What is the Slice Thickness of a 2D EIT Image of the Lungs?

Robert P, Patterson[1], Jie Zhang[2], and Fei Yang[3]
1. Department of Physical Medicine and Rehabilitation and Institute for Engineering in Medicine, University of Minnesota, Minneapolis MN USA (patte001@umn.edu)
2. Department of Radiology, University of Kentucky, Lexington, KY 40536 USA
3. School of Medicine, Washington University in St. Louis, St. Louis, MO 63110, USA

INTRODUCTION Many studies have reported clinical success in measuring ventilation using 2D EIT imaging of the lung. Recent studies have shown that using EIT to monitor ventilator dependent patients appears to have much promise (Frerichs et al. 2006). Its application allows a possible view of regional ventilation that is dependant on the amount of positive end expiratory pressure (PEEP). A question remains concerning the thickness of the lung slice that contributes to the image. Using a model, this study attempts to answer that question.

MEDHODS A thoracic model was created from human MR images that were obtained with a 1.5T Siemens Sonata scanner. A total of 43 transverse images were obtained from abdomen to neck and ECG gated to coincide with end-diastole. The images were digitized at a spatial resolution of 1.5 mm/pixel in lateral (right-left) and anterior-posterior directions. The resolution in the cranial-caudal direction was 5 mm/pixel identical to the MRI slice thickness. Upon segmentation, thirty-six tissue types and blood containing regions were obtained. Each tissue was assigned an appropriate electrical resistivity. A 3D electrical model of the thorax at the end of diastole was thus created, with a resolution of $1.5 \times 1.5 \times 5 mm^3$ and 3.8 million elements. The model was solved using a finite difference program developed in our laboratory (Belalcazar A and Patterson 2004, Yang and Patterson 2010).

In order to answer the question about lung slice thickness, 16 electrodes were place around the thorax in eight positions above and below the mid thorax level over a distance of eight cm. The array was placed at layer level 15, 17, 19, 21, 23, 25, 27and 29. The resistivity of the lungs was changed from 1400 to 1000 ohm-cm. The images for each of the eight locations were calculated using both back projection (Brown and Seagar, 1987) and EIDORS. A second test using the same electrode locations, but with only the lower four cm of the lungs (layers 21-29) changed to 1000 ohm-cm.

The areas and average resistivity change resulting from the lung modifications were calculated using 40% and 80% of the maximal change averaged over 10 pixels.

RESULTS Figure 1 shows the results for the entire lungs changed from 1400 ohm-cm to 1000 ohms-cm as function of electrode position using back projection for reconstruction. Figure 2 shows the same thing using EIDORS for reconstruction. Fig 3 shows the results with the lower region of the lungs modified.

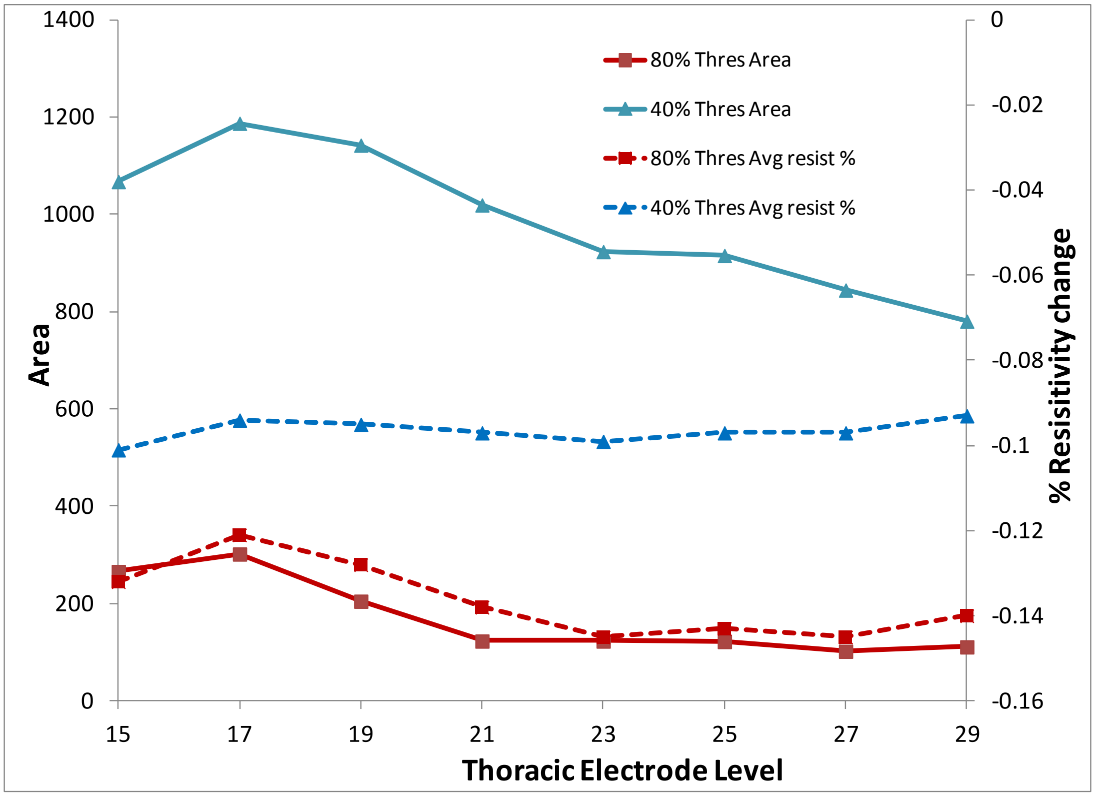

Figure 1 Using back projection the change in lung area and percentage change in resisitivity as function of electrode band level when lung resistivity was changed from 1400 to 1000 ohm-cm. Level 21 is mid-thorax and the typical location for the electrodes.

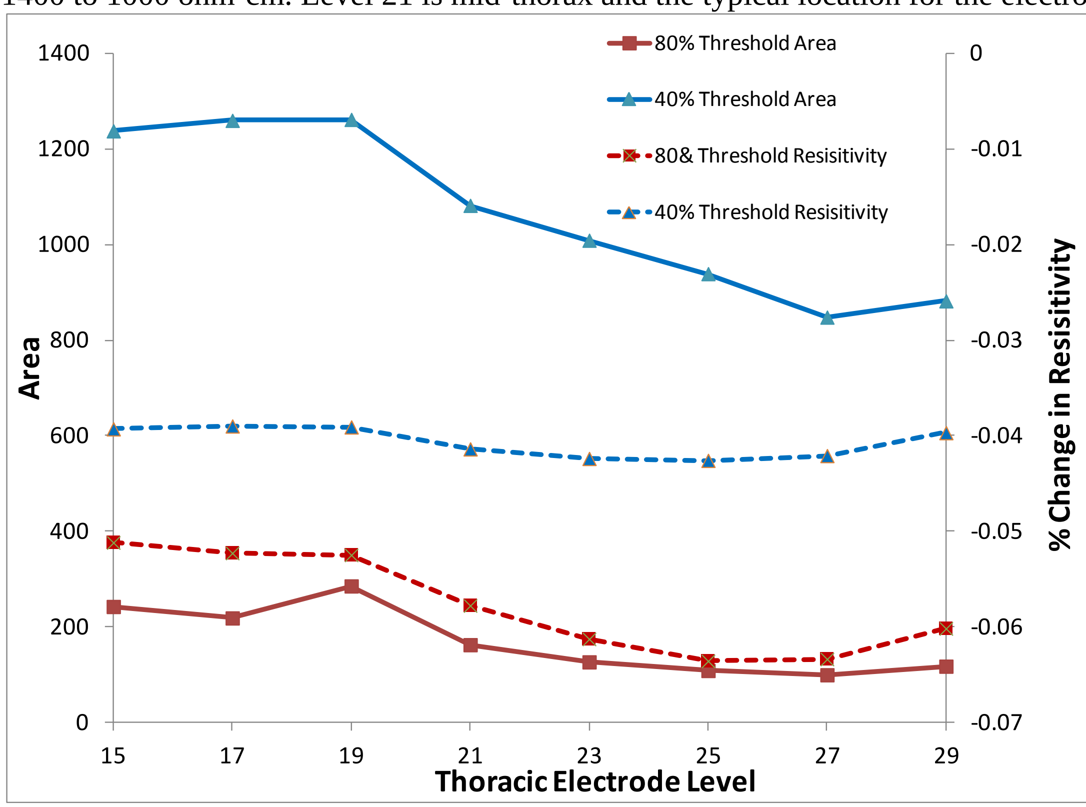

Figure 2 Same conditions as in Figure 1, but reconstructed using EIDORS.

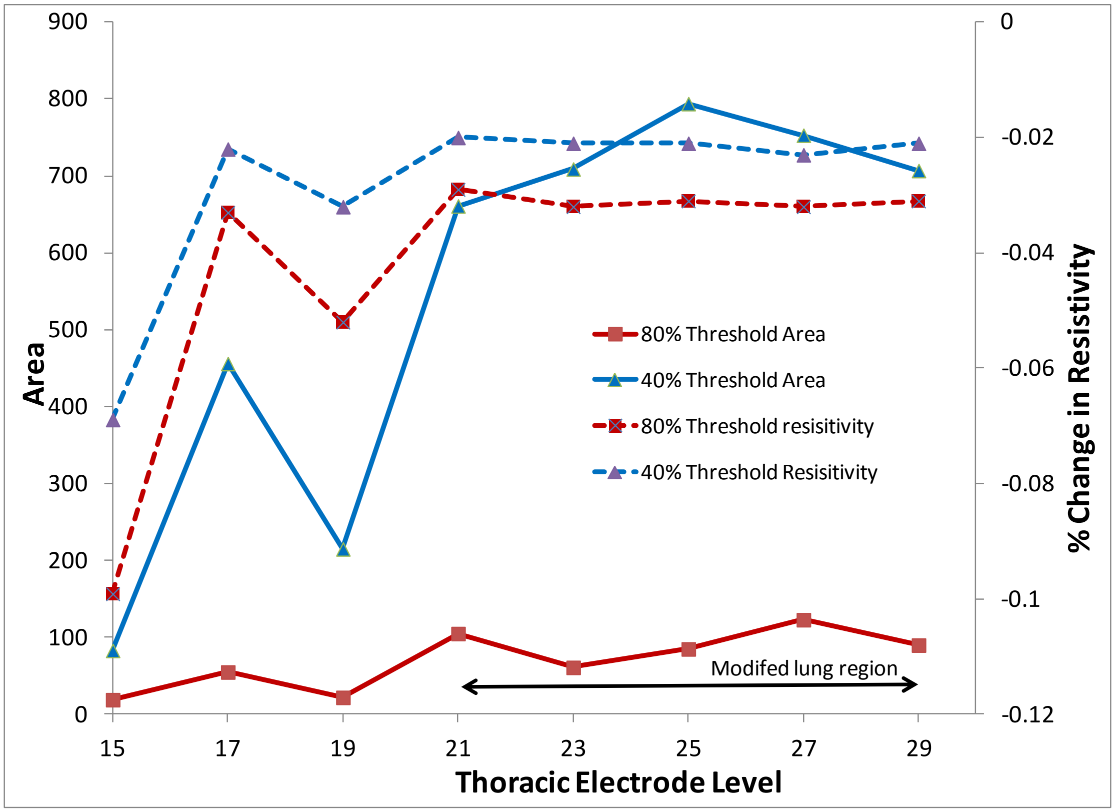

Figure 3 Using back projection the change in lung area and percentage change in resisitivity as function of electrode band level when lung resistivity was changed from 1400 to 1000 ohm–cm only in the lower level of the lung. Level 21 is the mid-thorax level and the typical location for electrode placement.

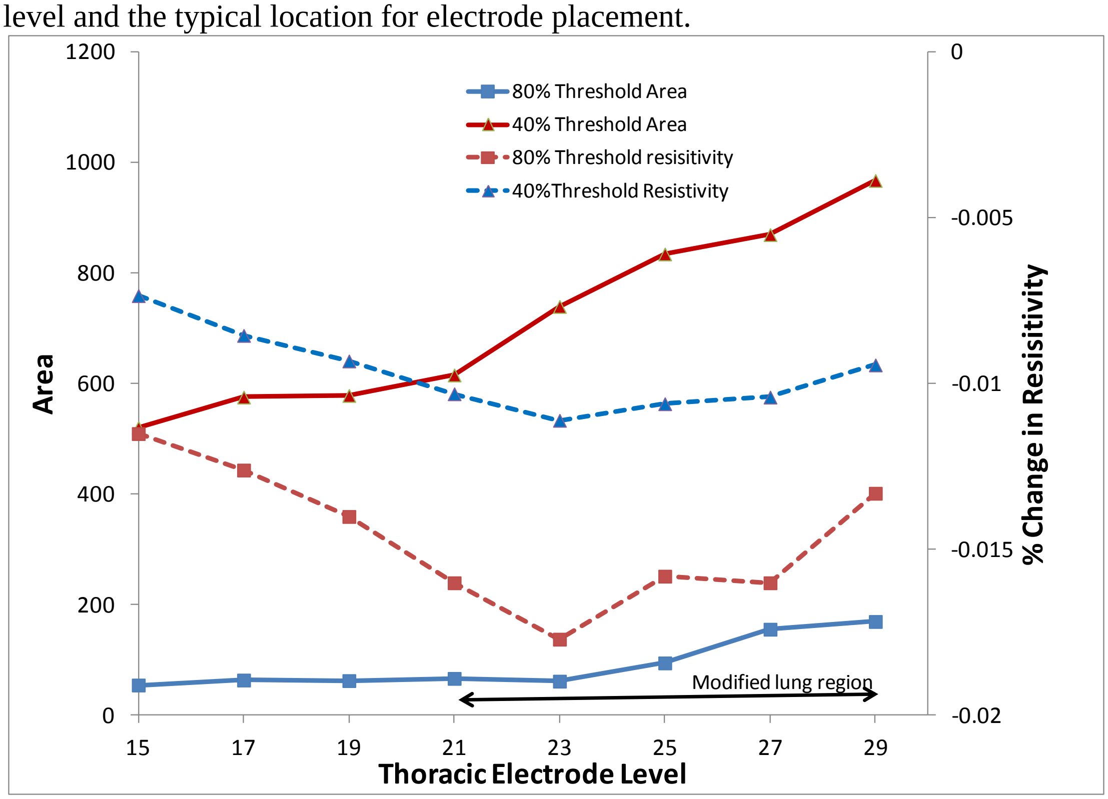

Figure 4 Same conditions as in Figure 3, but reconstructed using EIDORS.

DISCUSSION The changes that appeared on the reconstructed image resulting from modifying the resistivity of the entire lung shows only small differences as the electrode array was moving in the cephalic and caudal directions over a distance of eight cm, with a slight decrease in the area when moving in the caudal direction. The change in area in the caudal direction was opposite of the actual lung tissue area. This was true for both the back projection method and EIDORS.

When only the lower area of the lungs was changed, there was a significant change when the electrode array was outside of the modified lung resistivity region, but showed a smaller change as the electrodes were moved over the region of modified lung resistivity. Outside of the region with changed lung resistivity, the performance of the two reconstruction algorithms was very different.

In general, the results suggest that the thickness of the 2D lung image is relatively large.

References

Adler A, Arnold J H, Bayford R, Borsic A, Brown B, Dixon P, Faes T J C, Frerichs I, Gagnon H,Gaerber Y, Grychtol B, Hahn G, Lionheart W R B, Malik A, Patterson R P, Stocks J, Tizzard A, Weiler N and Wolf G K 2009 Physiol. Meas. 30, S35-S55.

Belalcazar A and Patterson R P 2004 Physiol. Meas. 25, 475-487.

Brown B H and Seagar A D 1987 Clin. Phys. Physiol. Meas. 8, 91-97.

Cheney M, Isaacson D, Newell J C, Simske S and Goble J 1990 Int. J. Imaging Syst. Technol. 2(2), 66-75.

Frerichs I, Scholz J and Weiler N 2006 Springer Berlin Heidelberg chapter 10: Electrical Impedance Tomography and its Perspectives in Intensive Care Medicine, pp. 437-447.

Yang F and Patterson R 2010 in `Proceedings of the 32nd Annual International Conference of the IEEE Engineering in Medicine Conference' Buenos Aires, Argentina pp. 3105-3108.