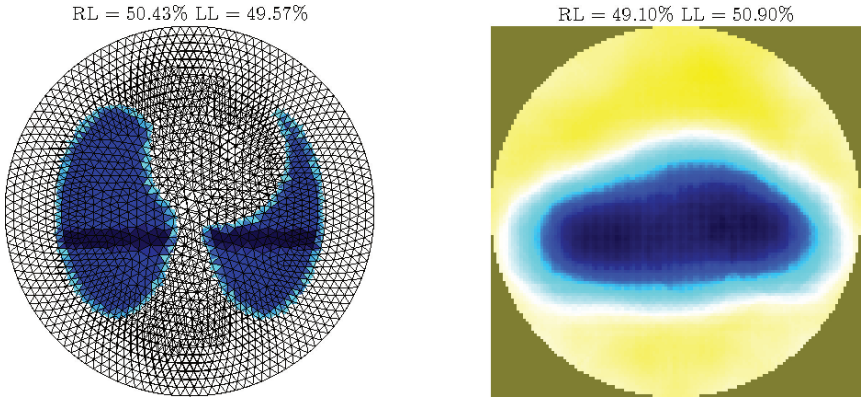
(b) $\Delta = -14.86\%$



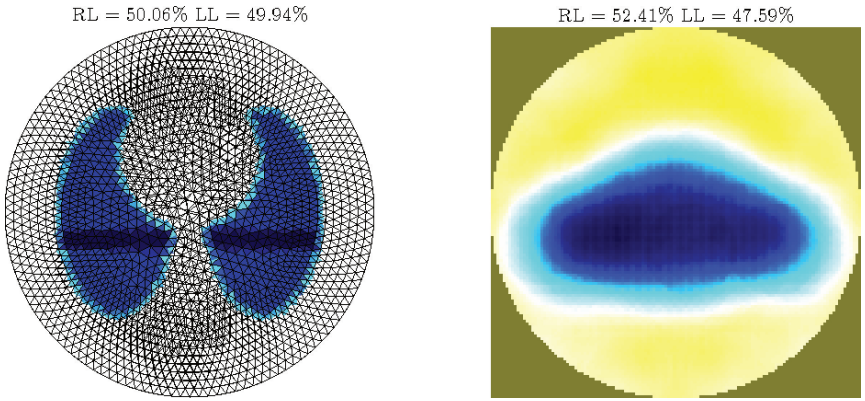
(c)

Figure: Deviation in left-right balance Δ as a function of vertical position of the contrast (positive in ventral direction).

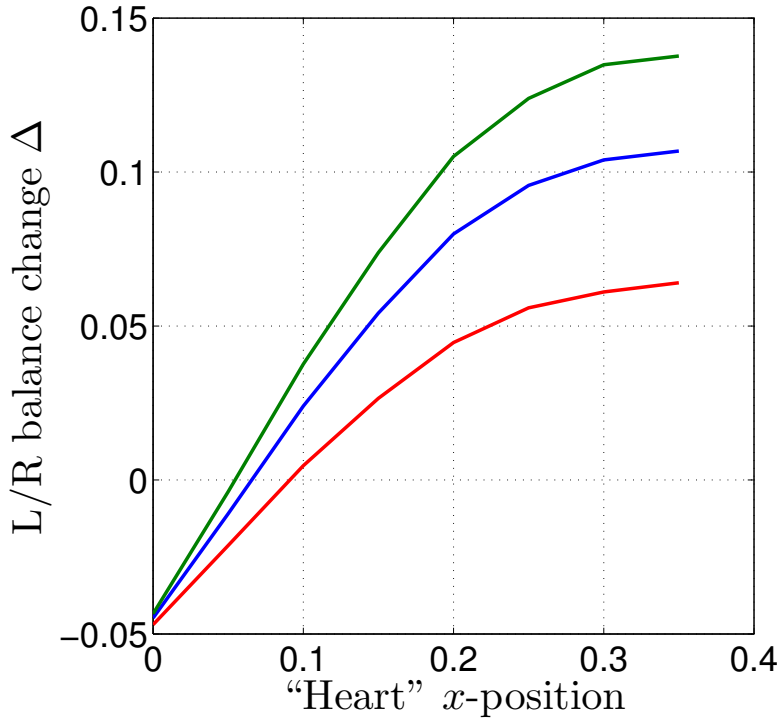
Selected tests: Heart conductivity and lung shape



(a) $\Delta = 2.66\%$



(b) $\Delta = -4.70\%$



(c)

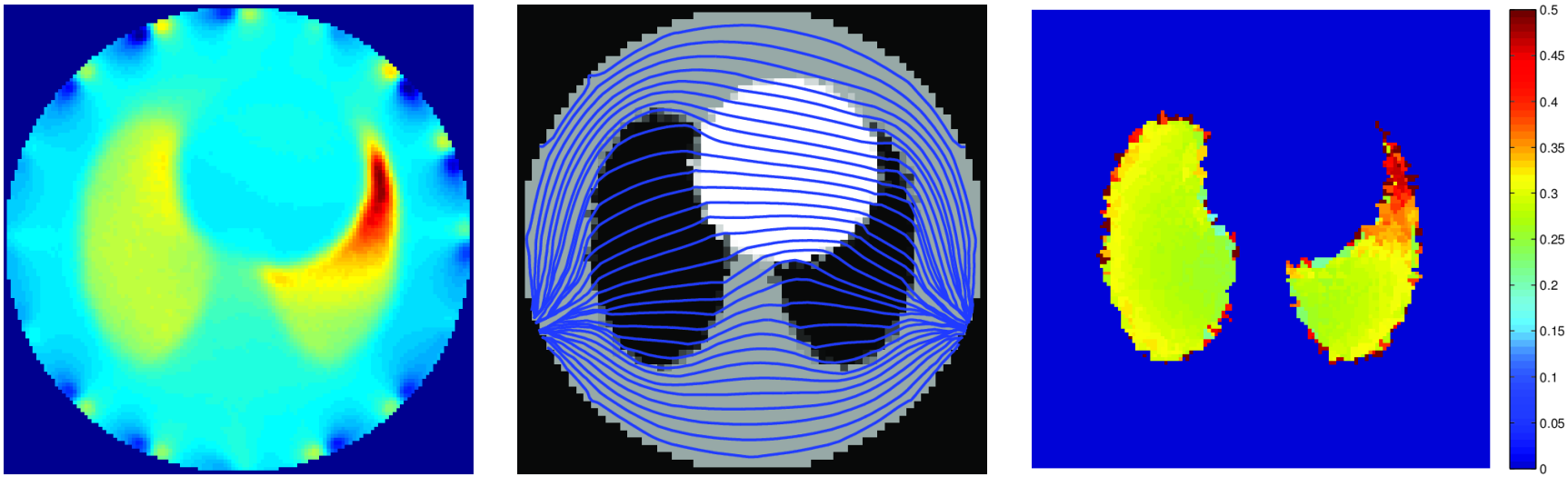
Figure: Deviation in left-right balance Δ as a function of lateral heart position for heart-to-background conductivity ratios of 1.0 (red), 1.5 (blue) and 2.0 (green).

Test summary

The effect of falsely asymmetric lung EIT images is ...

- present in both difference and normalized difference EIT
- primarily caused by the difference in shape of the two lungs
- increased by a bigger or more conductive heart
- most pronounced for conductivity changes in the ventral part of the lung
- independent of the current injection pattern

Causes

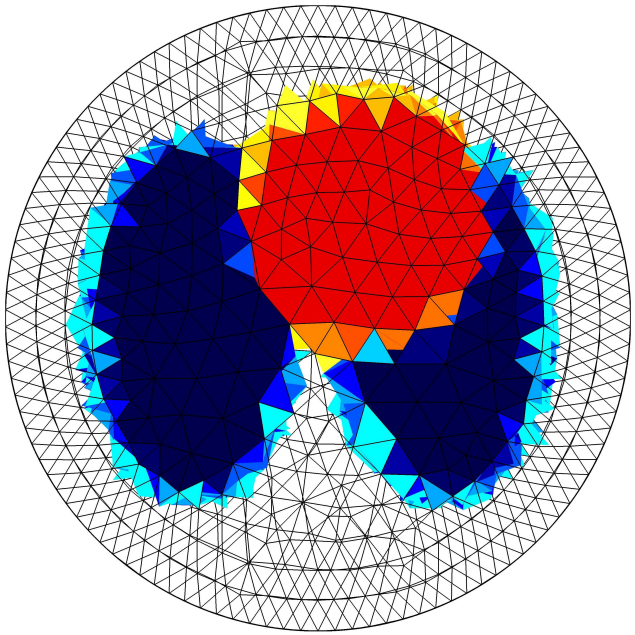


(a) Sensitivity map (b) Current streanlines (c) Current density

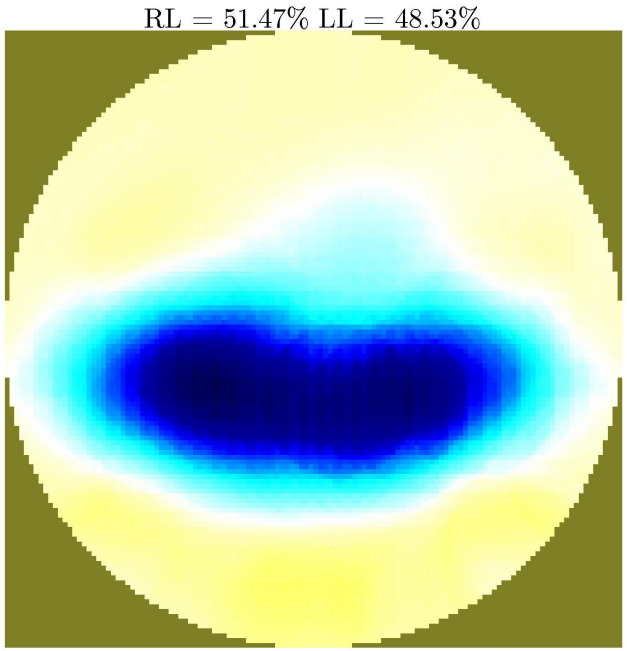
Figure: Sensitivity and current distribution in the model.

- More current flows through the left lung (lower resistance along path)
- but the forward model used for reconstruction is homogeneous !!

Forward model with true conductivity prior



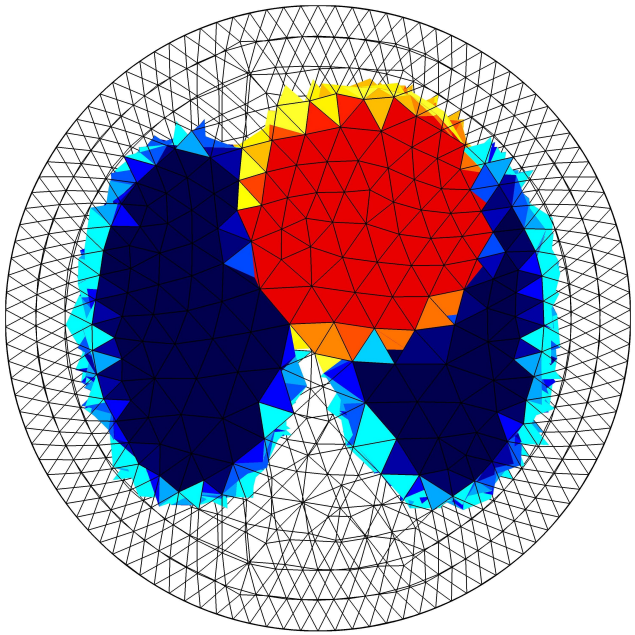
(a) Conductivity prior



(b) Reconstructed image

Figure: Reconstruction of data from reference setup with true conductivity background. $\Delta = -2.08\%$

Forward model with true conductivity prior



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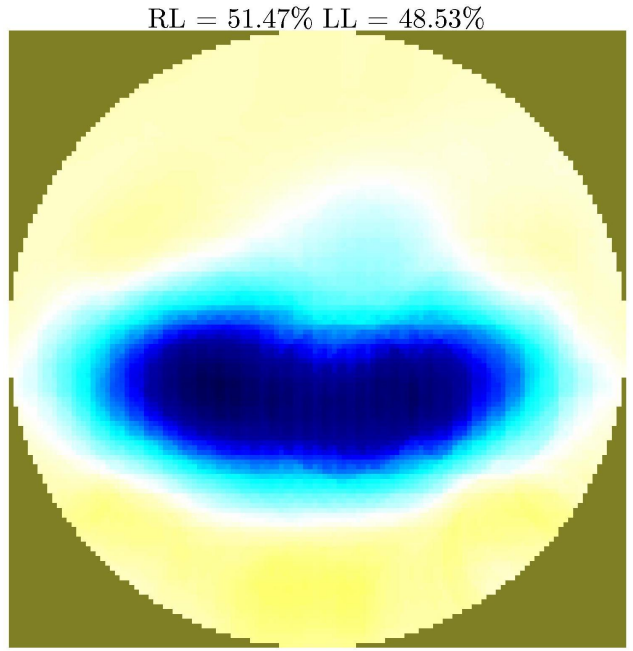

(b) Reconstructed image

Figure: Reconstruction of data from reference setup with true conductivity background. $\Delta = -2.08\%$

But this is only a partial solution !!
Equal changes in more conductive areas will still produce a stronger signal.

Implications

- Ventilation-induced impedance changes in the left lung may be habitually overestimated
- The effect is particularly strong for the kind of ventilation distribution expected in mechanically ventilated patients
- Including a conductivity prior offers significant improvement, but no real solution
- **It is impossible to separate ventilation and mean aeration in difference EIT** even when only tidal differences are considered.

Thank You!

Questions?

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