Influence of different thorax models on anatomical precision of EIT

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Abstract: To study the anatomical precision of EIT images, we compared 2D, 2.5D and 3D thorax models of varying complexity for EIT data of a healthy and an injured lung. We determined the lung shape as the averaged tidal image for several breaths. The overlap was computed for a reference CT shape. A 3D subvolume of the lung with large anatomical complexity achieves the best overlap scores for most cases.

1 Introduction

It is a general understanding in the EIT community that patient-specific models are necessary to reduce artifacts, noise and anatomical uncertainty in EIT images, especially concerning the lung and heart shape. With this study we aim to quantitatively compare a large variety of body models in terms of overlap of lung and heart shapes in EIT images with the respective shapes in reference CT data. We formulated several research questions. What is a better reference: a CT slice, as used by Ferrario et al. [1], or a projection of the 3D lung shape into the electrode plane? How do models of different dimensionalities and anatomical complexities compare? Is there a difference in heart overlap precision for mechanical ventilation, apnoe, and saline bolus injection? We used CT and EIT data from one pig. CT data were recorded before and after the lung injury. EIT datasets include mechanical ventilation before and after the lung injury, a lowflow maneuver, and a phase of apnoe, followed by a saline bolus injection.

2 Methods

Each set of models was generated with different anatomical complexities, starting with the thorax shape, adding lung and heart shape, known pathological lung regions, and finally major blood vessels. 2D models were computed using *distmesh*, while EIDORS was used for the 2.5D models. 3D models were computed as described in [2]. Also, 3D models from only ten CT slices of the whole lung were generated, as well as a subset of the lung extending to 3 cm above and below the electrode plane.

After image reconstruction with GREIT, we separated the ventilation and perfusion signals using the method by Deibele et al. [3]. As anatomical reference both the CT slice closest to the electrode plane and a weighted projection of the whole thorax into this plane were used. Thorax shapes of EIT and CT images were registered to properly compare the overlap. To extract the shape of the lung function from the EIT images, we averaged the tidal images for each breath during a period of 40 seconds during each EIT recording. The fraction of EIT pixels overlapping with the CT shape was computed with the formula used by Ferrario et al. [1]. Similar to their approach, we thresholded and thereby reduced the size of the tidal image until an overlap of 50%, 75%, and 90% was achieved (compare Figure 1). We assume that the lower the threshold necessary to achieve a large overlap, the better the image quality and the anatomical precision of the body model. The heart shape was determined as the largest ventral cluster of pixels with strong signal changes over time in the perfusion signal.

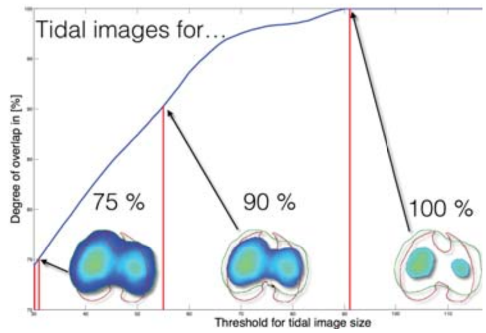

Figure 1: The tidal image thresholds to achieve 75%, 90%, and 100% lung overlap for the 3D subvolume model.

3 Results

The reference slice achieves much better lung overlap scores than the projection, but performs very poorly for the heart overlap due to the small heart shape in the slice (see Conclusion). Compared to the reference slice, 2.5D models achieve the best overlap, very closely followed by the 6 cm subvolume. For the reference projection, 2D models and the 6 cm subvolume perform best. Models of high complexity (using thorax, lung, heart and pathological lung shape) perform better than simple models. The heart overlap during apnoe is almost identical to the saline bolus dataset. During ventilation, the heart overlap is even slightly better than during bolus injection.

4 Conclusion

Our results indicate that the overlap formula is not very well-suited since only the fraction of EIT pixels inside the reference shape is considered. Thus, a small EIT shape that lies completely within the reference shape, but only covers a small part of this shape, achieves very high overlap scores. Vice versa, a large EIT shape gets very low overlap scores if the reference shape is very small (as is the heart shape in our CT reference slice). We will investigate a formula that also incorporates the fraction of the reference shape that is covered by the EIT shape.

References

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