Lung EIT: Should we reconstruct resistivity or conductivity?

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MOTIVATION: In lung EIT, the quantity of interest is the change in regional air volume in the lungs. However, the actual quantity reconstructed is change in a bulk electrical property, usually conductivity, which is not always easy to interpret. In this study, we investigate how the choice of the reconstructed physical quantity affects the properties of the sensitivity matrix and images obtained with linear reconstruction algorithms.

METHODS: We simulate EIT measurements on a 3D finite element model with 16 electrodes in a plane. The model contains two non-conductive objects that represent the lungs. Assuming that lung resistivity is linearly proportional to air volume [1], we divide the lungs into an upper and lower part whose aeration we manipulate. We then reconstruct a difference measurement representing a fixed total tidal volume (0.5 L) distributed between the upper and lower lung area as conductivity (σ), log conductivity ($\log \sigma$) or resistivity (ρ). We present results of 3 simulations with different initial lung aeration and distribution of tidal volume (Figure 1, left), roughly corresponding to a recruitment maneuver. We use the NOSER [2] approach to linear image reconstruction, as implemented in EIDORS, where the sensitivity matrix is calculated either on a homogeneous model or one reflecting the actual initial aeration.

RESULTS: Sensitivity (measurement response to unit change in a single element) varies greatly depending on the physical quantity (unit) reconstructed (Figure 1, right). Sensitivity to conductivity change is highest in non-conductive lung, while the opposite holds for resistivity and (to lesser degree) log conductivity.

Reconstructions using homogeneous background (Figure 2, left) are not affected by the choice of physical quantity and show increased sensitivity to changes in conductive (less aerated) lung areas. In case 3, the uniformly distributed tidal volume appears concentrated in the lower part of the image. When a background is used (Figure 2, right), pronounced differences between the three approaches emerge. Resistivity reconstructions recover the tidal volume distribution accurately, while log conductivity and conductivity reconstructions remain skewed towards conductive lung areas. They also show a variability in image amplitude not reflecting changes in total tidal volume.

CONCLUSION: Lung EIT images reconstructed without regard for the non-homogeneous distribution of conductivity in the thorax are a poor reflection of the distribution of tidal volume changes. When a realistic background conductivity is used, more accurate images can be obtained, depending on the choice of reconstructed quantity and reconstruction algorithm.

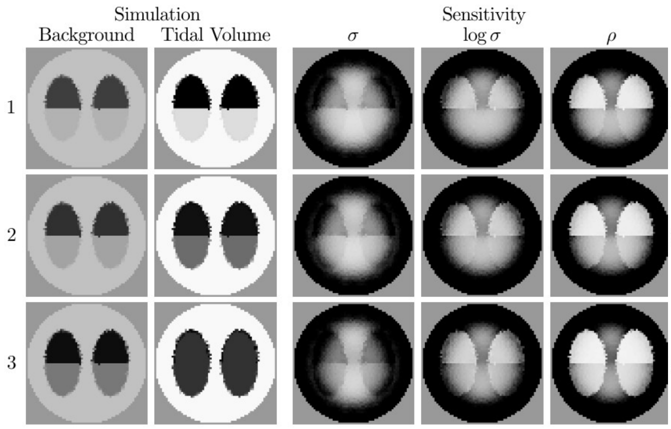

Figure 1: Simulation setup and measurement sensitivity.

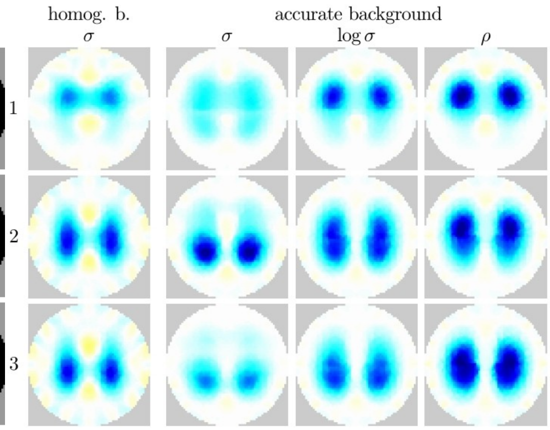

Figure 2: Reconstructions.

[1] Nopp, P., Harris, N. D., Zhao, T. X., & Brown, B. H. (1997). Model for the dielectric properties of human lung tissue against frequency and air content. Medical & biological engineering & computing, 35(6), 695–702.
[2] Cheney, M., Isaacson, D., Newell, J. C., Simske, S., & Goble, J. (1990). NOSER: An Algorithm for Solving the Inverse Conductivity Problem. International Journal of Imaging Systems and Technology, 2(2), 66–75.