

Electrical Impedance Tomography

EIT and animals: from subject to patient

Conf. EIT 2024, Hangzhou, China

Andy Adler

Carleton University, Ottawa, Canada

2024-06-29

Biomedical Applications of Electrical Impedance

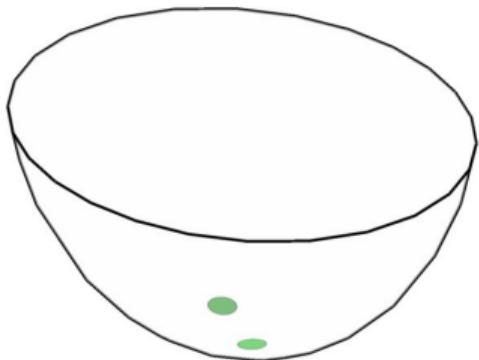
Biomedical Applications of Electrical Impedance

[1]



¹Fisher-Price Cheer for Me! Potty, toddler toilet training seat with music and sounds

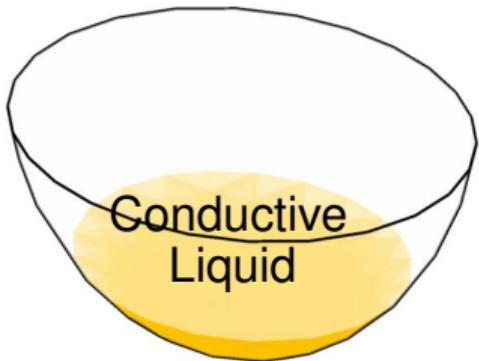
Biomedical Applications of Electrical Impedance



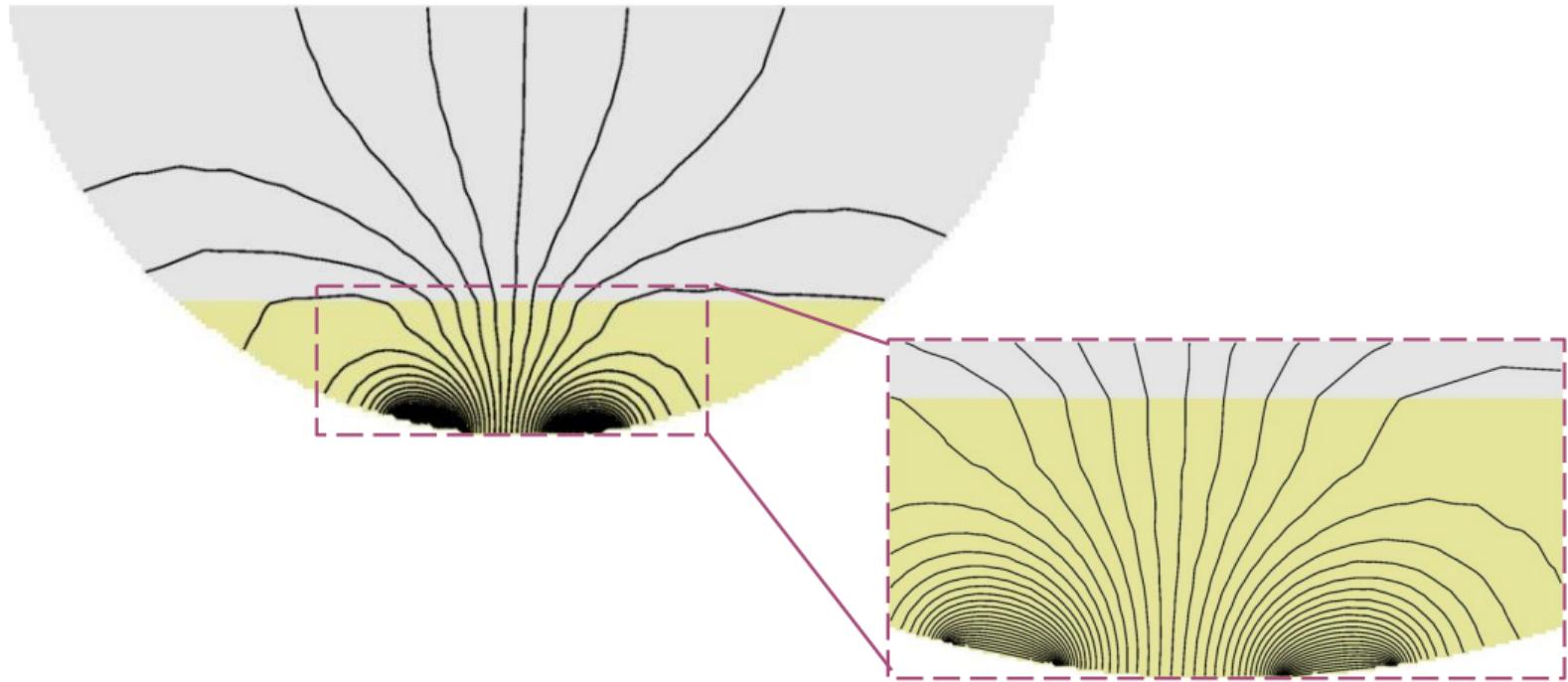
Biomedical Applications of Electrical Impedance



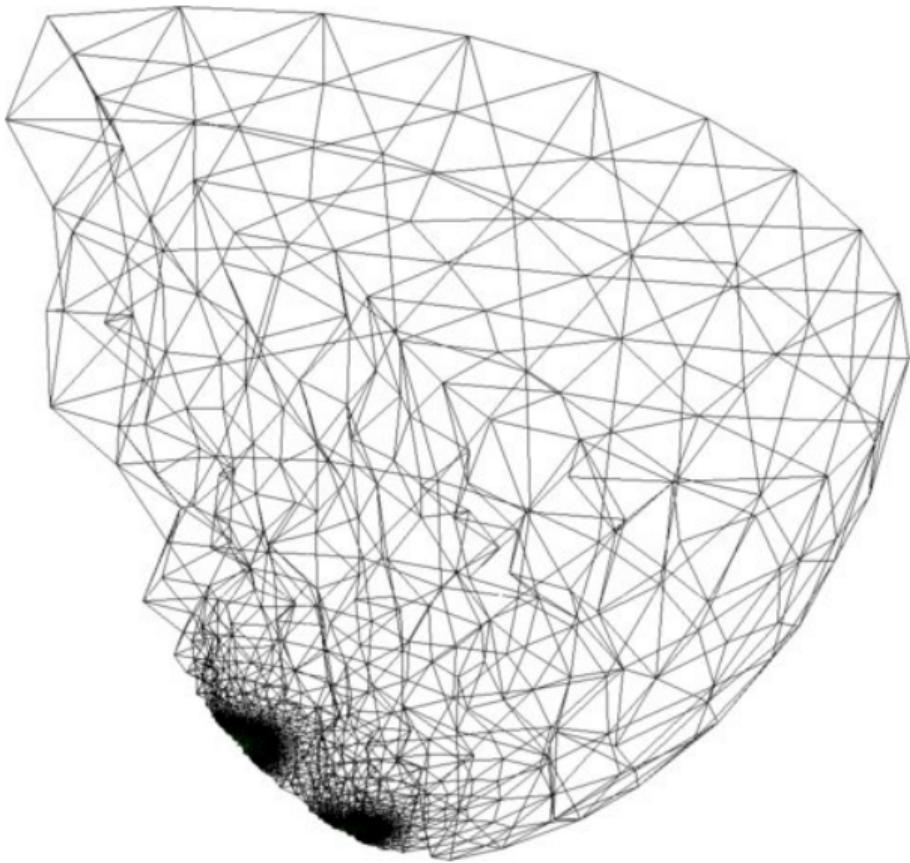
Biomedical Applications of Electrical Impedance



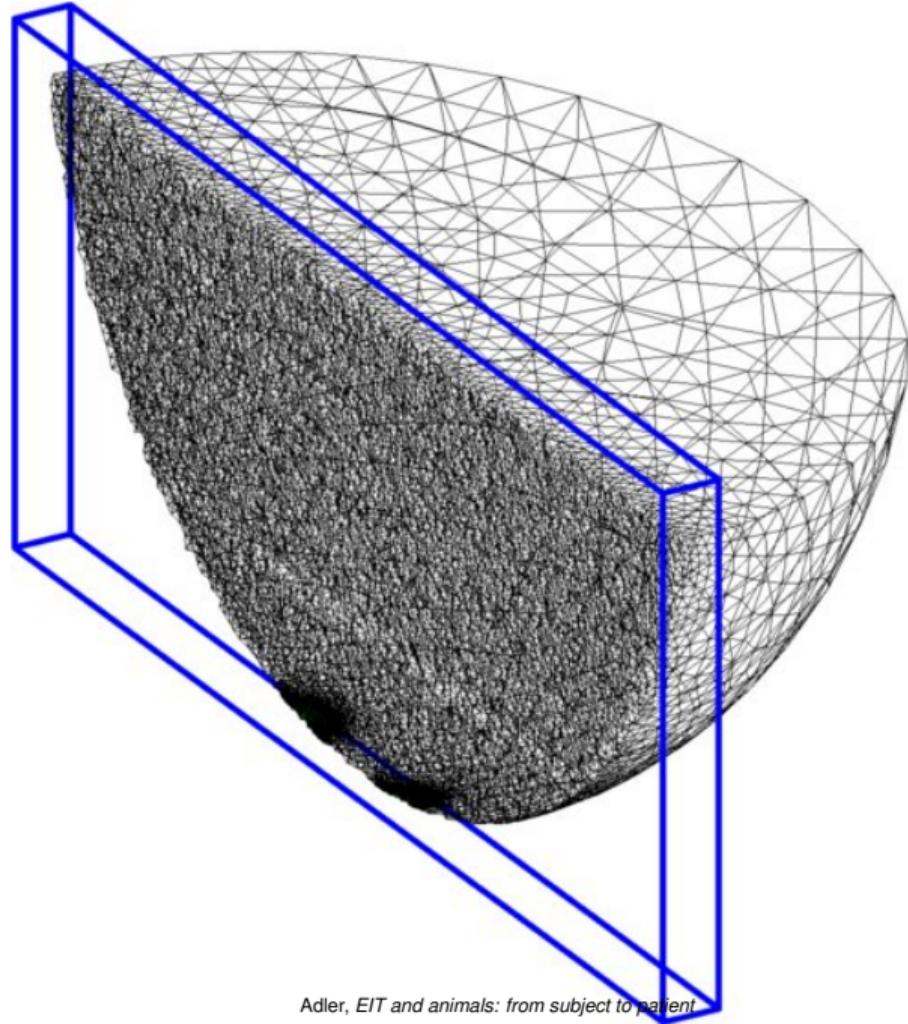
Electrical current flows between electrodes



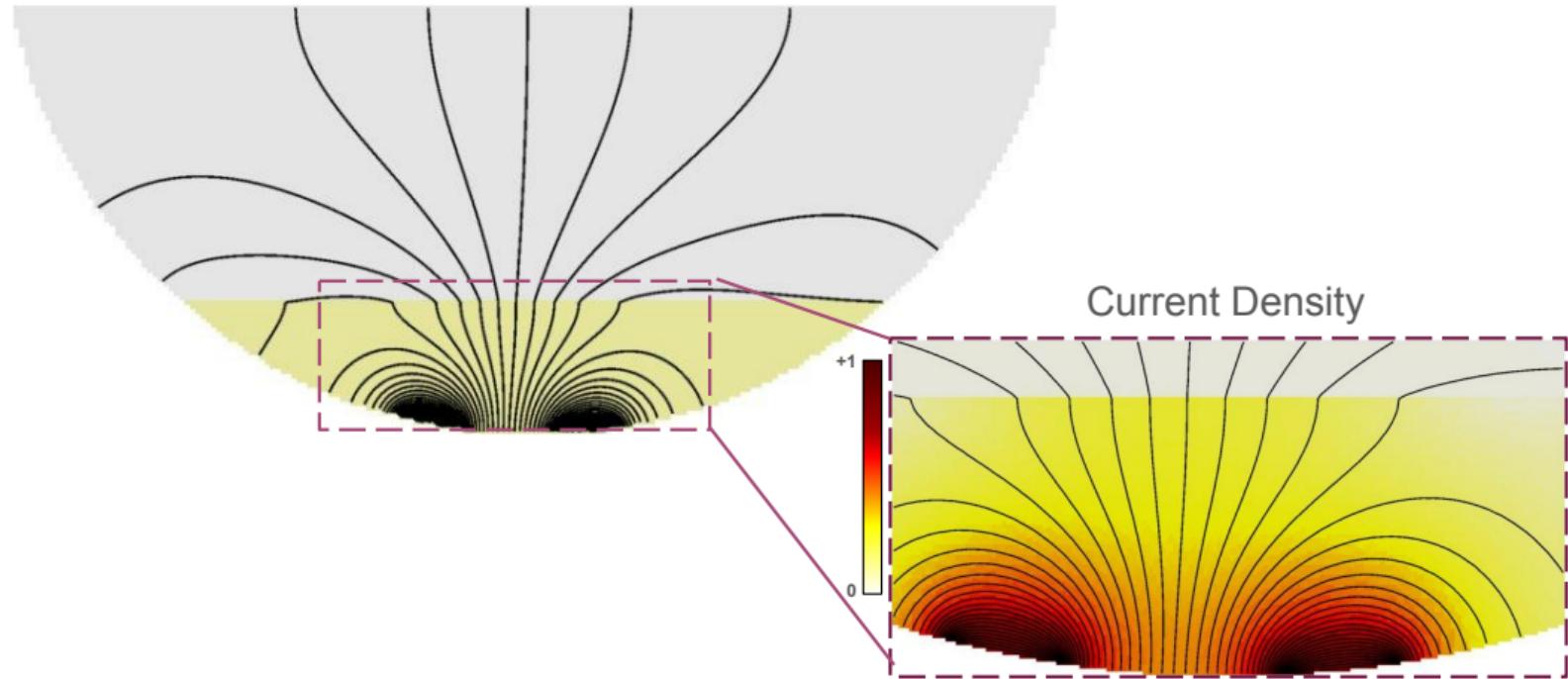
Why so ugly?



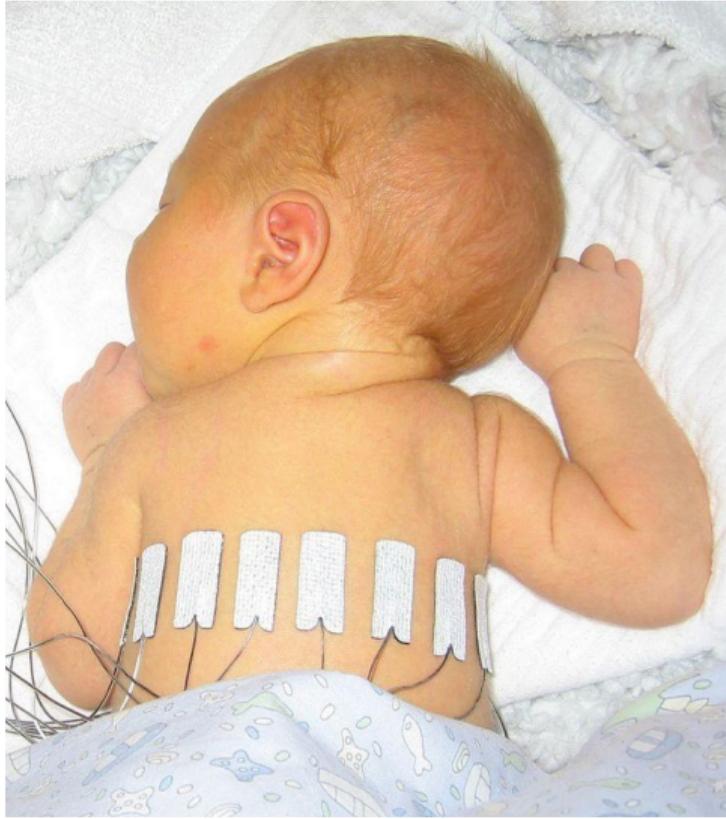
Better FEM model:
use 500k elements
(up from 5k)



Electrical current density and equipotentials between electrodes (v2)



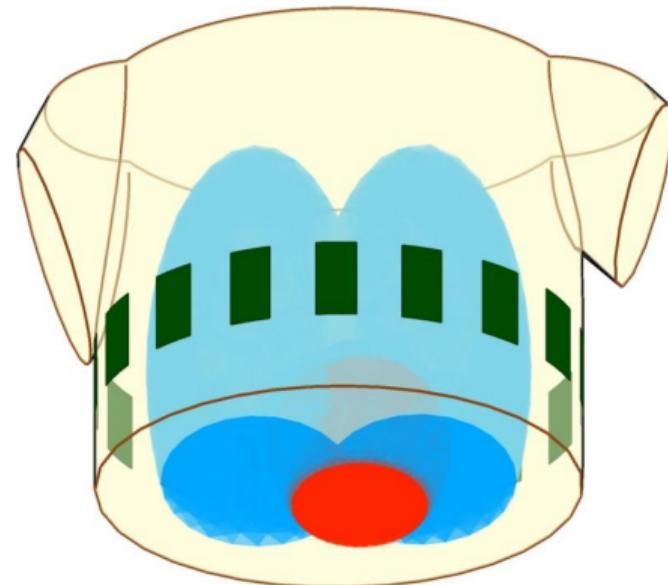
EIT: “Wikipedia” baby



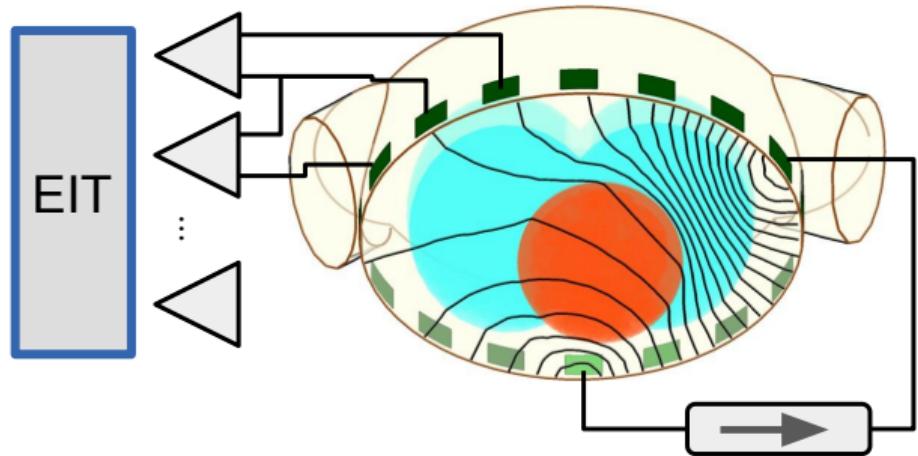
[1]

²Heinrich *et al* (2006) Body and head position effects on regional lung ventilation in infants . . . Int Care Med 32:1392–1398

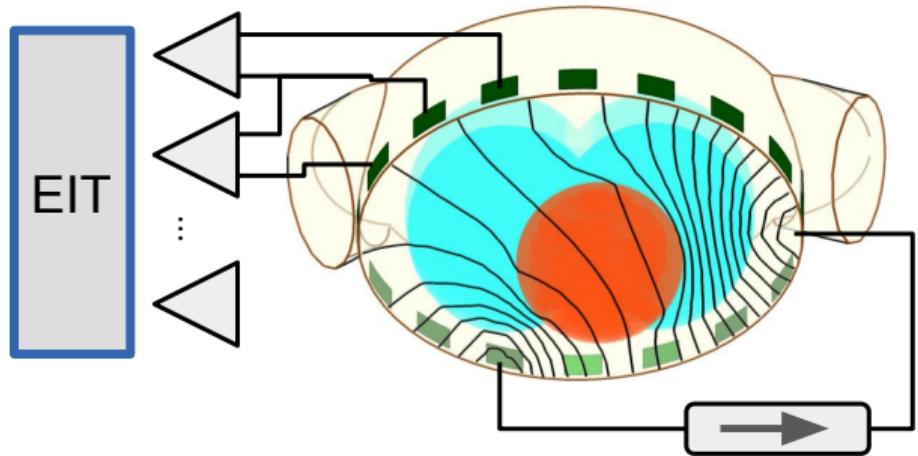
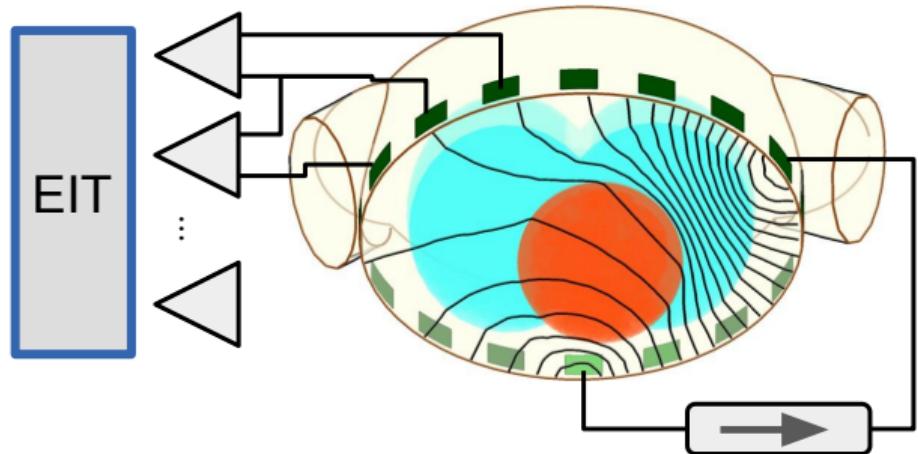
EIT and Body Model



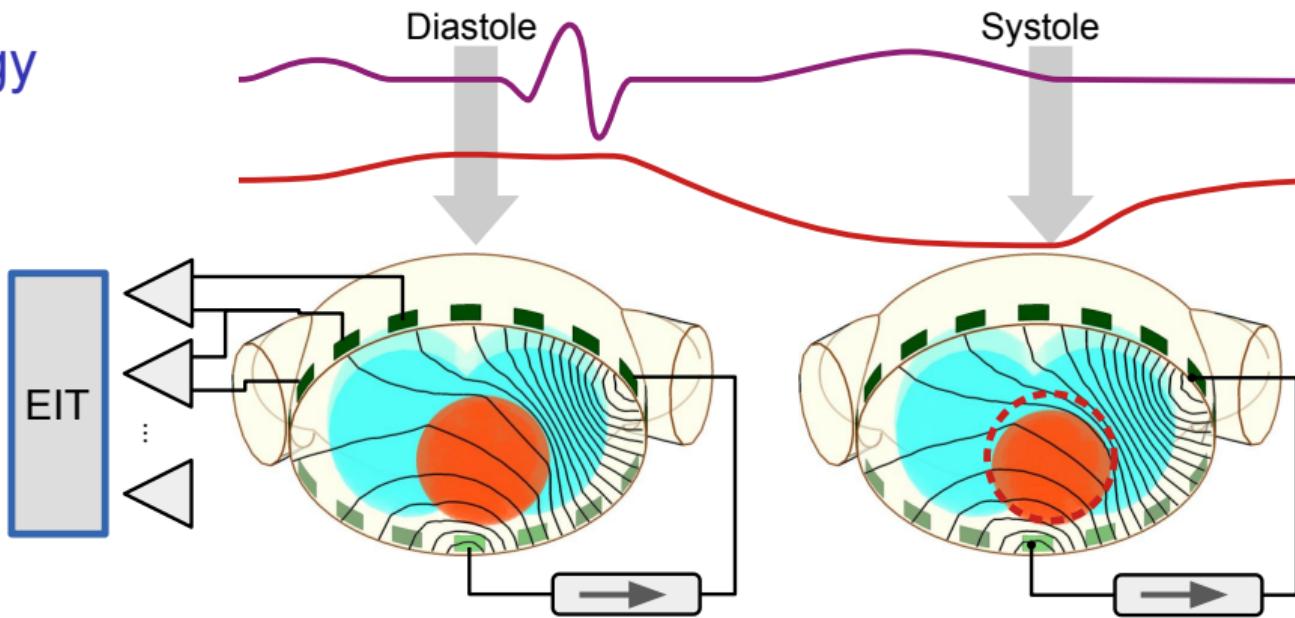
EIT: apply current
and measure voltages



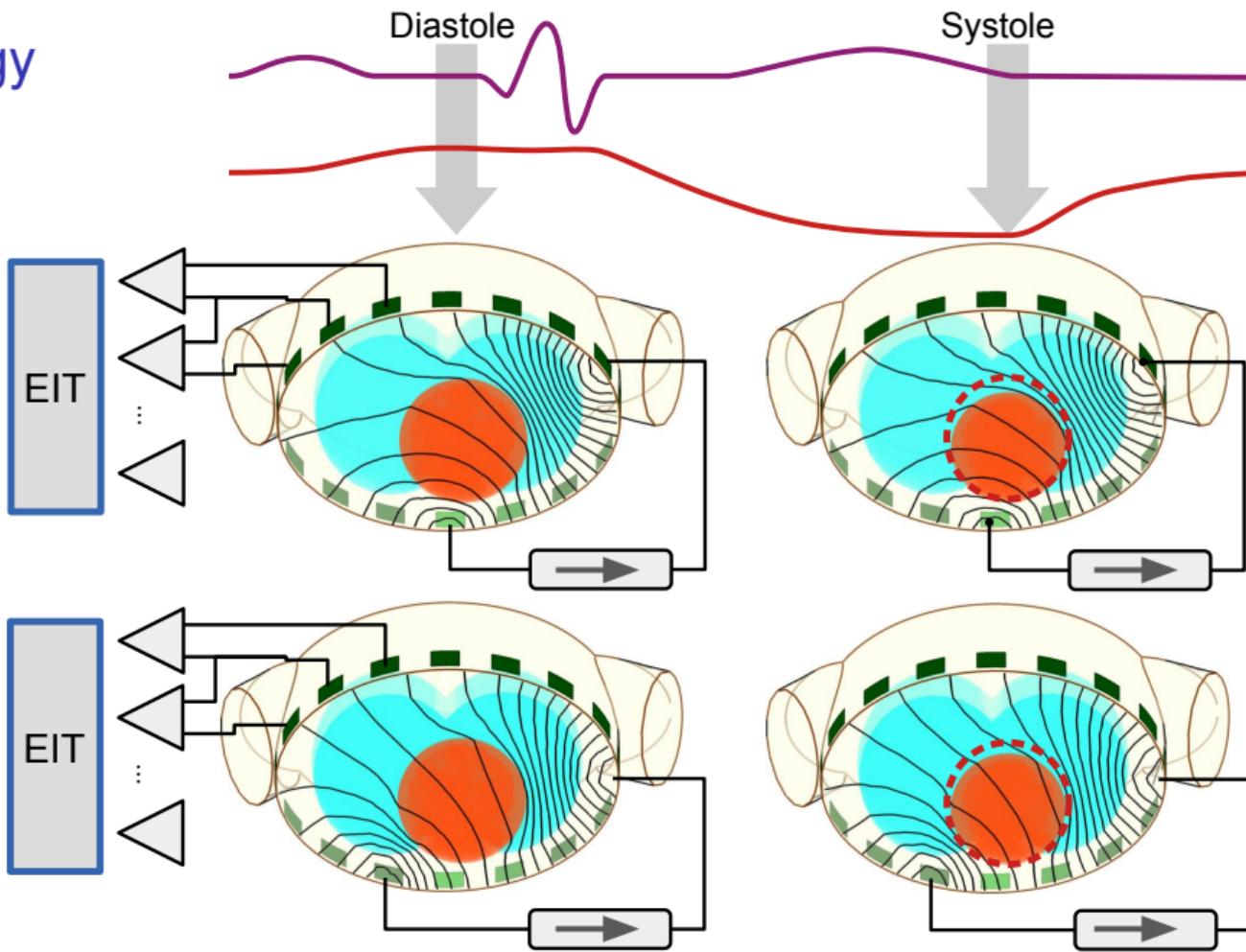
EIT: apply current
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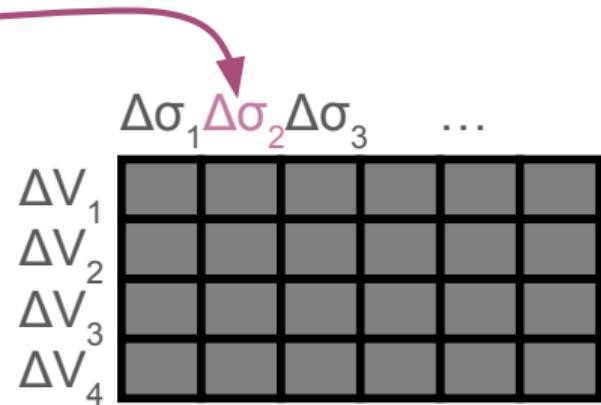
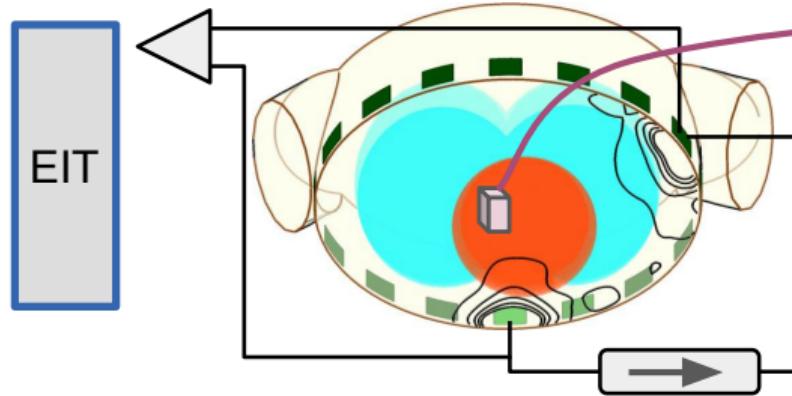
EIT: Physiology



EIT: Physiology

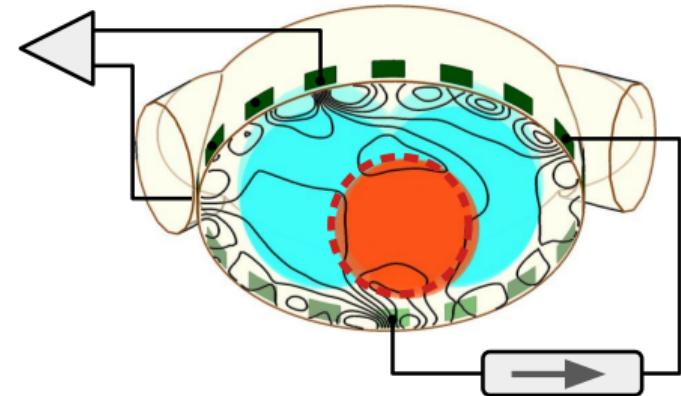
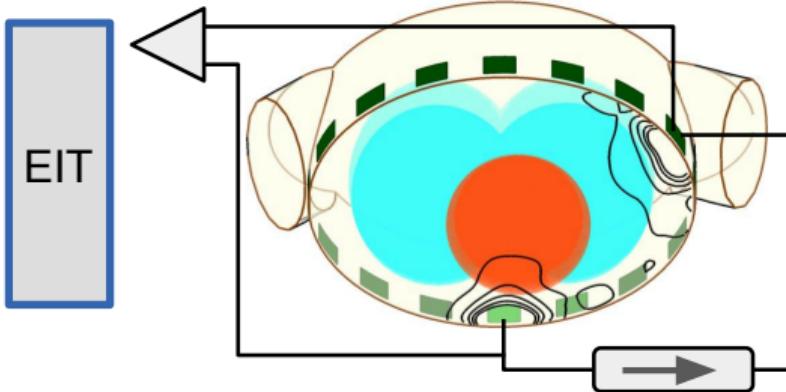


EIT Sensitivity



Jacobian
(Sensitivity)

EIT Sensitivity



EIT Sensitivity

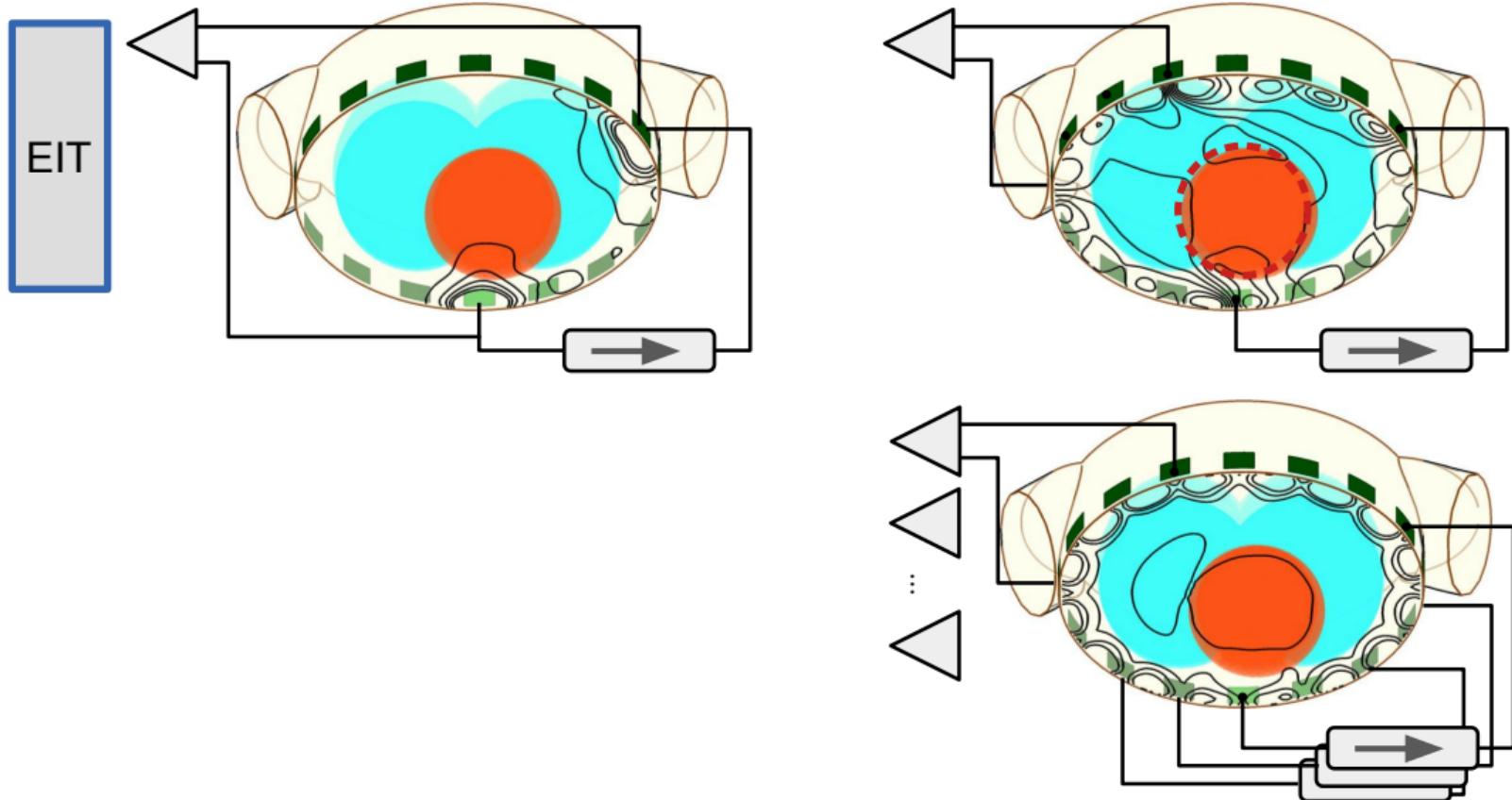


Image Reconstruction: Concept = Optimization

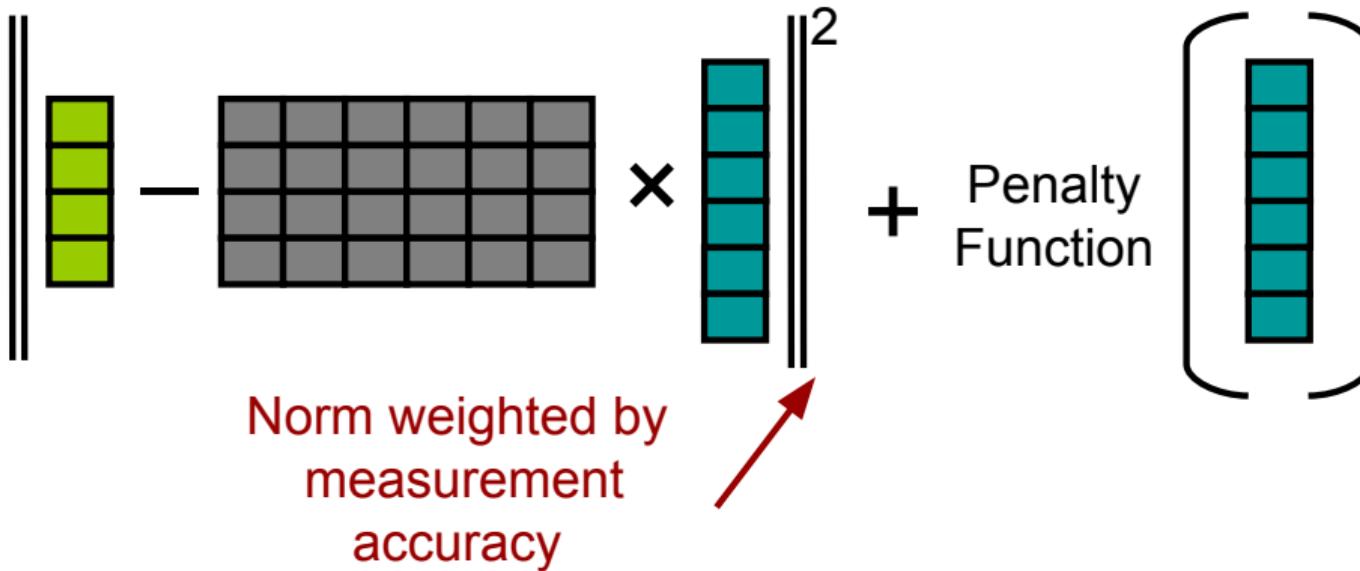
$$\text{Measurements (difference)} \rightarrow \begin{matrix} \text{Jacobian} \\ (\text{Sensitivity}) \end{matrix} = \begin{matrix} \text{Image} \\ (\text{difference}) \end{matrix} + \text{noise}$$

The diagram illustrates the mathematical model for image reconstruction. It shows a matrix multiplication equation: $\text{Measurements (difference)} = \text{Jacobian} (\text{Sensitivity}) \times \text{Image} (\text{difference}) + \text{noise}$. The Jacobian matrix is represented by a grid of gray squares. The image difference vector is represented by a vertical column of teal squares. The noise term is represented by a vertical column of black squares. Red arrows point from the text labels to their corresponding components in the equation.

Reconstructed image : $\min(\text{data } \square \text{ mismatch} + \text{image penalty})$

$$\left\| \begin{array}{c} \text{green} \\ \text{green} \\ \text{green} \end{array} \right\| - \begin{array}{|c|c|c|c|c|c|} \hline & \times & \begin{array}{c} \text{teal} \\ \text{teal} \\ \text{teal} \\ \text{teal} \end{array} & \| ^2 + \text{Penalty Function} \end{array}$$

Norm weighted by measurement accuracy



Data errors: Modify data SNR for that channel

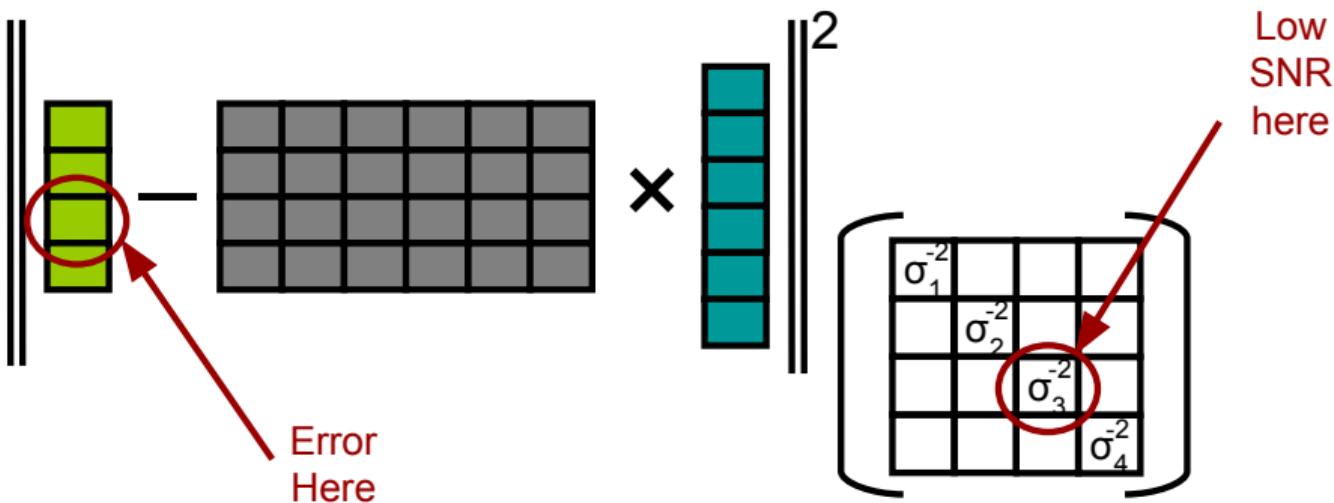


Image Reconstruction

Image Reconstruction

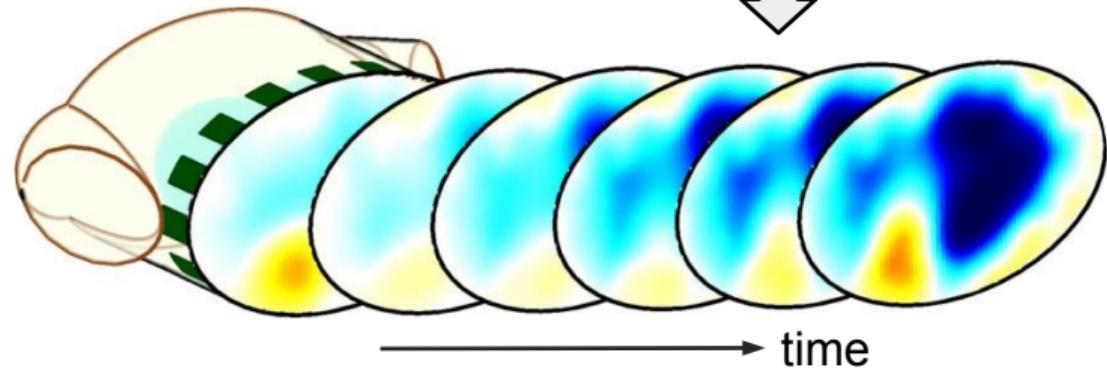
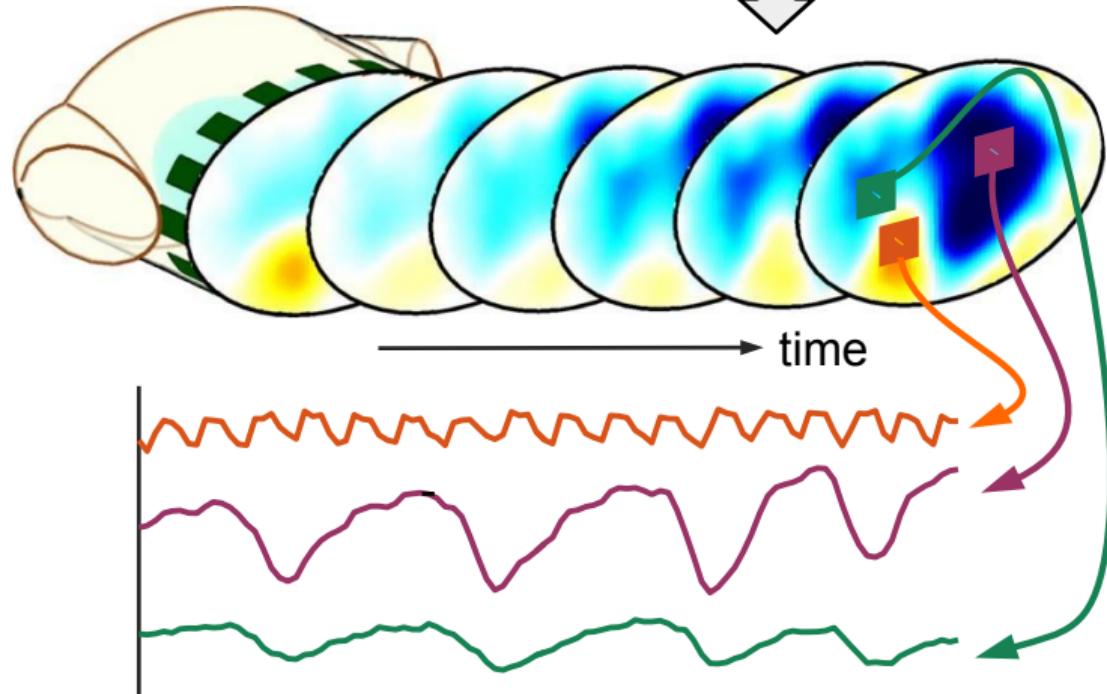
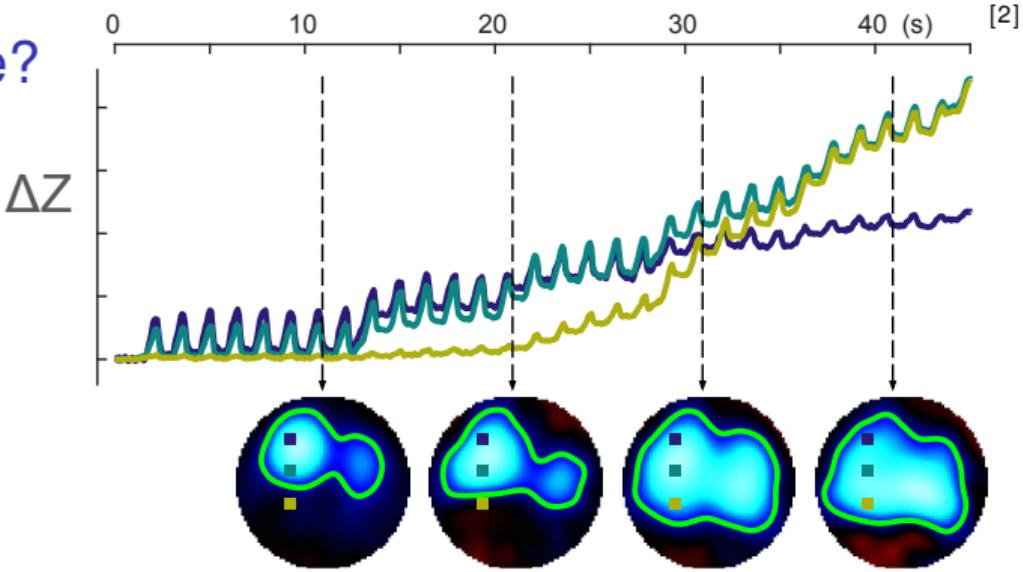


Image Reconstruction

Image Reconstruction

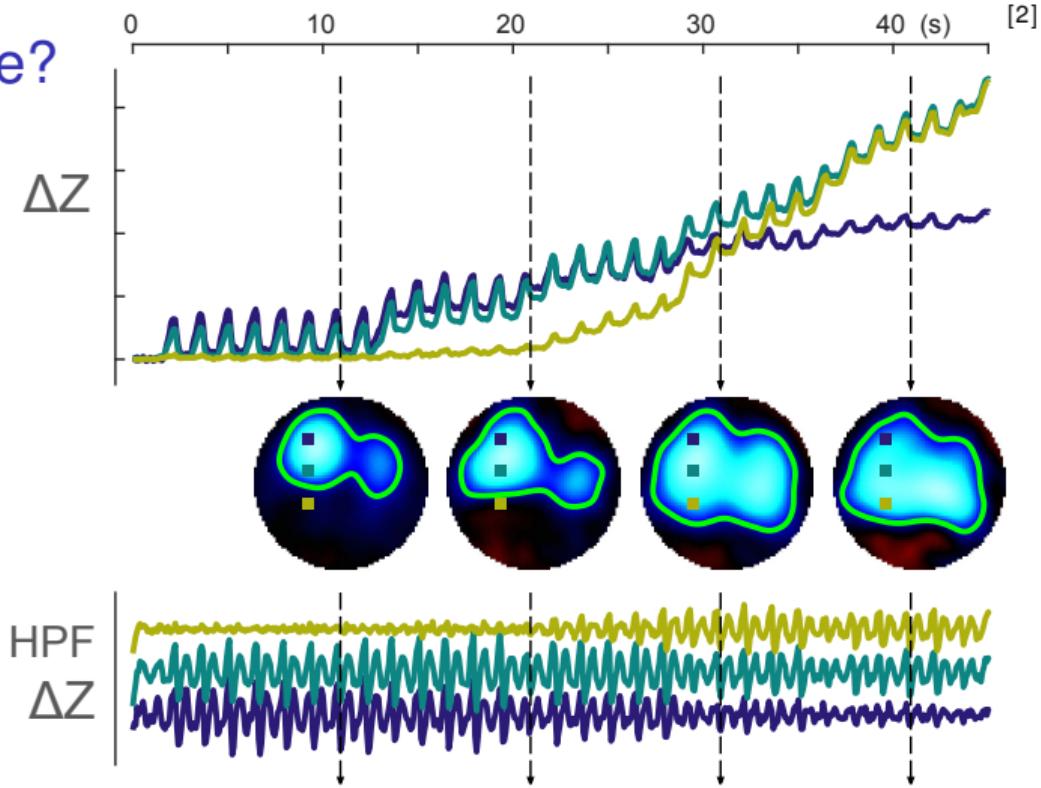


What does EIT measure?



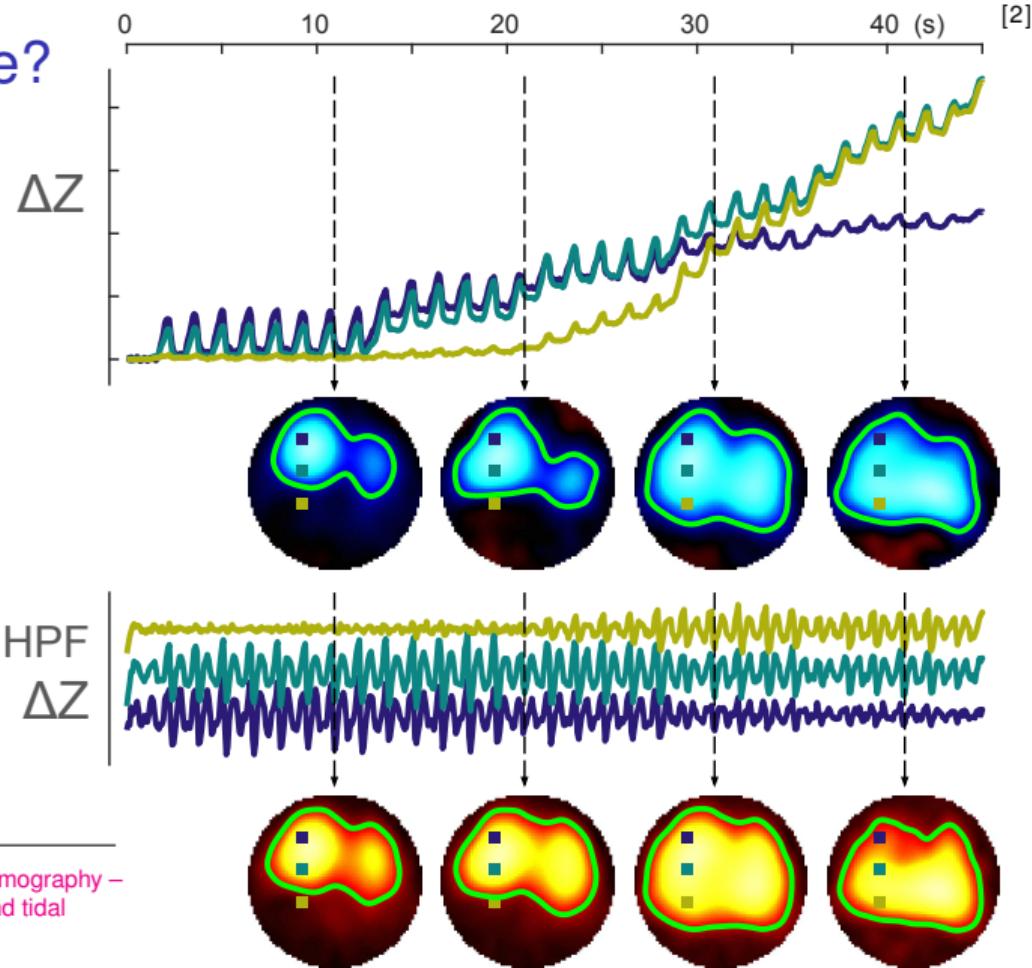
²Frerichs et al (2003) Electrical Impedance Tomography – a method for monitoring regional lung aeration and tidal volume distribution *Int Care Med* 29:2312–2316

What does EIT measure?



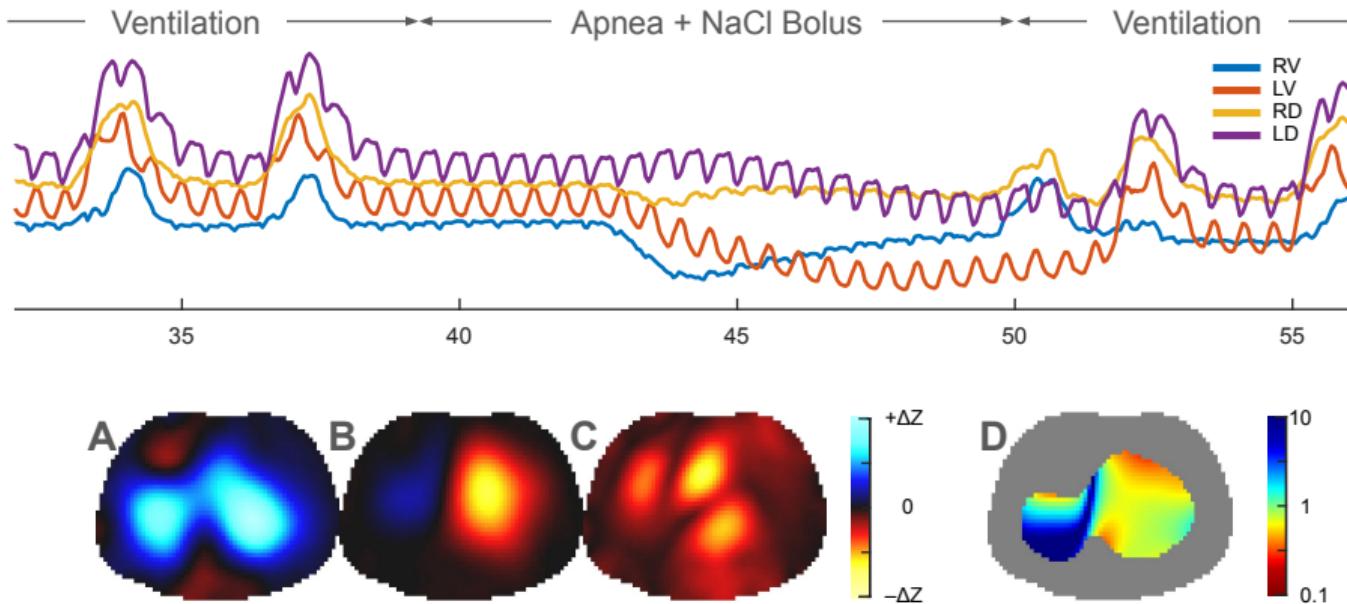
²Frerichs et al (2003) Electrical Impedance Tomography – a method for monitoring regional lung aeration and tidal volume distribution *Int Care Med* 29:2312–2316

What does EIT measure?



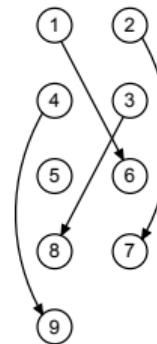
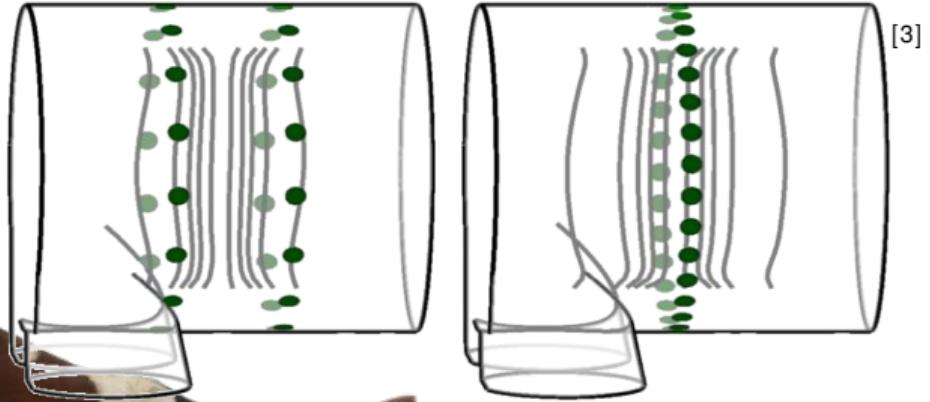
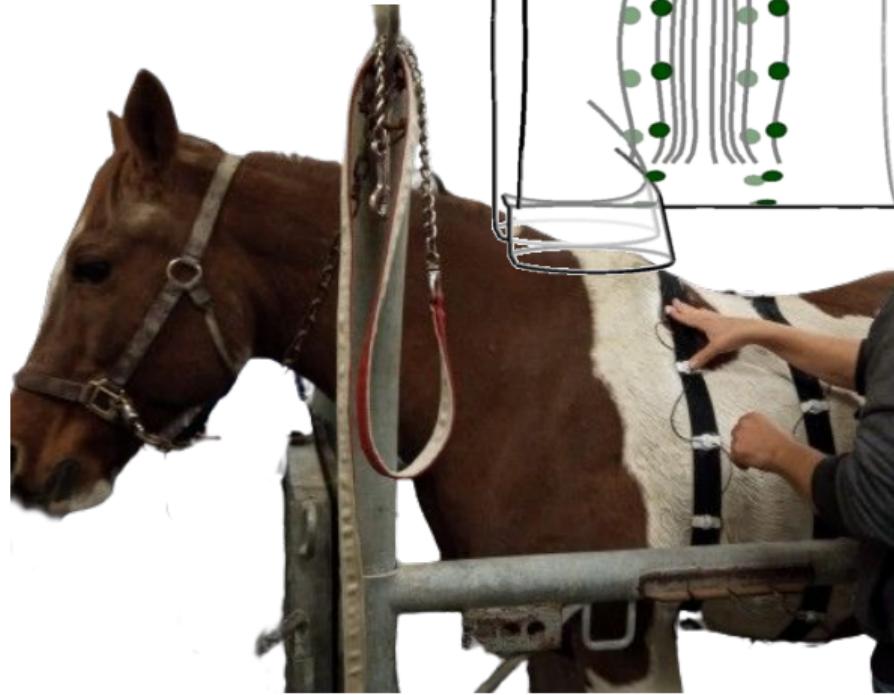
²Frerichs et al (2003) Electrical Impedance Tomography – a method for monitoring regional lung aeration and tidal volume distribution *Int Care Med* 29:2312–2316

EIT and blood flow: Bolus- and Filtering-based



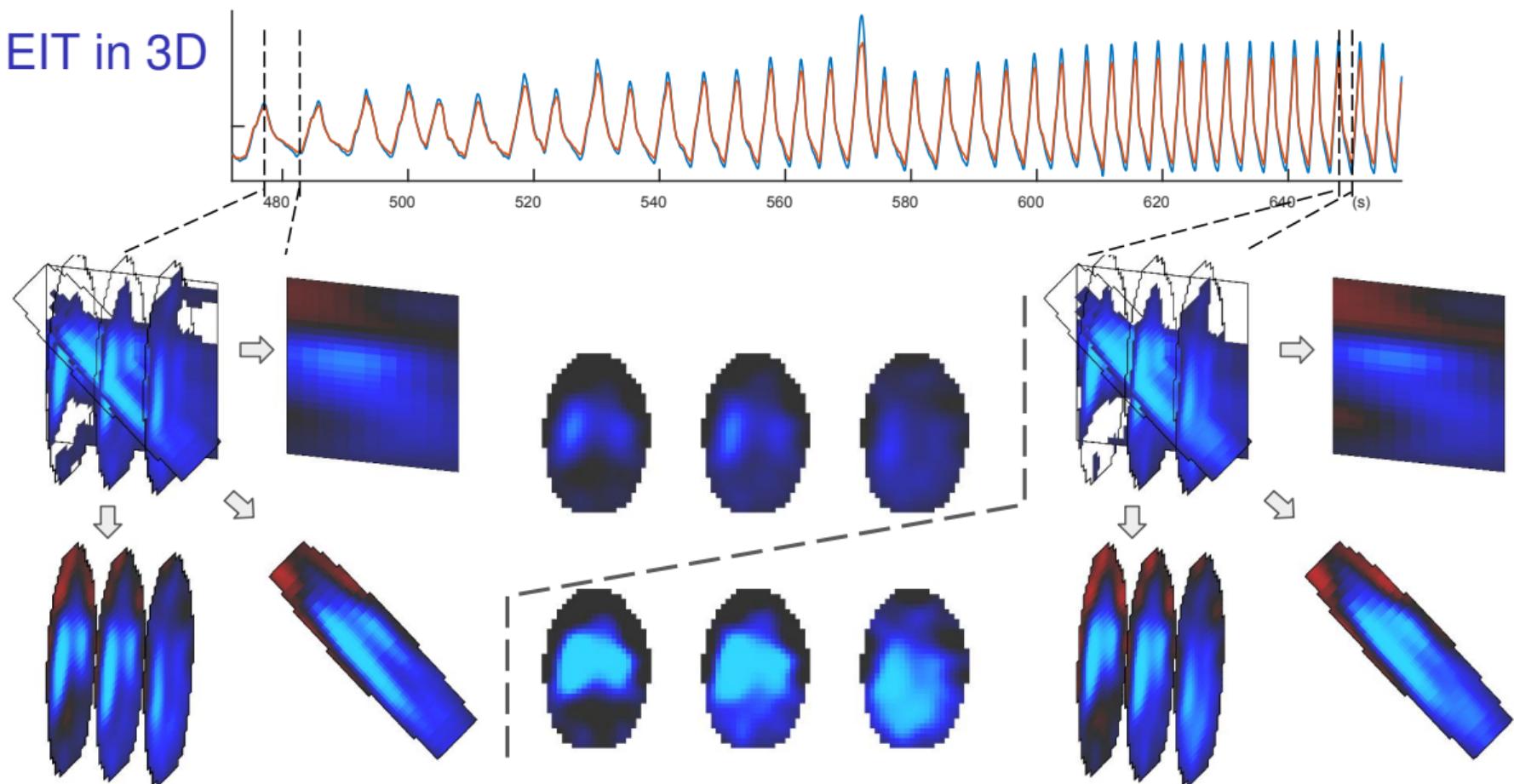
EIT waveforms and images from [Wang et al 2024] during a NaCl bolus and apnea (38–50 s) in 4 quadrants.
A) Tidal Ventilation, B) Bolus-based perfusion image, C) HR-filtered EIT image, D) relative EIT-V/Q in lungs.

EIT in 3D

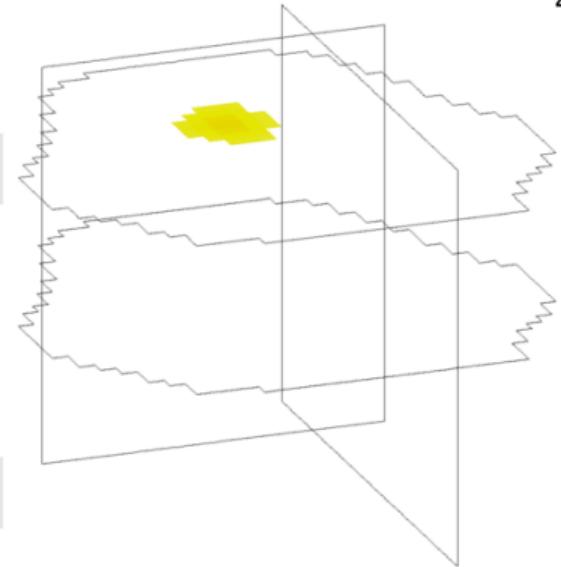
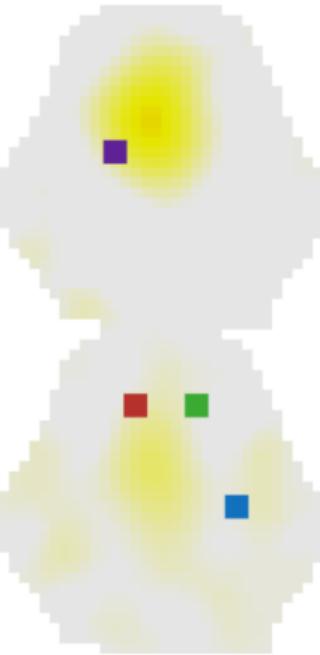
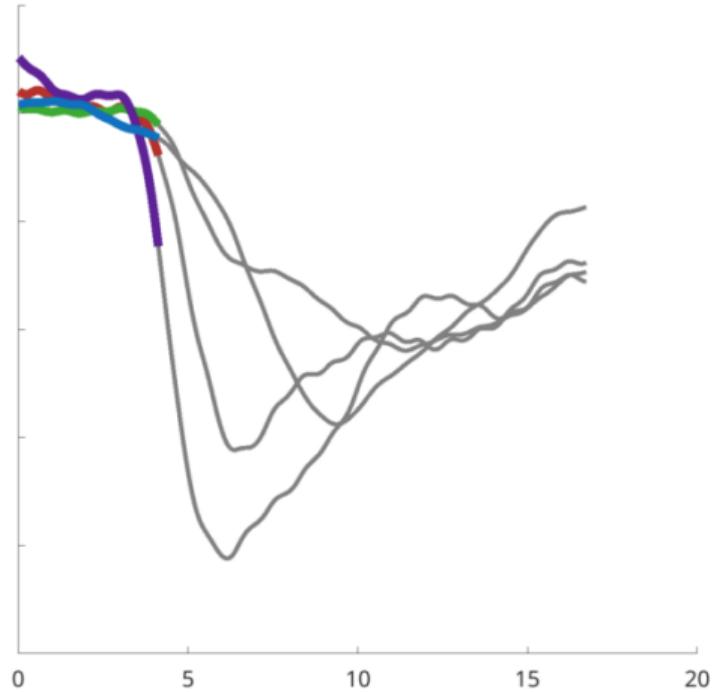


³Byrne et al (2023) Validation of three-dimensional thoracic ... *Physiol Meas* 45:035010

EIT in 3D

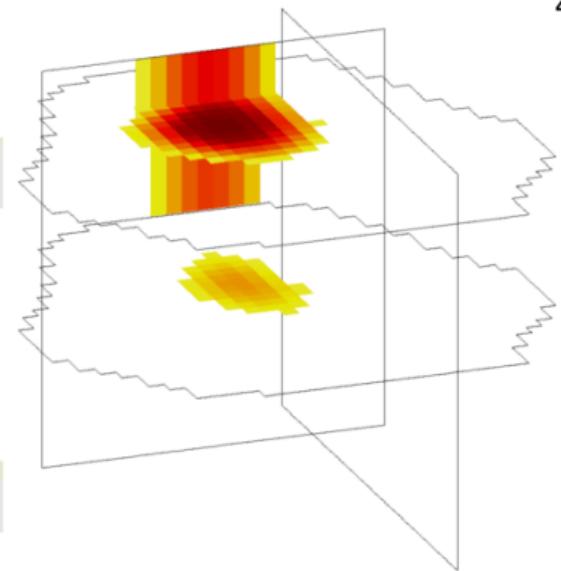
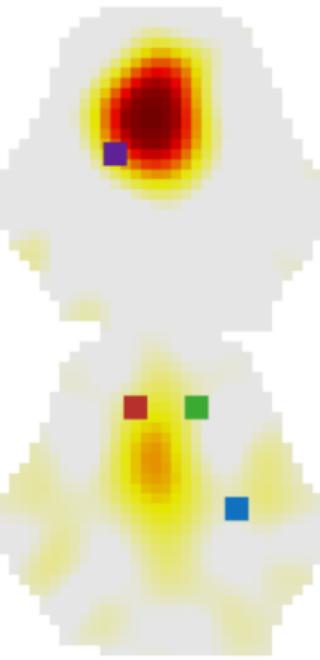
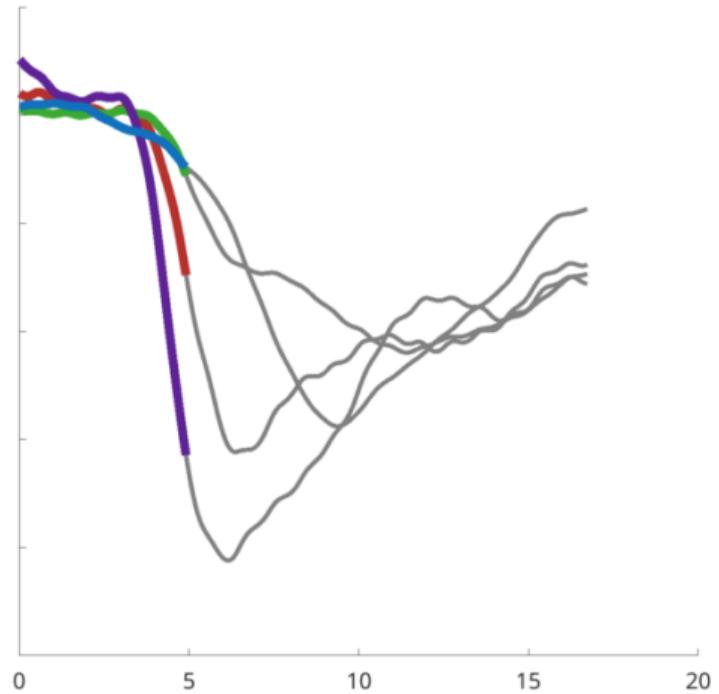


Perfusion with 3D EIT



⁴Larrabee et al (2023) Am J Physiol: Lung

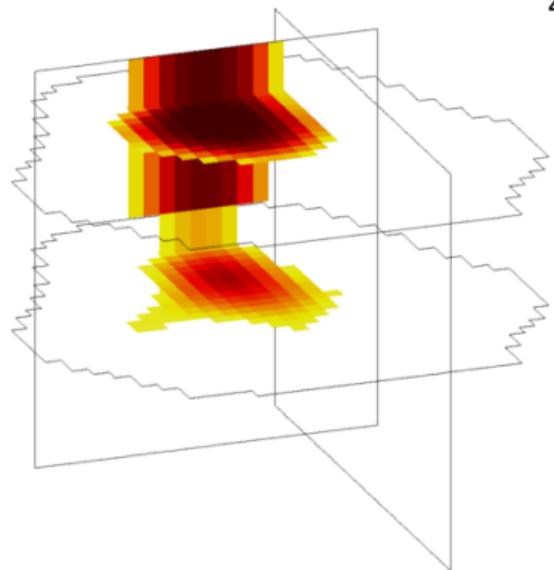
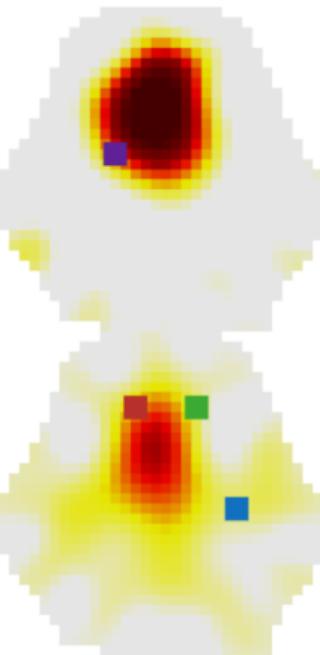
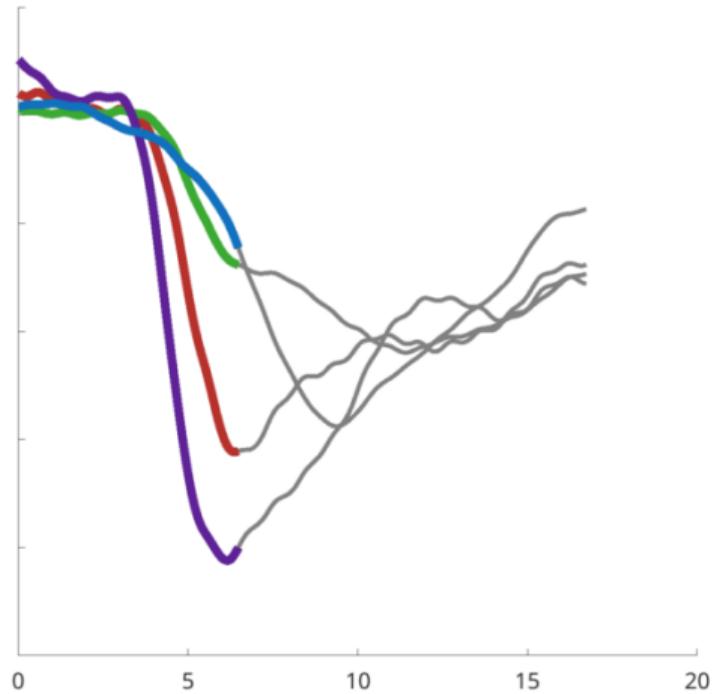
Perfusion with 3D EIT



4

⁴Larrabee et al (2023) Am J Physiol: Lung

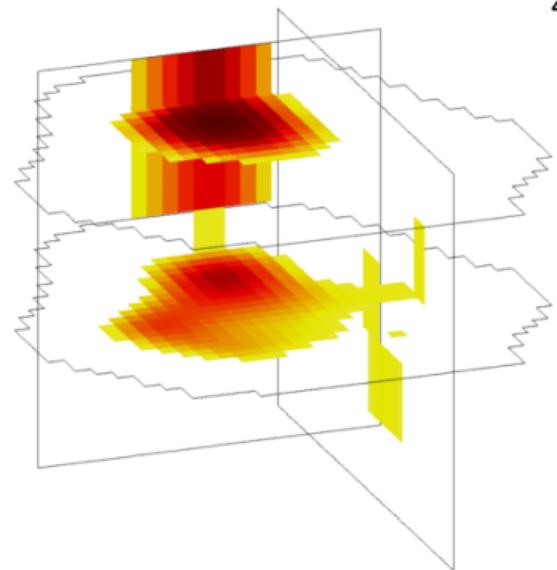
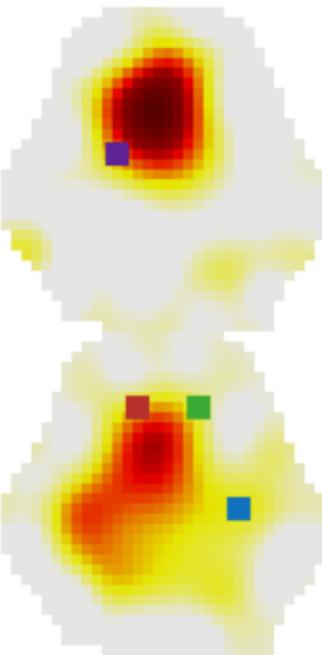
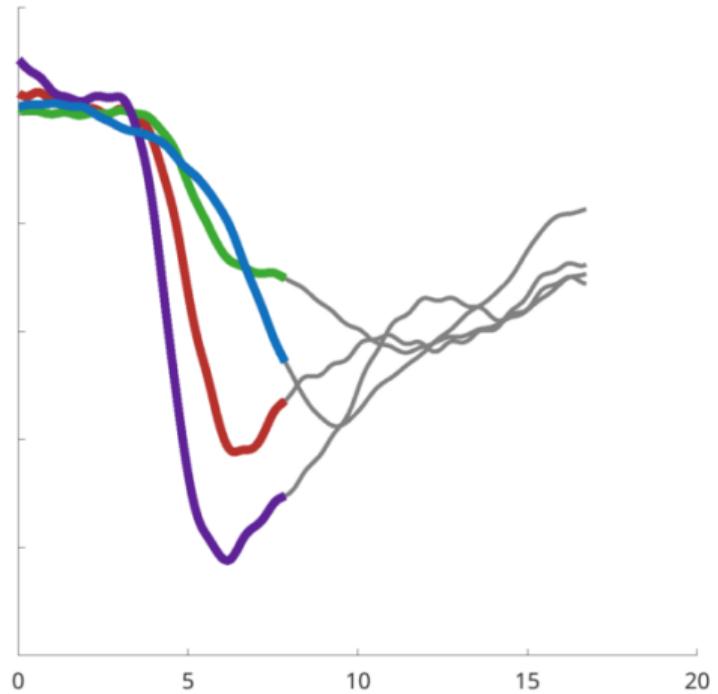
Perfusion with 3D EIT



4

⁴Larrabee et al (2023) Am J Physiol: Lung

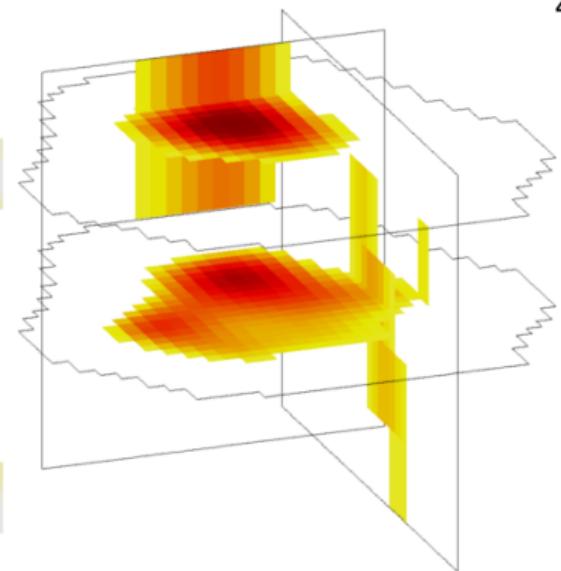
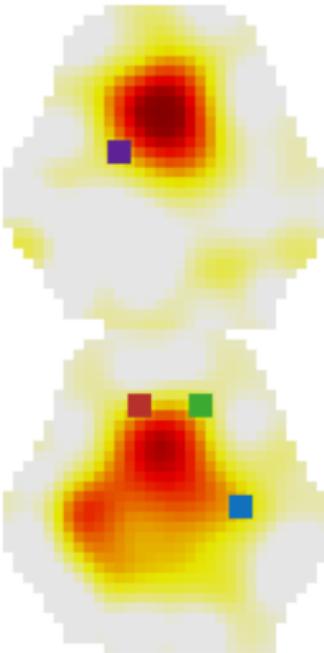
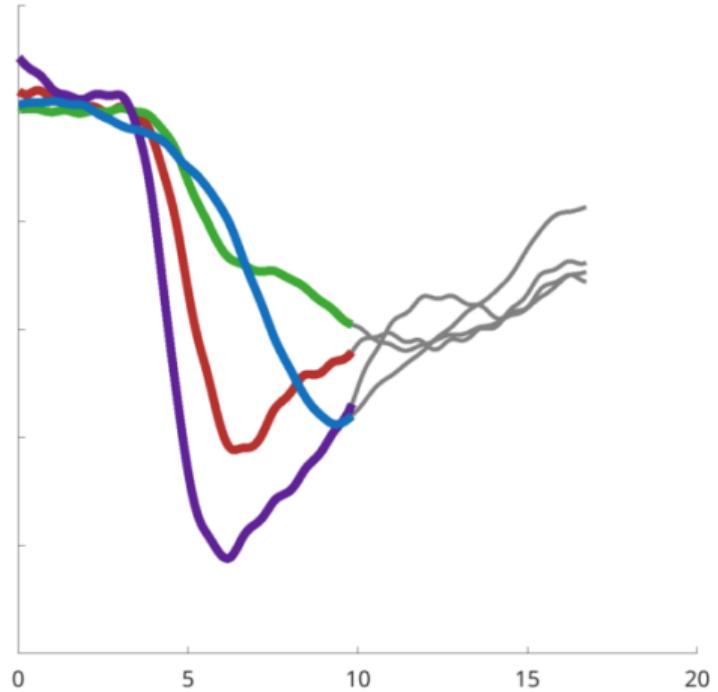
Perfusion with 3D EIT



4

⁴Larrabee et al (2023) Am J Physiol: Lung

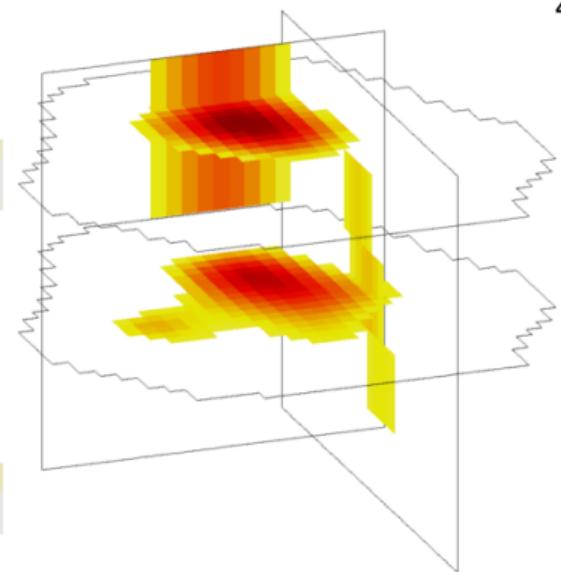
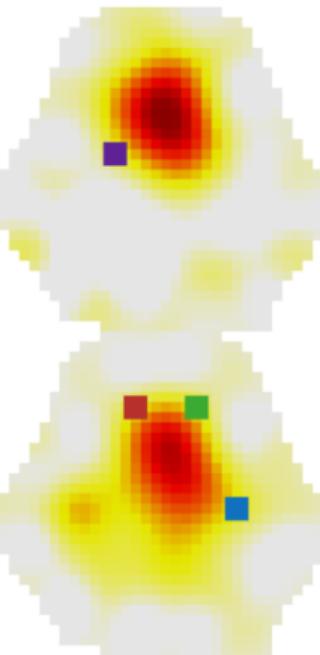
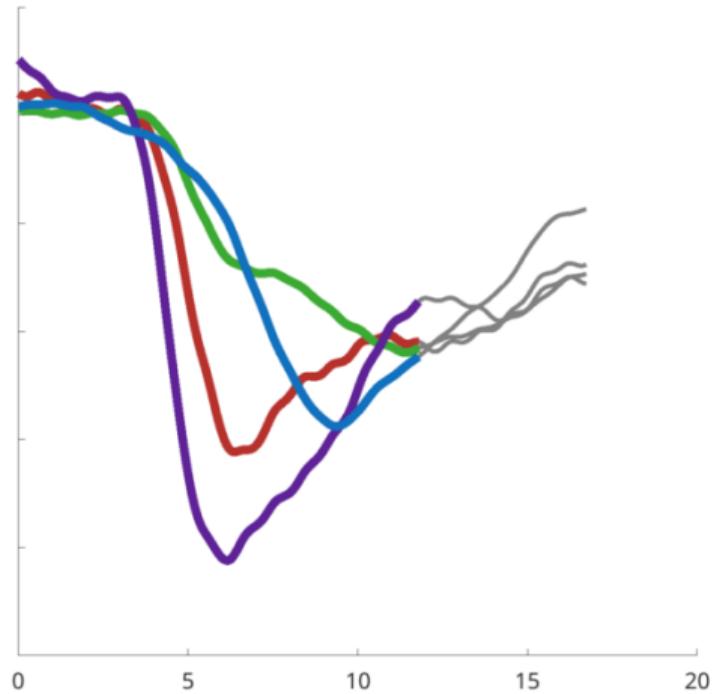
Perfusion with 3D EIT



4

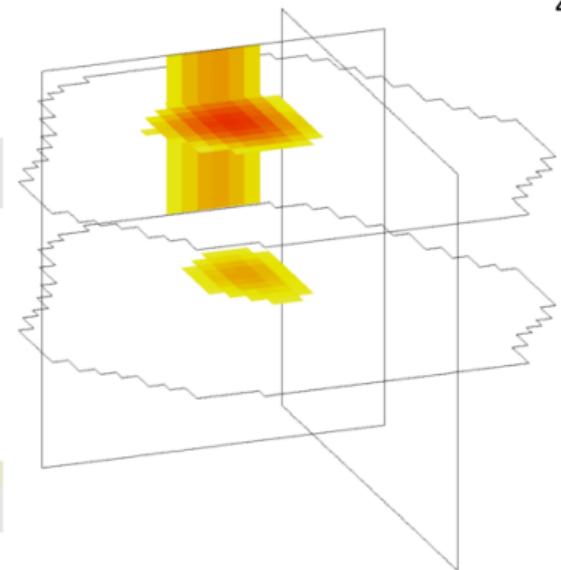
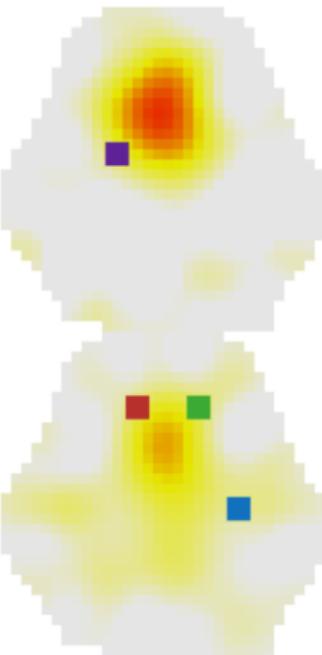
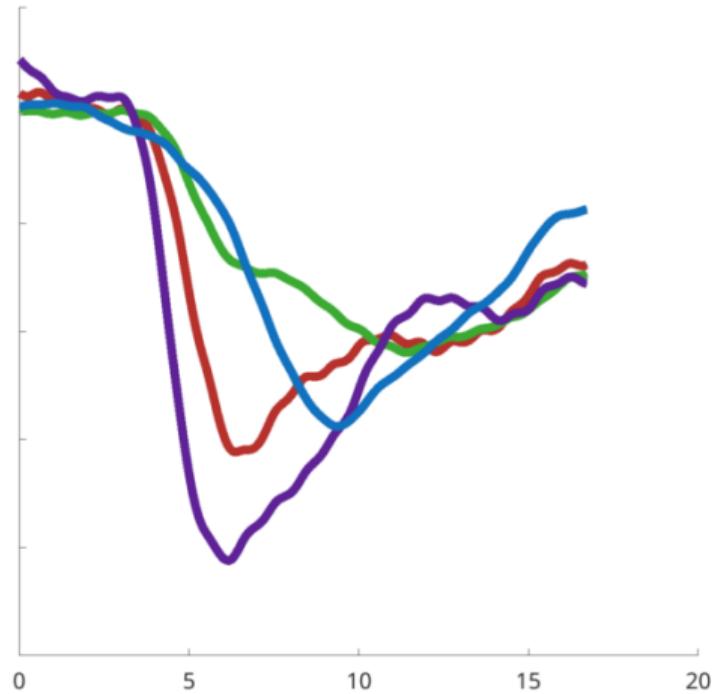
⁴Larrabee et al (2023) Am J Physiol: Lung

Perfusion with 3D EIT



⁴Larrabee *et al* (2023) Am J Physiol: Lung

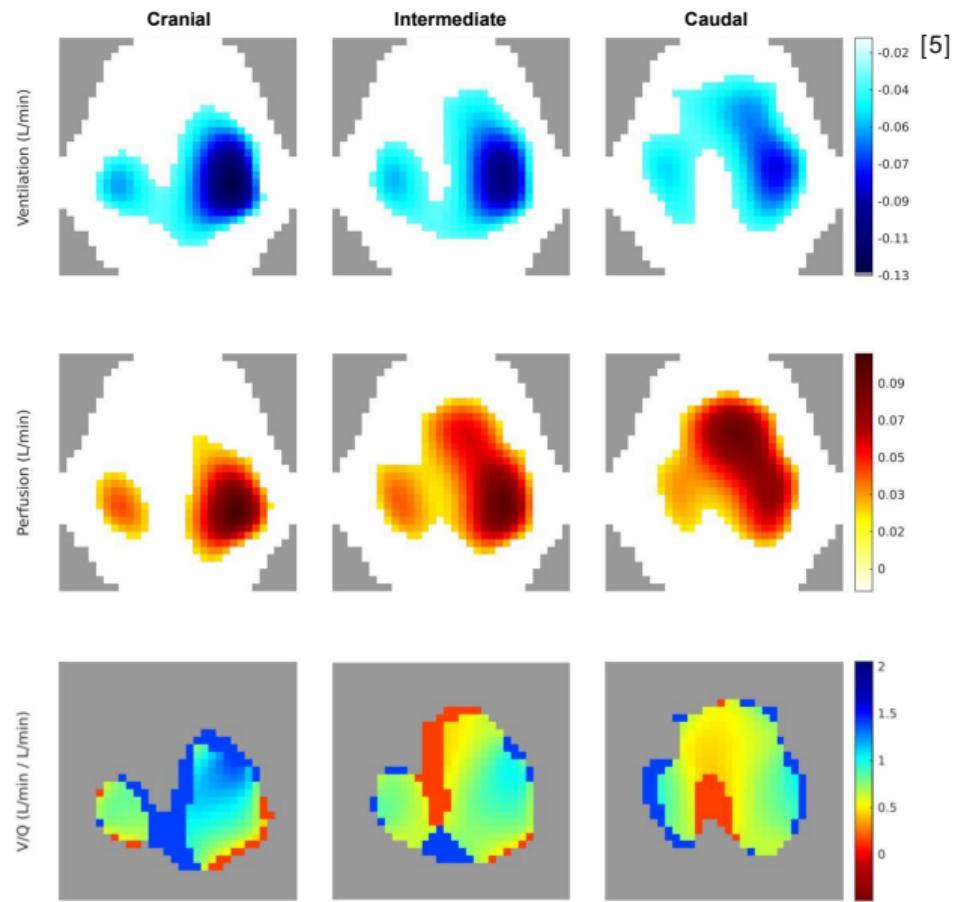
Perfusion with 3D EIT



4

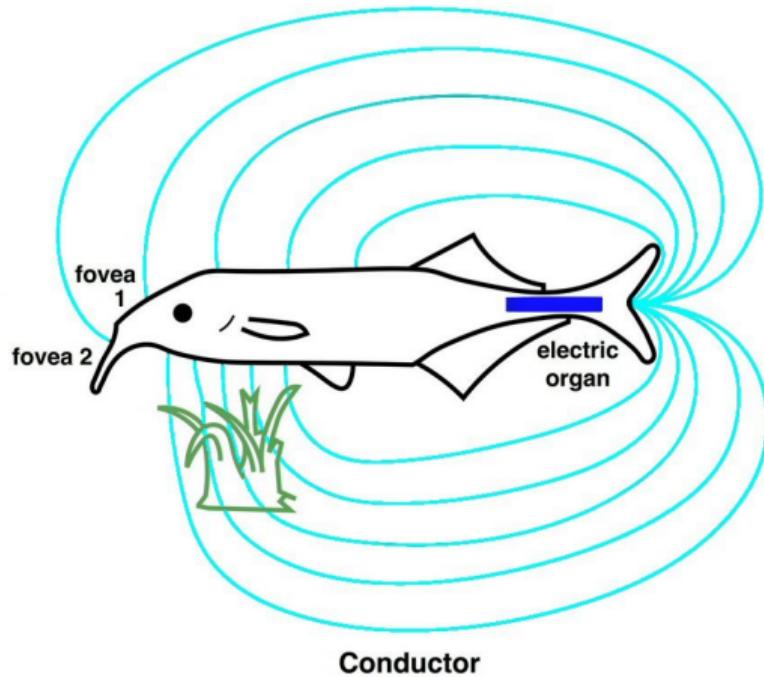
⁴Larrabee et al (2023) Am J Physiol: Lung

3D Ventilation / Perfusion \dot{V} / Q

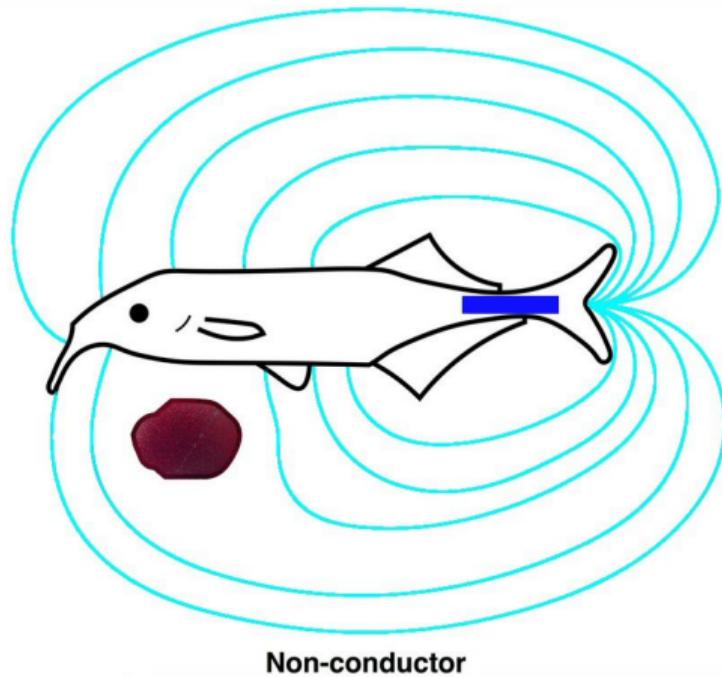


Can animals benefit from EIT?

Electrically Sensitive Fish

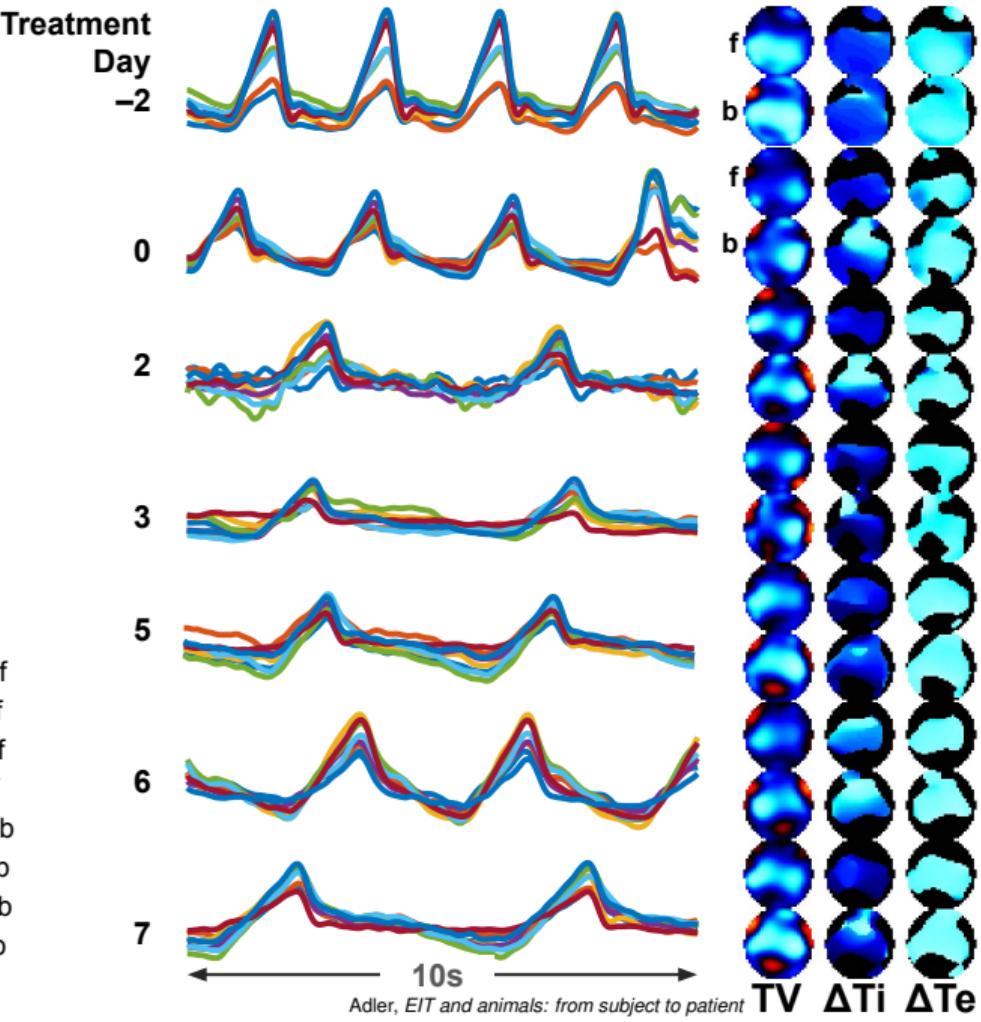
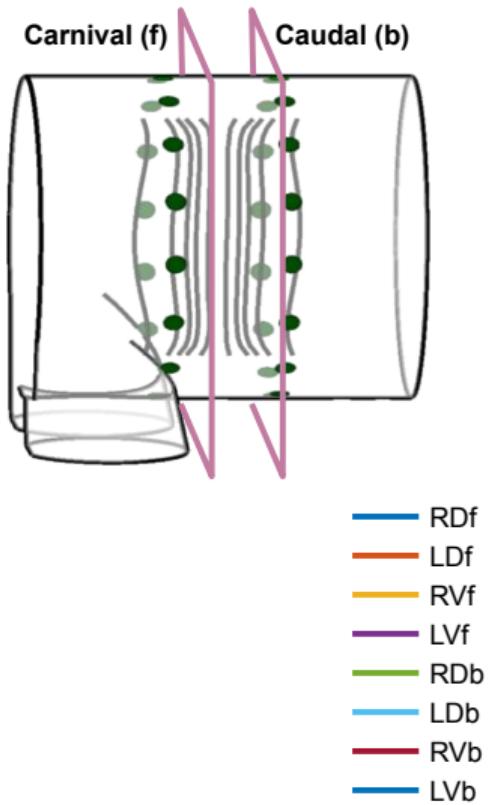


[6]

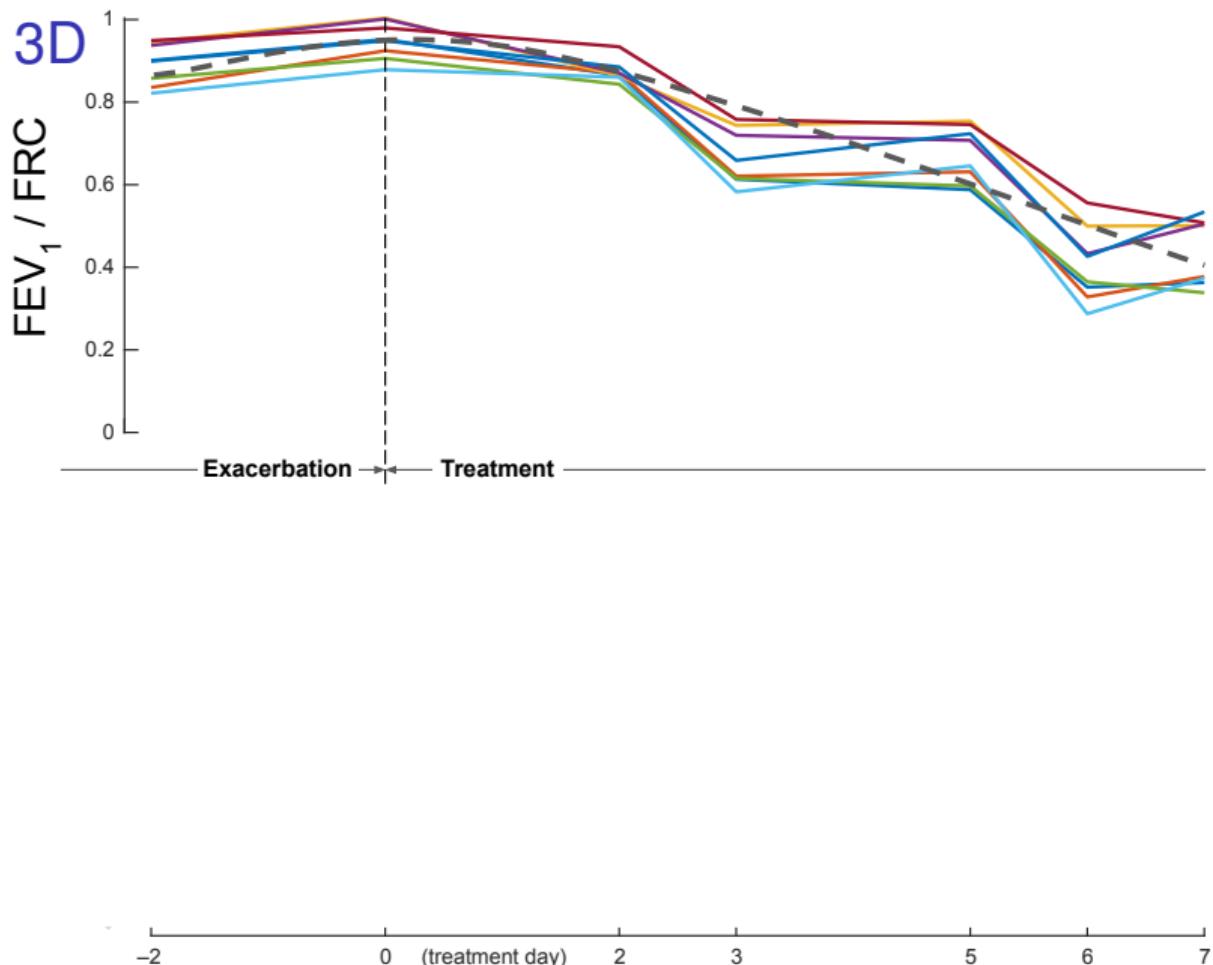


⁶en.wikipedia.org/wiki/Electroreception_and_electrogenesis

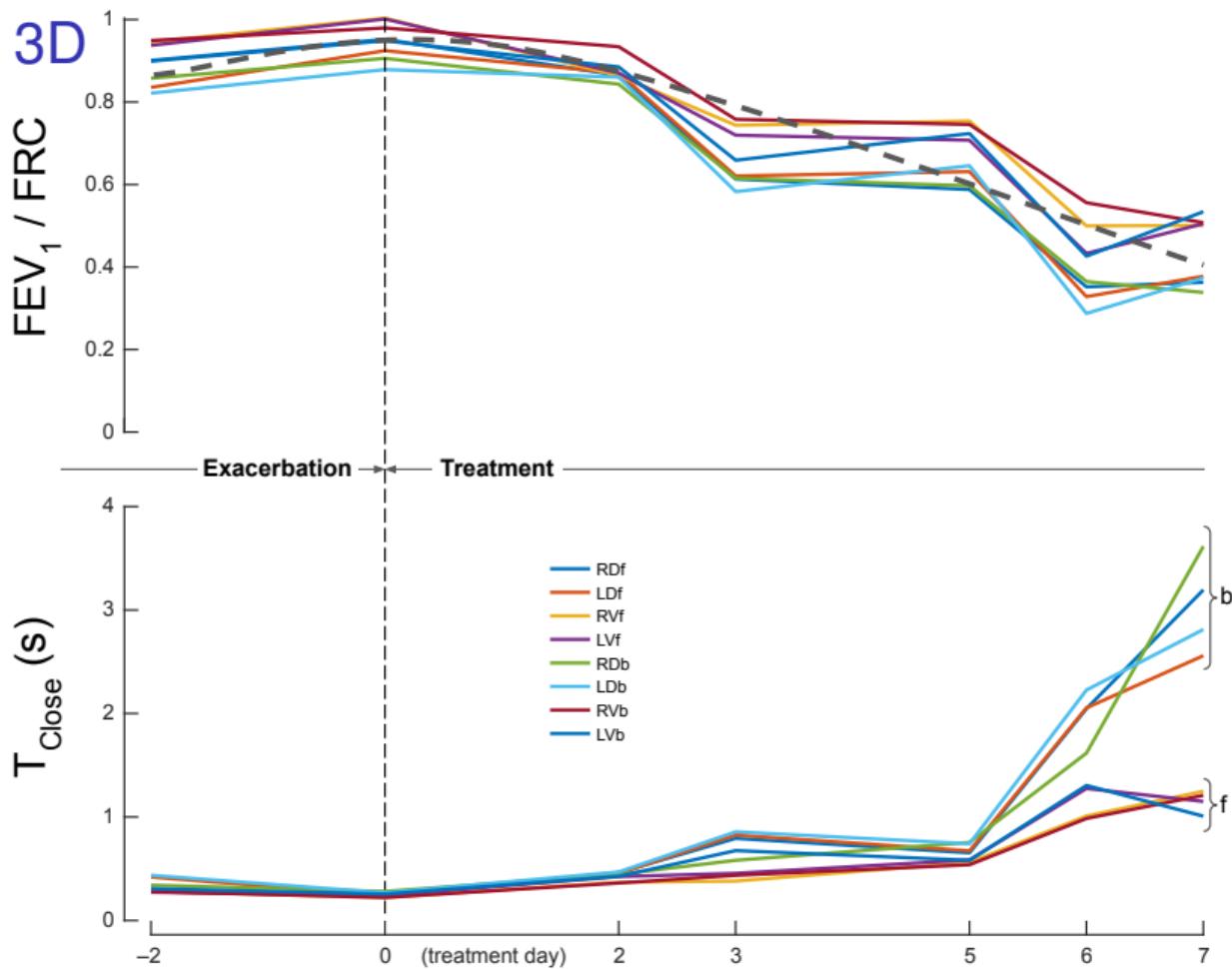
Horse asthma in 3D



Horse asthma in 3D



Horse asthma in 3D

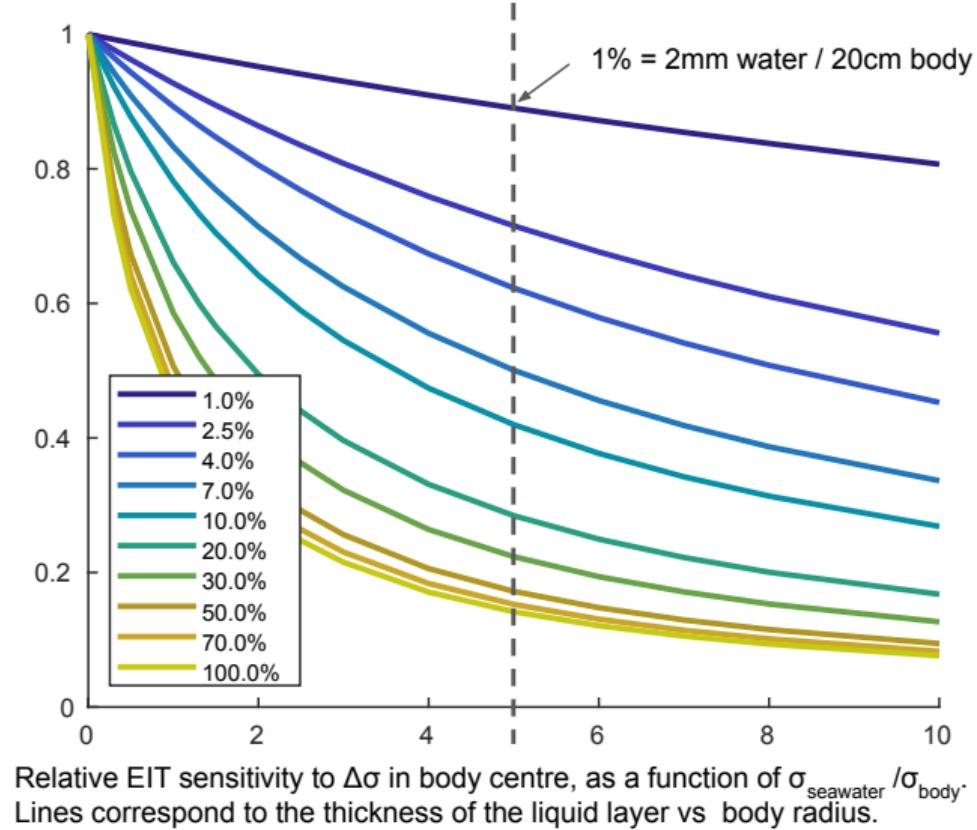
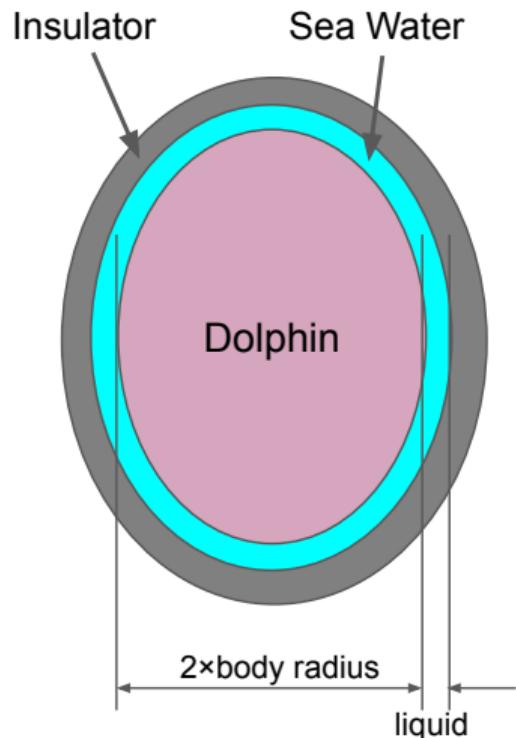


Sea Mammals



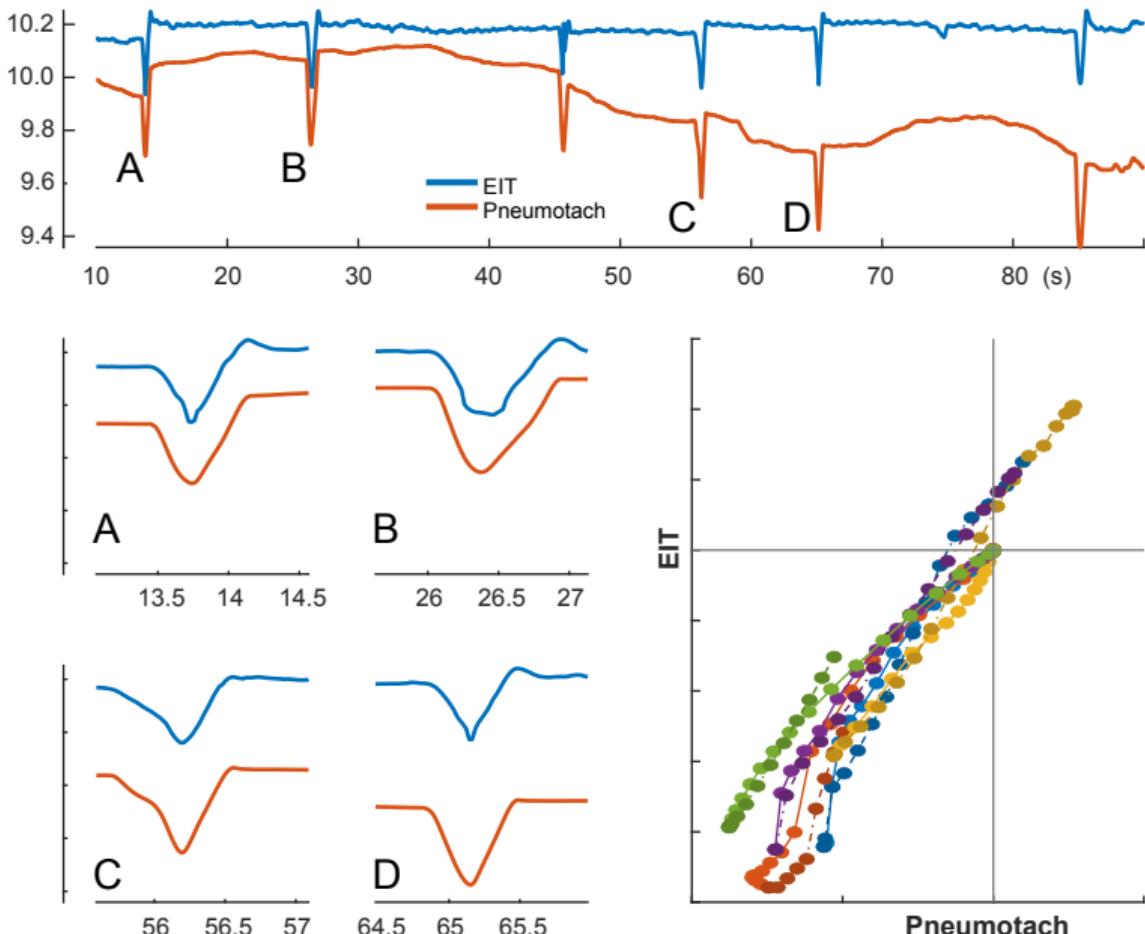
Problem: Seawater is conductive

[7]

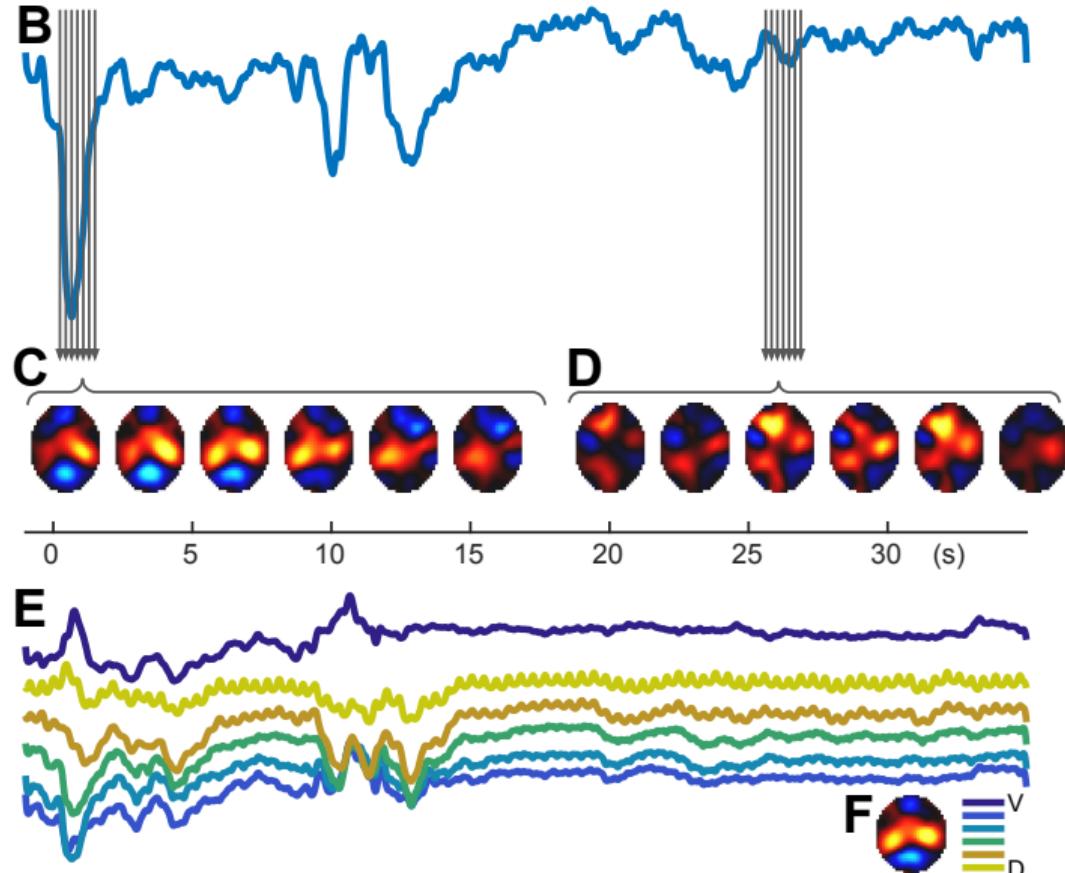


⁷ Adler et al (2021) Feasibility of Thoracic Impedance Measurements in Seawater p.68 Conf EIT 2021

Dolphins: EIT vs Spirometry



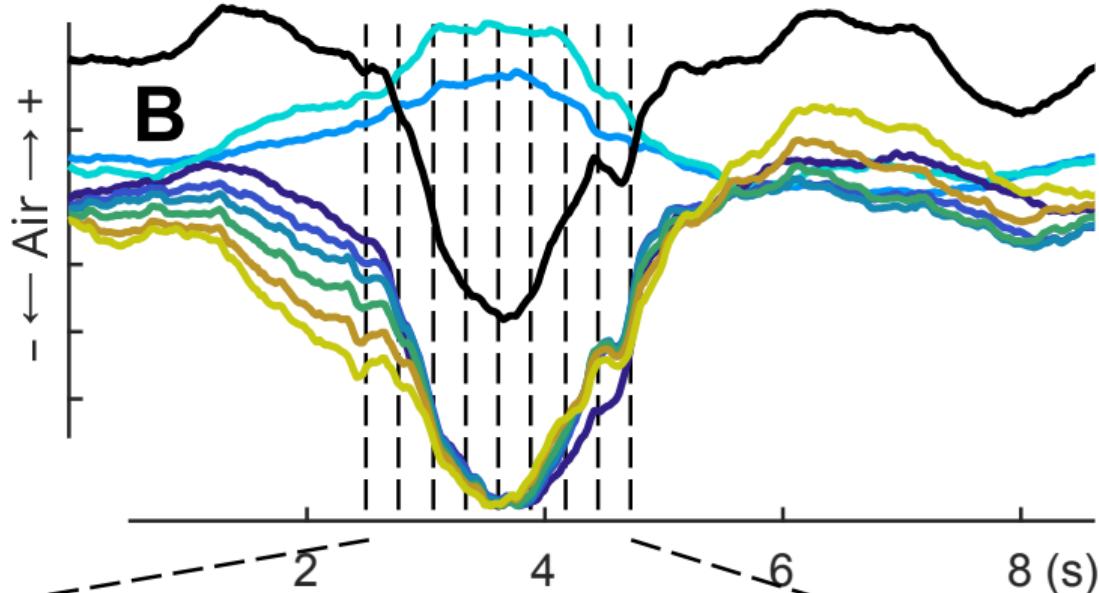
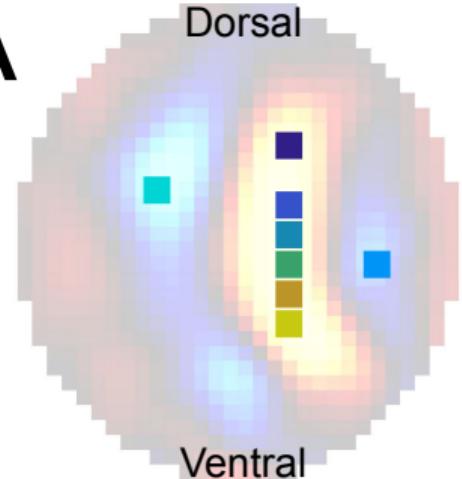
Dolphins



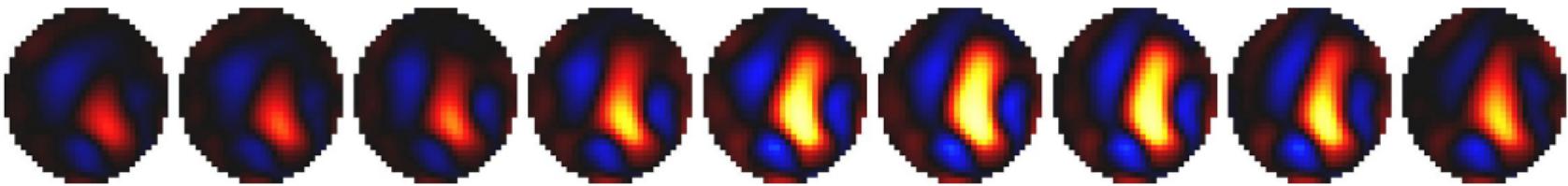
⁸Adler et al (2024) Conf EIT

Dolphins: One Breath

A



C



Next Steps

EIT is exciting tool for

- Physiological monitoring of experimental animals
- Surgical and post-operative monitoring of pet animals
- Cattle health monitoring
- Monitoring wild animals non-invasively

Challenges

- Need 3D EIT systems
- Contact-quality is difficult: need compensation
- Is there a market for veterinary devices?
- Software tools are needed