Resolution as a function of Stimulation and Measurement Patterns

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Abstract: Pair-drive EIT systems can be described by a *skip* parameter – the separation between excitiation and measurement pairs. A larger skip distance increases the current flow through the centre of the body and thus improves the distinguishability of the EIT images. Low skip values improve resolution. We discuss the origin of this result.

1 Introduction

Most EIT systems use pair drive and measurements: current is applied between electrodes separated by $skip_{\mathrm{stim}}$ and voltage is measured separated by $skip_{\mathrm{meas}}$. In this scenario the adjacent (Sheffield) configuration is $skip_{\mathrm{stim}} = skip_{\mathrm{meas}} = 0$. A number of authors have looked at the distinguishability of EIT and shown that it increases as a function of *skip* [2–4]. However, our experience shows that stimulation and measurement patterns (SMP) which maximize distinguishability do not show the best resolution.

For example, Fig 1 shows typical images with adjacent and larger skip patterns. Left shows better lung separation, but also a central inverse region.

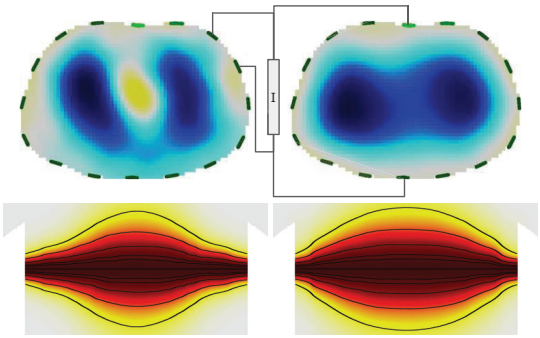

Figure 1: *Top*: Tidal breathing in healthy subject for different SMP. Left: $skip_{\mathrm{stim}} = skip_{\mathrm{meas}} = 0$. Right: $skip_{\mathrm{stim}} = 7$, $skip_{\mathrm{meas}} = 0$. *Bottom*: Vertical sensitivity in coronal plane; contour lines show sensitivity fraction of maximum: 25%, 50%, 75%, 90%, 95%.

The goal of our study is to explore this unexpected result: why do adjacent SMP have improved resolution but decreased distinguishability compared to larger skip patterns. Fig 1 (bottom) shows adjacent patterns have lower off-plane sensitivity [1]. These lung regions are "pushed" toward the image centre, and this effect increases with skip.

2 Methods and Results

Difference EIT reconstruction estimates an image (2D for this paper) $\hat{\mathbf{x}} = \mathbf{R}_{\mathrm{SMP}}\mathbf{y}$, from difference measurements $\mathbf{y}$ and a SMP-dependent reconstruction matrix $\mathbf{R}$.

Our calculations of image resolution vs SMP are shown in Fig 2. The *distinguishability* of EIT has been defined as area-weighted image amplitude $\sum_A \hat{\mathbf{x}}$ for a small contrast (Fig 2B). This parameter varies with spatial position and is largest near the electrodes. Image resolution can be defined by the ability of EIT to resolve high spatial-resolution features. Fig 2C and 2D show horizontal and vertical circles split into positive and negative halves.

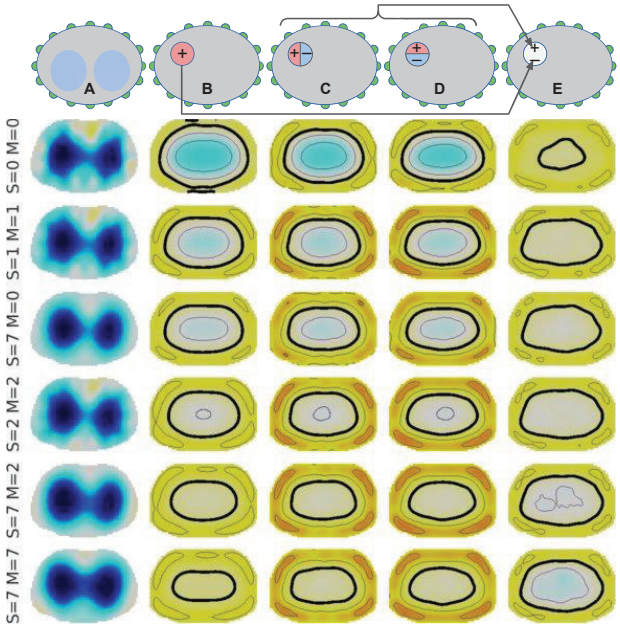

Figure 2: Distinguishability and resolution for several SMP (Stim(S) and Meas(M) skip at right). From left to right: amplitude image, distinguishability, horizontal and vertical resolution and ratio (resolution/distinguishability). The top row illustrates the calculation: each circle in rows B–E is swepth across the image to each pixel location. Colours correspond to log-sensitivity (yellow larger, blue smaller) Contour lines and shown with a bold reference level across images.

Reconstruction of such a target requires resolution. Finally, the ratio between resolution and distinguishability is shown in Fig 2E. Several features can be seen in Fig 2. First, in the amplitude image, we see poor resolution as skip increases. The adjacent (S=0,M=0) protocol has low distinguishability and a higher resolution, but has a larger ratio in the center (2E). Conversely, as skip increases, the ratio decreases in the center, even as the overall distinguishability and resolution increase.

3 Discussion

We consider the paradoxical result that adjacent SMP give often improved resolution images, while providing overall poor distinguishability. Here we show a measure of resolution based on nearby contrasts, and calculate the distinguishability/resolution ratio. Also, increased off-plane sensitivity at higher skip values "projects" more lung regions to the centre, and may also explain this effect.

References

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