V̇/Q analysis with 3D EIT

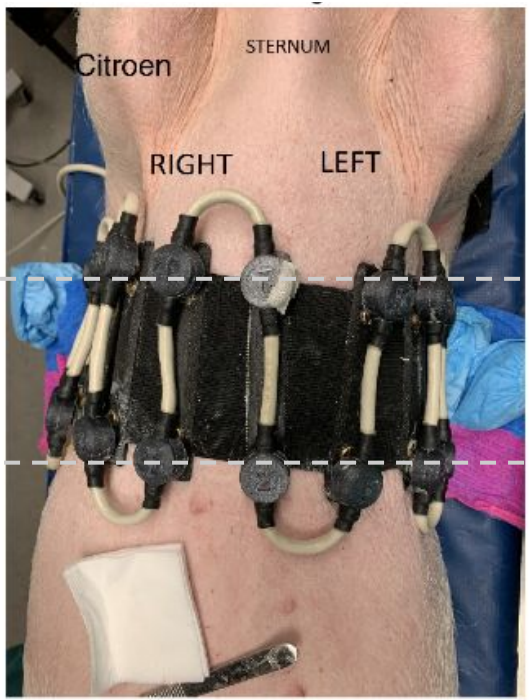
Joaquin Araos[1], Symon Stowe[2], Andy Adler[2]

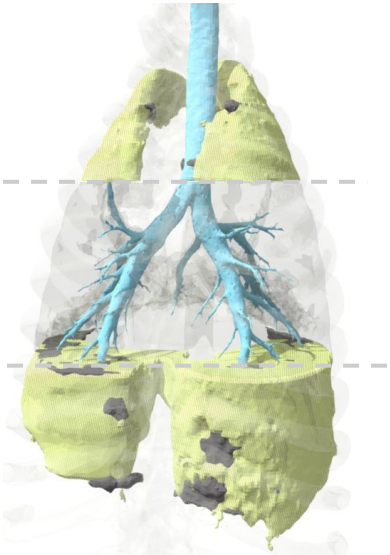
[1]Dept Clinical Science, College of Veterinary Medicine, Cornell University, Ithaca, USA
[2]Systems and Computer Engineering, Carleton University, Ottawa, Canada

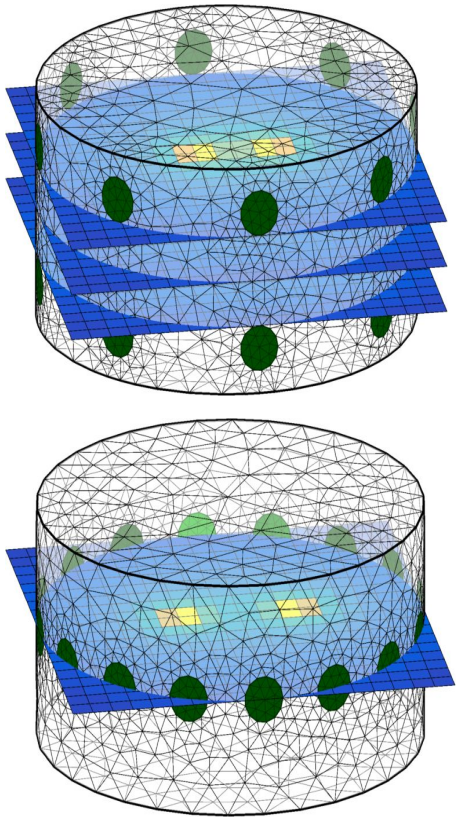
Background

- Critically ill patients often have significant alterations in gas exchange. Regional matching of ventilation and perfusion ($\dot{V}/\dot{Q}$) is key to ensure optimal gas exchange in the lungs.
- Current work in EIT-based $\dot{V}/\dot{Q}$ is single 2D image [1].
- We develop a two-plane, 3D analysis of regional $\dot{V}/\dot{Q}$.
- While EIT-based measurement of air flow ($\dot{V}$) is well understood, work on perfusion ($\dot{Q}$) is ongoing, and both pusatility- and conductivity bolus-based techniques are used.
- Lung perfusion analysis needs signal processing to remove the cardiac component.
- This software is made available (see [3]) under open licence.

3D EIT







Araos et al, *V/Q analysis with 3D EIT*, Conf EIT 2023

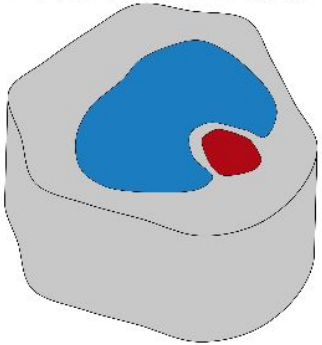
Methods

With ethics approval,

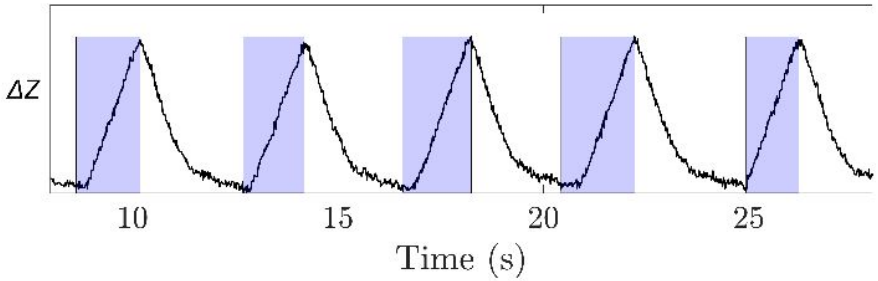
- Yorkshire cross pigs (8 @ 4 months, 55–59 kg).
- sedated, anesthetized and mechanically ventilated supine
- With PA catheter, inject NaCl bolus (10 mL of 7.2%) at apnea.
- The study consisted of phases designed to modify Q̇
  - Baseline
  - Dobutamine infusion,
  - Phenylephrine infusion,
  - Controlled hemorrhage.
- EIT data with Pioneer Set and custom, 2×16 electrode EIT belt.
- Three transverse EIT image layers were reconstructed [2].

EIT Methods: Ventilation

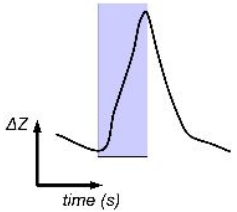
Record 3D EIT data



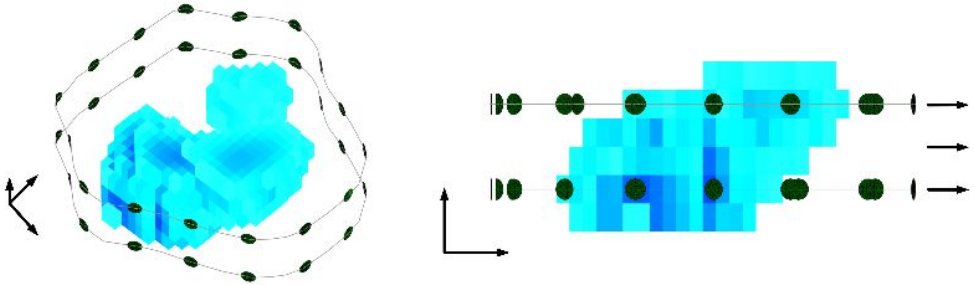
Identify breaths in raw data



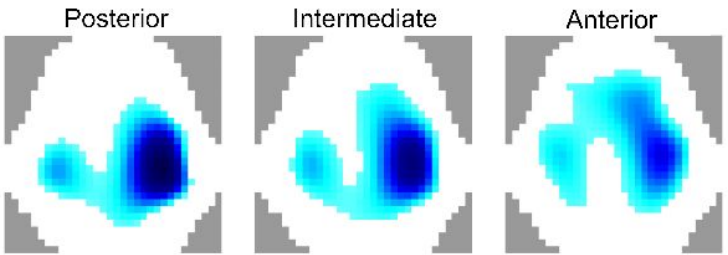
Average all breaths



EIT image reconstruction



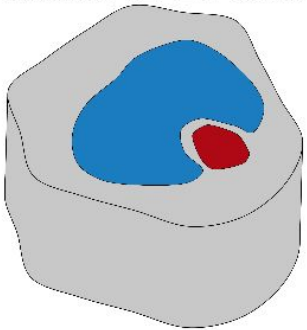
EIT image display



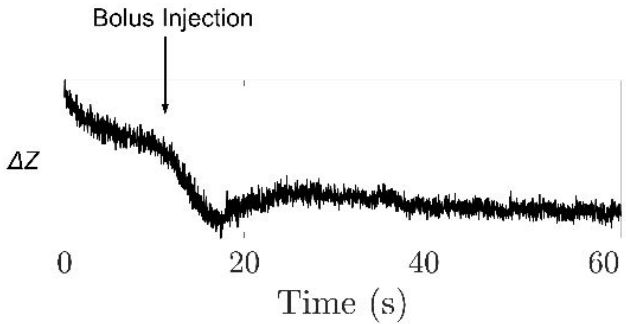
Araos et al, *V/Q analysis with 3D EIT*, Conf EIT 2023

EIT Methods: Perfusion

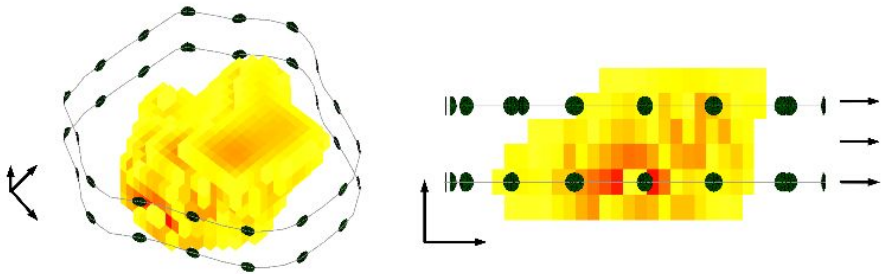
Record 3D EIT data



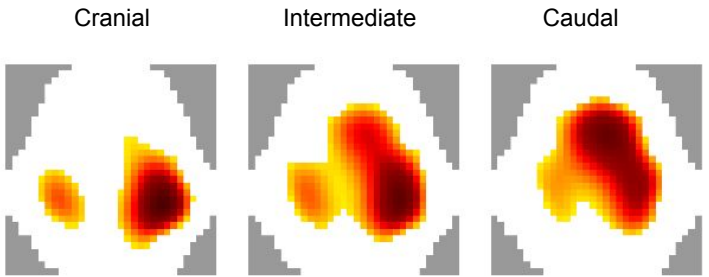
Apnoea Segment



Isolated Lung Perfusion



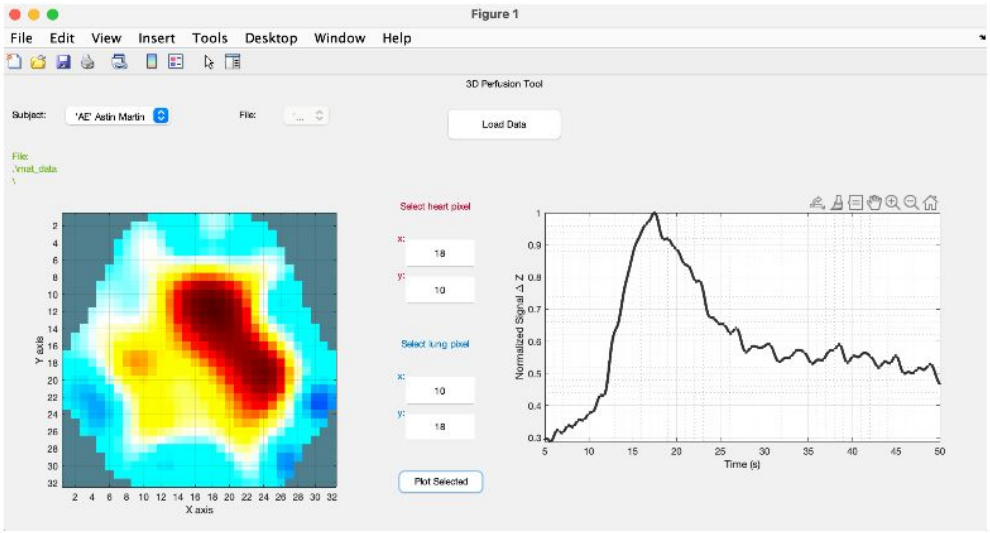
EIT image display



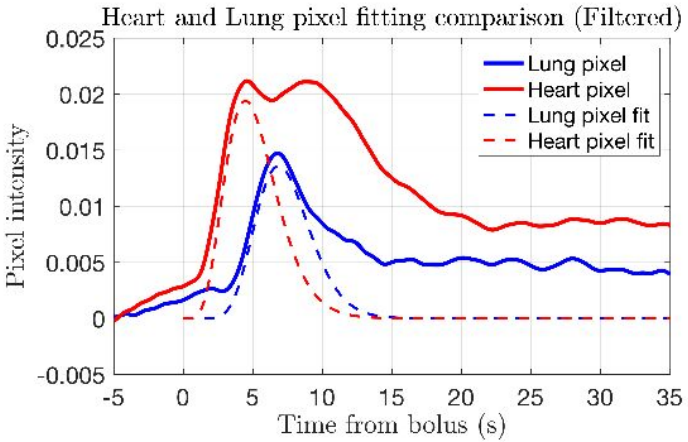
Araos et al, *V/Q analysis with 3D EIT*, Conf EIT 2023

EIT Perfusion: Fitting Gamma function

Select Lung and Heart Pixels



Fit gamma functions



Araos et al, *V/Q analysis with 3D EIT*, Conf EIT 2023

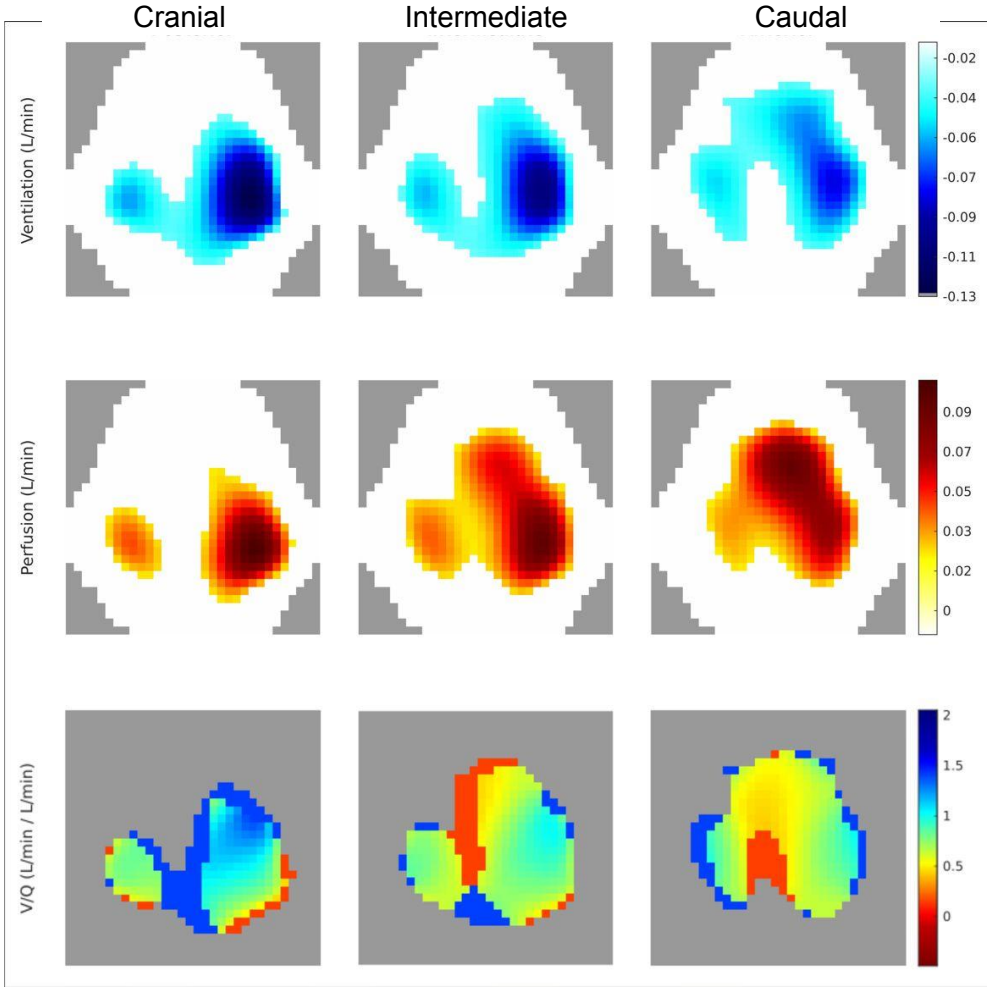
Voxel V̇/Q̇

$$\frac{\dot{\mathrm{V}}_{\mathrm{vox}}}{\dot{\mathrm{Q}}_{\mathrm{vox}}} = \frac{\frac{\Delta Z_{\dot{\mathrm{V}},\mathrm{vox}}}{\Delta Z_{\dot{\mathrm{V}},\mathrm{tot}}} \times V_T \times RR \times (1 - \frac{V_D}{V_T})}{\frac{\Delta Z_{\dot{\mathrm{Q}},\mathrm{vox}}}{\Delta Z_{\dot{\mathrm{Q}},\mathrm{tot}}} \times CO}$$

Impedance ratios represent the unitless ΔZ in each voxel.
Conversion to V̇ and Q̇ units requires multiplication by air and blood flows
V_T × RR × (1 − V_D/V_T) represents effective alveolar ventilation.

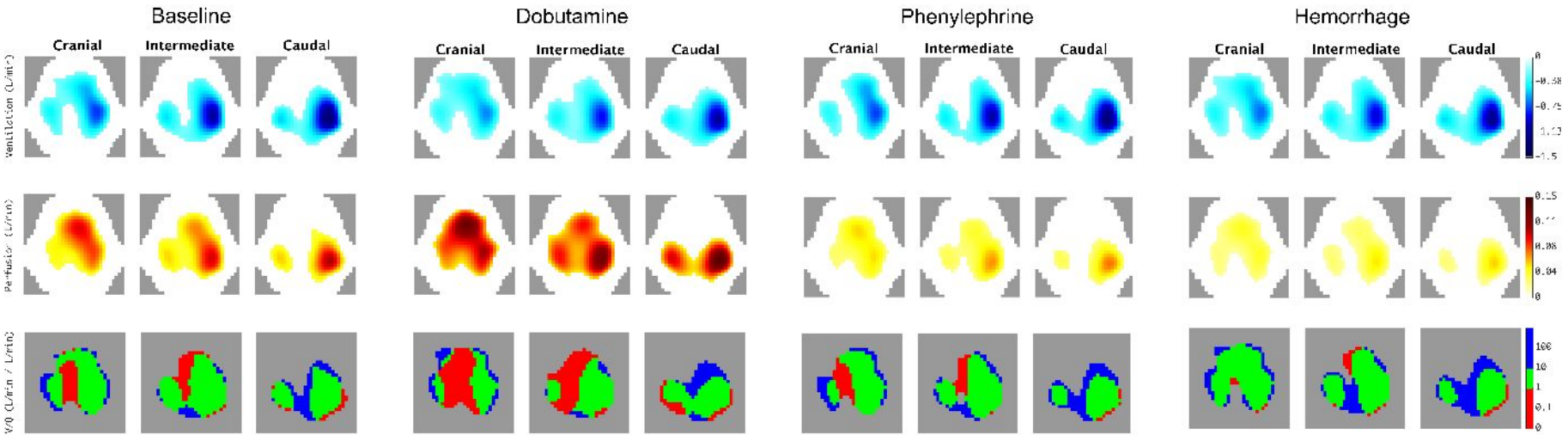
Araos et al, *V/Q analysis with 3D EIT*, Conf EIT 2023

Example Images Baseline



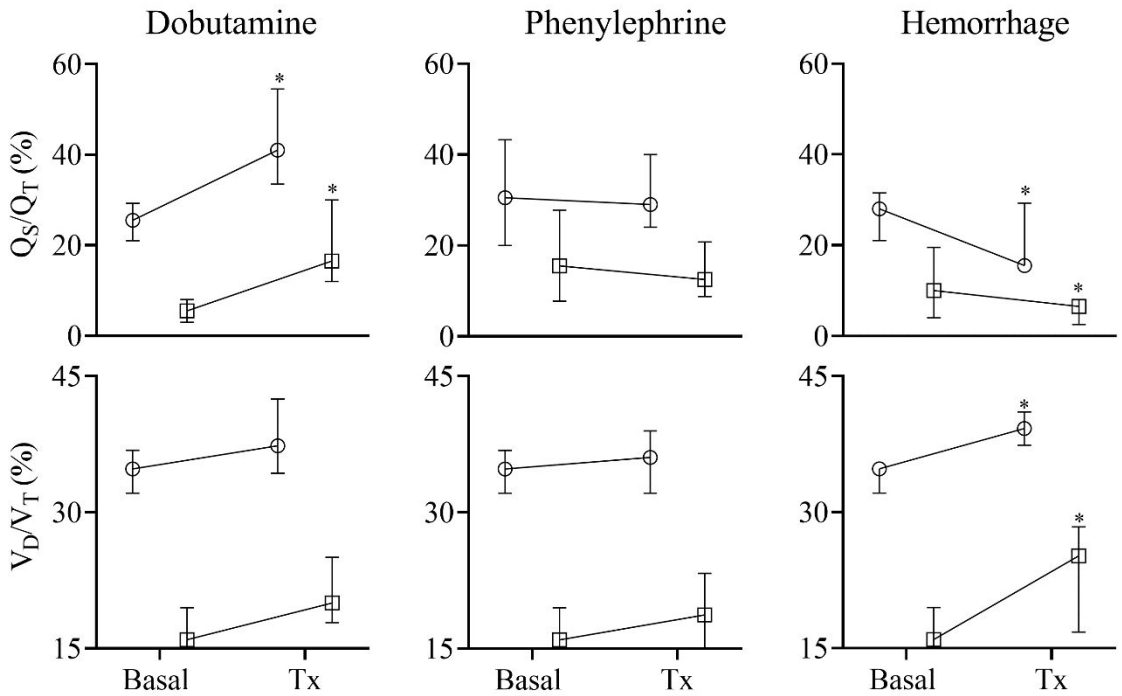
Araos et al, *V/Q analysis with 3D EIT*, Conf EIT 2023

Images vs Condition



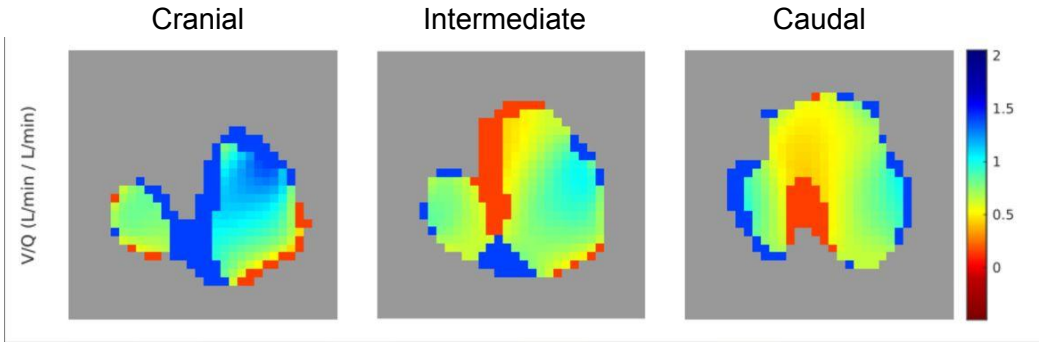
Araos et al, *V/Q analysis with 3D EIT*, Conf EIT 2023

Comparison to Gold Standard



Global changes in V̇/Q̇ mismatch during each study phase. Open circles = gold standard measure, open square = EIT-derived measure. * $p < 0.05$.

V̇/Q analysis with 3D EIT



Abstract: Bedside measurement of V̇/Q matching with EIT has clinical potential. Previous work showed feasibility in 2D, but 3D lung heterogeneity is significant. We show V̇/Q in 3D in pig data. Additionally, analysis software is made available.

References:

[1] JB Borges et al (2012) “Regional lung perfusion estimated by electrical impedance tomography in a piglet model of lung collapse” *J Appl Physiol* 112:225–236

[2] B Grychtol et al (2019) “Thoracic EIT in 3D – experiences and recommendations” *Physiol Meas* 40:074006

[3] J Araos et al (2019) “V̇/Q analysis software", sourceforge.net/p/eidors3d/code/HEAD/tree/trunk/dev/VQ_analyze/