Validation and parameter selection for the GREIT reconstruction algorithm

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Introduction

One of the most promising applications of EIT is to monitor the regional distribution of ventilation in mechanically ventilated patients. Based on EIT images, ventilation strategies could be optimized to hopefully improve gas exchange, recruit atelectatic areas, minimize regional overdistension and therefore reduce ventilator induced lung injury. One key limitation is that the majority of clinical and experimental EIT research has been performed with the Sheffield backprojection reconstruction algorithm developed in the early 90's; this is an obstacle to interpretation of EIT images because the reconstructed images are not well characterized. To address this issue, we are developing a consensus linear reconstruction algorithm for lung EIT, called GREIT (Graz consensus Reconstruction algorithm for EIT). The goal of GREIT is to develop a consensus on the desired properties of a linear reconstruction algorithm, and implement an approach to achieve a good fit to these properties. This paper describes the GREIT image reconstruction framework developed, and current work to choose select values for algorithm parameter to provide stable and accurate clinical images.

GREIT Image Reconstruction Framework

The framework developed[1] consists of: 1) detailed finite element models of a representative adult and neonatal thorax; 2) consensus on the performance figures of merit for EIT image reconstruction; and 3) a systematic approach to optimize a linear reconstruction matrix to desired performance measures (Fig. 1, Left). The consensus figures of merit (Fig. 1, Centre) in agreed order of importance, are: a) uniform amplitude response (AR), b) small and uniform position error (PE), c) small ringing artefacts (RNG), d) uniform resolution (RES), e) limited shape deformation (SD), and f) high resolution (RES). As shown in Fig. 1 (Right), GREIT is able to achieve more uniform spatial resolution with low ringing at the expense of a decrease in spatial resolution near the boundary.

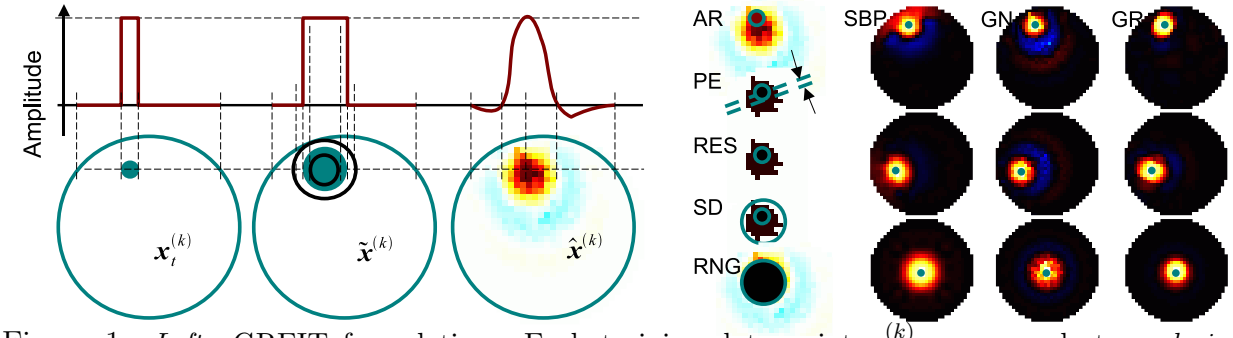

Figure 1: *Left:* GREIT formulation. Each training data point $\mathbf{x}_t^{(k)}$ corresponds to a *desired response*, $\tilde{\mathbf{x}}^{(k)}$, and a reconstructed image, $\hat{\mathbf{x}}^{(k)}$; *Centre:* Figures of merit calculated from $\hat{\mathbf{x}}^{(k)}$; *Right:* Example reconstructed images for three different targets from Sheffield Backprojection (SBP), a NOSER type Gauss-Newton solver (GN), and GREIT (GR).

Selection of parameter values

Several parameters in the GREIT framework need to be determined based on a careful evaluation strategy: 1) training noise levels, 2) model accuracy, 3) the use (or not) of normalized difference imaging, 4) parameter settings for movement compensation, and 5) assumptions about the reference conductivity of the thorax.

In this section, we illustrate the effect of one parameter with a significant impact on reconstructed images: the reference conductivity of the thorax. While most time-difference EIT images of the lungs assume a homogeneous conductivity distribution, this is clearly not valid for the thorax. The homogeneous assumption tests to "squeeze" the lung images together. Fig. 2 shows images of tidal volume in a pig lung injury model (data from [2]) and the effect of the reference conductivity parameter. Interestingly, the effect of changing the reference conductivity is different for 2D and 3D models, which underlines the importance of using accurate FEM models.

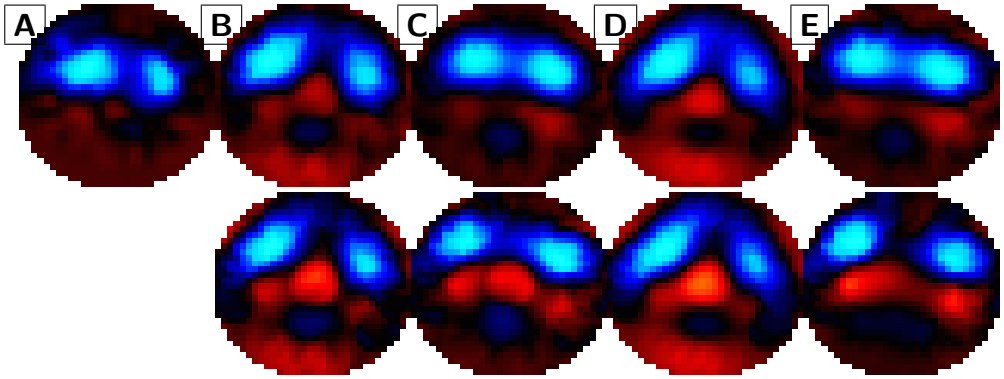

Figure 2: Images of tidal volume in lung-injured piglet during a recruitment manouvre at PEEP=10cmH_2O (data from [2]) using different reconstruction algorithm parameter values. All algorithms are normalized to have the same noise performance as Sheffield Backprojection. *Top Row:* Uniform reference conductivity *Bottom Row:* Central region conductivity of 0.3×reference. *A:* Sheffield Backprojection *B:* GREIT (3D model, normalized difference) *C:* GREIT (3D model, difference) *D:* GREIT (2D model, normalized difference) *E:* GREIT (2D model, difference)

Clinical and experimental evaluation of GREIT is being performed in order to choose appropriate algorithm values, and evaluate image reconstruction performance with clinical data collected from ventilated subjects. A collection of clinical and experimental data has been assembled from animal and human studies in neonates, children and adult patients in Canada, Germany, UK and USA. Evaluation will consist of reconstructing images with variants of GREIT, and asking experts to score the images. One concern with any new medical imaging algorithm is its performance in the presence of data artefacts. With experience, such artefacts can be identified in the images; thus, another goal of GREIT evaluation is to develop a set of heuristics to detect such data errors.

Discussion

The goal of GREIT is to develop a well characterized 2D linear difference EIT algorithm for lung imaging. We seek to develop a robust algorithm which incorporates the key developments in EIT lung image reconstruction. Our experience to date with GREIT shows improvements in resolution of image features as well as reduced image artefacts when compared with an implementation of the Sheffield backprojection algorithm. In order to facilitate use of GREIT, all software and data to implement and test the algorithm have been made available on the internet at eidors.org/GREIT under an open source license which allows free research and commercial use.

References

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[2] Frerichs I Dargavillle PA Dudykevych T Rimensberger PM (2003) *Int Care Med* 29:2312-6