Electrical impedance tomography methods for miniaturised 3D systems

In this study, we explore the potential of electrical impedance tomography (EIT) for miniaturised 3D samples to provide a noninvasive approach for future applications in tissue engineering and 3D cell culturing. We evaluated two different electrode configurations using an array of nine circular chambers (ø 10 mm), each having eight gold plated needle electrodes vertically integrated along the chamber perimeter. As first method, the adjacent electrode configuration was tested solving the computationally simple back-projection algorithm using Comsol Multiphysics in time-difference EIT (t-EIT). Subsequently, a more elaborate method based on the "polar-offset" configuration (having an additional electrode at the centre of the chamber) was evaluated using linear t-EIT and linear weighted frequency-difference EIT (f-EIT). Image reconstruction was done using a customised algorithm that has been previously validated for EIT imaging of neural activity. All the finite element simulations and impedance measurements on test objects leading to image reconstruction utilised an electrolyte having an ionic strength close to physiological solutions. The chosen number of electrodes and consequently number of electrode configurations aimed at maximising the quality of image reconstruction while minimising the number of required measurements. This is significant when designing a technique suitable for tissue engineering applications where time-based monitoring of cellular behaviour in 3D scaffolds is of interest. The performed tests indicated that the method based on the adjacent configuration in combination with the backprojection algorithm was only able to provide image reconstruction when using a test object having a higher conductivity than the background electrolyte. Due to limitations in the mesh quality, the reconstructed image had significant irregularities and the position was slightly shifted toward the perimeter of the chamber. On the other hand, the method based on the polar-offset configuration combined with the customised algorithm proved to be suitable for image reconstruction when using non-conductive and cell-based test objects (down to 1% of the measurement chamber volume), indicating its suitability for future tissue engineering applications with polymeric scaffolds.

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