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Author(s)	McDermott, Barry; Porter, Emily; Jones, Marggie; McGinley, Brian; O'Halloran, Martin
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ELECTRICAL IMPEDANCE TOMOGRAPHY WITH EXPLOITATION OF SYMMETRY

McDermott, B.[1], **Porter, E.**[1], **Jones, M.**[1], **McGinley, B.**[1], **O'Halloran, M.**[1]
[1] Translational Medical Device Lab, National University of Ireland, Galway
email: b.mcdermott3@nuigalway.ie

INTRODUCTION

Electrical Impedance Tomography (EIT) is an imaging technique involving an electrode array positioned around the area of interest. Alternating current is injected, and voltage measured, between electrode pairs in a prescribed pattern to produce a measurement set. This set is then processed to generate an image of the area. EIT has several potential biomedical applications including thoracic and neural imaging. Different EIT variants exist with most success being in the production of time difference images. Generation of absolute images (i.e., images generated from a single measurement time) is challenging due to the sensitivity of EIT to errors such as those of electrode placement. This challenge makes imaging of static or very slowly changing scenes, such as those featuring a tumour or an established haemorrhage, very difficult with EIT. In this work, the natural symmetry of an anatomy, such as the sagittal symmetry in the human head, is used to create a difference image without a time change. Measurements are taken from both mirror images of the scene with the difference of the sets processed to produce an image highlighting any deviations in symmetry. This proposed technique allows detection of unilateral pathologies, such as, for example, a bleed in stroke patients.

MATERIALS AND METHODS

An anatomically accurate numerical model of the head was produced with a single ring of 16 EIT electrodes positioned symmetrically across the sagittal plane. Spherical perturbations modelling haemorrhages were positioned inside the brain compartment of the model. EIT simulation software (EIDORS) was used, and modified, to generate two measurement sets simultaneously from the ring in both clockwise and counter-clockwise (i.e. symmetrical) orientations. These two sets were differenced and processed to produce an image of the plane of the ring, with differences in symmetry being detected and quantitatively analysed for significance. Different scenarios were studied: bleeds were simulated as 2 ml, 10 ml, 20 ml and 30 ml volume spheres at a variety of locations in the brain and at noise levels from 10 dB to 80 dB signal to noise ratio (SNR).

RESULTS

The algorithm performed best for perturbations that were larger, near the exterior of the brain and at high SNR. Quantitative metrics were applied to the resultant image to give an objective measure of performance:

1. Percentage Symmetry (PS) of the image across the midline: ideally 0 if no perturbation and 1 if one present.
2. Centroid Location Difference (CLD): calculated based on the centroid locations of the largest regions of interest on both sides: ideally 0 if perturbation present.
3. F1 Score: compares the expected and actual locations of pixels: 0 indicates an extremely inaccurate image and 1 being perfectly accurate.

In the example shown in Fig. 1, the PS was 0.88, the CLD was 1.4 pixels, and the F1 score was 0.90, indicating strong detection of a bleed in the appropriate hemisphere.

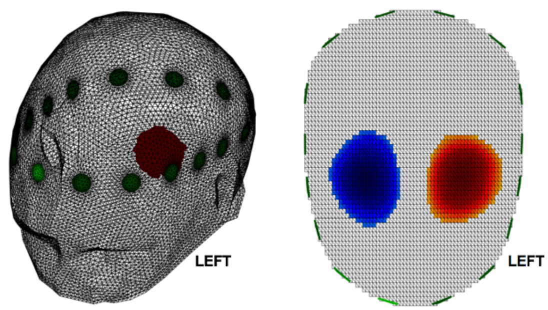

Figure 1 Left: Numerical model of the head with spherical lesion modelling a 20 ml haemorrhage (red) on the left side of the brain, in the electrode ring plane (green). Internal layers of the head are hidden in the image for clarity. Right: The resultant image produced from the clockwise and counterclockwise EIT measurements of the scene at a SNR of 80 dB. The deviation in symmetry indicates presence of a bleed on the left or an inverted perturbation on the right.

DISCUSSION

This new variant of EIT has been shown in simulation experiments to be able to detect static unilateral pathologies in situations where there is a natural line of symmetry in the image. This method will support successful EIT imaging in important diseases such as stroke, where rapid lesion identification allows prompt initiation of treatment.

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