About monitoring wound size with time difference EIT

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Abstract: Electrical Impedance Tomography (EIT) is a non-invasive imaging technique, mainly applied to lung function monitoring. To determine its suitability to monitor healing dynamics of a wound, in a first step the time difference method (tdEIT) is applied to a cavity in a petri dish containing a thin layer of saline gelatin. The position error (PE) and area error (AE) for reconstructed tdEIT images were calculated for different frequencies and hyperparameter values. Evaluation of PE and AE shows that images reconstructed using hyperparameter range 0.005- 0.01 and higher frequencies produce more accurate results. Further studies are necessary with human 3D-tissue samples.

I. Introduction

Wound treatment is an important medical problem. As of 2012, chronic wounds were having a prevalence of 786,407 and incidence of 196,602 where the frequency is increasing every year [1]. Thus, there remains a need for wound treatment interventions which may improve healing time. In-vitro experiments are being conducted to determine characteristics of the wound healing processes under technical stimulation like Photobiomodulation (PBM), Negative pressure wound therapy (NPWT) and electrical stimulation (ES) [2,3]. Efforts are being made for speeding up the healing process. To embed such stimulation into a closed loop control system, a monitoring technique needs to be established [2]. Since electrodes are already available for stimulation this project investigates if they can be used for monitoring the wound healing process.

Electrical Impedance Tomography (EIT) is a real-time and cost-effective medical imaging technique that has no known harmful side effects on living tissues. There are multiple medical applications that exist, which extend from brain imaging to pulmonary monitoring [4,5]. It visualizes regional changes in electrical conductivity, that are determined by injecting low intensity low frequency (in kHz range) currents between two electrodes, and then measuring induced voltage differences among the rest of the remaining electrode pairs.

EIT might be suitable for the monitoring of a wound and its healing dynamics. The purpose of the research was to determine the possible use of tdEIT to evaluate healing dynamics of a wound in *in-vitro* experiments [2]. Skin, a multilayer organ is a primary component of gelatin. A thin layer of gelatin was considered for the initial experiments.

II. Material and methods

As a first step, experiments were conducted in a petri dish of diameter 90mm to evaluate tdEIT behavior in a thin medium (saline gelatin mix with salinity 10 mS/cm) of 2 mm thickness. 16 electrodes were placed on the circumference of the petri dish with electrode tips inside this medium. These electrodes were connected to the electrode port of the switching relay circuit via a 32-pin bus. The switching relay circuit was powered by 12V supply and its sensor port was connected to the Swisstom sensor belt (Pioneer Set, Swisstom, Landquart, Switzerland). This sensor belt was connected to the laptop via the Swisstom interfacing module.

The EIT data was collected with the Swisstom EIT software (STEM). Multiple frequencies (45 kHz, 71 kHz, 111 kHz, 156 kHz and 195 kHz) were used for EIT data collection. The input current was fixed to 8mA, as for a value below it, the hardware could not differentiate between connected and disconnected electrodes owing to high impedances present between the electrodes. The first set of measurements was collected for the medium without any cavity.

A cavity was made having a diameter of 18mm with its center at 23 mm from electrode no 5 towards the center of the petri dish. The second set of measurements was collected for the medium with this cavity. A measurement was taken for every of the 5 frequency mentioned above.

tdEIT images were reconstructed with the Eidors (v3.9.1) toolbox in MATLAB R2019 (Mathworks, MA, USA). Primarily 'MK_COMMON_MODEL' function and other parameters for 2d circular EIT reconstruction were used. During reconstruction of tdEIT images, different values for the regularization hyperparameter ('0.005', '0.001', '0.05', '0.01') were tested to explore the sensitivity of the approach to regularization. EIT data files of same frequencies were paired from both the first and second set to obtain the tdEIT images.

Subsequently, for image analysis only the blue color component was used. Thresholding (value was set to '0.15') and boundary detection algorithms were applied for segmentation. Area error (AE) and the position error (PE) were computed with reference to the true area and position.

III. Results and discussion

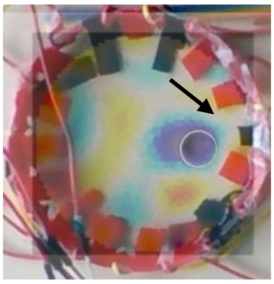

Figure 1: Superimposed image of an tdEIT image on petri dish with the white circle drawn to depict the cavity.

In Fig 1, the tdEIT reconstructed image is superimposed on the petri dish to display an example of a cavity detection. Figure 2 shows an array of images produced for different hyperparameter values and frequencies. The reconstructed tdEIT images were analyzed for area error (AE) and position error (PE) which are depicted in Fig. 3 and 4.

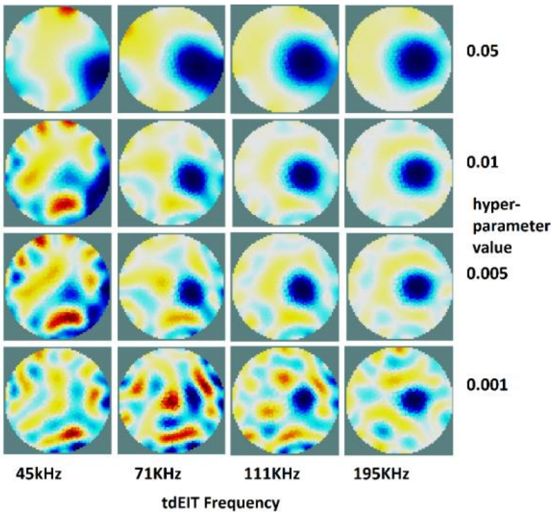

Figure 2: Reproduced EIT images for different hyperparameter values and frequencies.

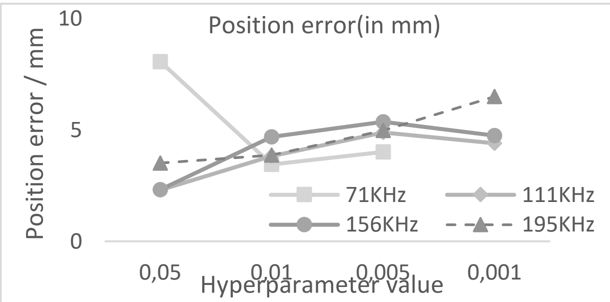

Figure 3: Position Error of tdEIT images when compared with actual cavity position for different hyperparameter values and frequencies.

As indicated in fig 3, the position error is found to be the highest for lower frequencies. For higher frequencies(111-195Khz), however, the PE is low for higher values of hyperparameter. The PE increases with reducing slope as the value of hyperparameter reduces to ‘0.001’ or lower. For hyperparameter value ‘0.001’ and ‘0.005’, the lower frequencies(45kHz) are unable to reproduce a detected cavity area and thus the PE or AE for these values is unavailable.

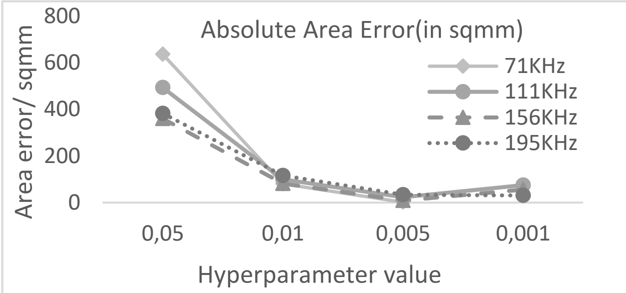

Figure 4: Area Error of tdEIT images when compared with actual cavity area for different hyperparameter values and frequencies.

The actual area of the cavity is 308 sqmm. As indicated in fig 4, the Area error is found to be the highest for higher values of hyperparameter. The area error for all the frequencies reduces with decreasing hyperparameter values till 0.005. Further reduction of the hyperparameter may cause severe shrinking of the region of interest and thus increase the Area error. For 45kHz, neither PE nor AE can be determined in a meaningful way which is obvious from Fig 2.

IV. Conclusions

The best hyperparameter values for the given setup are ‘0.01’ and ‘0.005’, whereas frequencies 111Khz and greater produce better results evaluating the AE and PE. There could be more accurate boundary detection and automatic segmentation methods developed that could provide different results. Considering the specific composition and properties of skin could be carefully emulated in gelatin medium for better accuracy before experimenting on real skin. Frequency difference EIT (fdEIT) images could be produced for further in-vitro experiments

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AUTHOR’S STATEMENT

The authors declare that there are no conflicts of interest.

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