Focusing EIT reconstructions using two electrode planes

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Abstract: EIT of the thorax has traditionally used a single electrode plane, and is sensitive to contrasts above and below the plane. It may be possible to improve (focus) the sensitivity using a two-plane placement of EIT electrodes. In this work, our objective is, first, to understand the impact of electrode placement and reconstruction parameter choices in simulations, and then to study these in experiments in horses. Pilot results show good images and slice sensitivity.

1 Introduction

Most clinical and experimental EIT studies for lung imaging have used a single plane of electrodes[1], which is sensitive to conductivity changes within about $\frac{1}{2}$ of the body diameter. This can interfere with EIT interpretation if image regions represent an average over a large volume, or if images are sensitive to out-of-plane effects such as movement of organs in the abdomen. To address both effects, 3D EIT reconstruction using two planes shows promising results [2, 3]. However, such work for lung EIT has mostly given example images, and not systematically evaluated how to choose various configuration details, or their robustness. Our *hypothesis* is that a 2-plane electrode placement for EIT can give improved 2D cross-sectional images, versus a single plane placement of the same number of electrodes. Here, we do not focus on 3D imaging; instead, we seek to take a first step: to see if two-plane electrode placement can give better 2D images.

We evaluated data measured from a horse model (Fig. 1A). Due to their size and specific anatomy, horse lungs are more exposed to gravity-related pressure changes during anaesthesia, and their large abdominal organs with huge amounts of gas lie, in a diagonal fashion, directly ventral to main parts of the lung. Thus, as the diaphragm moves backwards and forward during inspiration and expiration, air is moved in and out of the plane of interest. Clinically, equine asthma is a very common disease with enormous diagnostic challenges, which introduces patchy inhomogeneous changes to lung function. Better resolution would make EIT an improved diagnostic tool.

2 Methods and Results

For a pilot study, an EIT electrode belt was developed to allow combined placement of both: (1×32) 32 electrodes in a single plane, and (2×16) two planes of 16 electrodes, each separated by 12 cm from the single plane and arranged in a "square" pattern[2]. Using the Swisstom BBVet system, data were acquired during quiet tidal breathing and reconstructed with GREIT[2] for 1×32 (Fig. 1B), and then 2×16 (Fig. 1C).

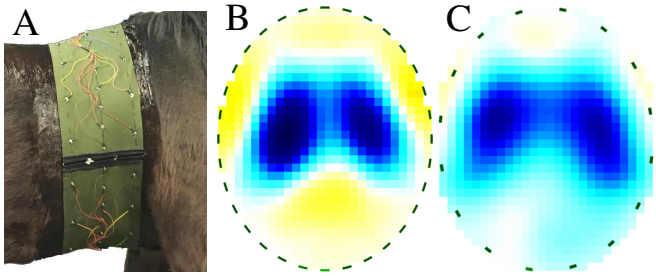

Figure 1: Horse with electrode belt system (A) and tidal ventilation images with 1×32 (B) and 2×16 (C) electrode configurations.

To understand the behaviour of a two-plane EIT, many details of the configuration need to be investigated, including: *1*) separation between planes, *2*) electrode stimulation and measurement pattern, *3*) regularization hyperparameter (via the noise figure, NF), and *4*) penalty for off-plane targets in the reconstruction. In Fig. 2, we study details *#1* and *#3*.

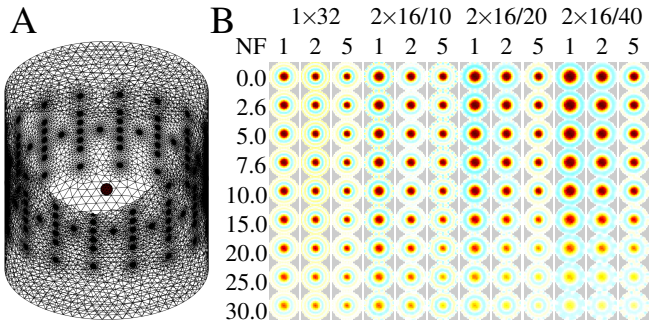

Figure 2: Off-plane rejection as a function of plane spacing (10, 20, 40 cm) and the hyperparameter (NF), using GREIT [2], and skip 4 square pattern. Images (B) show the central slice between the electrode planes in reconstructions of a small spherical target at various distances (in cm) above the cylindrical model centre (A) (h=100 cm).

We find that the 2×16 arrangement offers better off-plane contrast rejection than 1×32, with greater electrode plane separation producing greater improvement. At the same time, for the same NF, greater separation results in lower resolution.

3 Conclusion

Here, we study whether a 2×16 electrode configuration can outperform the traditional 1×32. Initial results appear promising, both in terms of robust images and improved rejection of off-plane contrasts.

References

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