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Kim, Sungwhan; Lee, Eun Jung; Woo, Eung Je; Seo, Jin Keun

Asymptotic analysis of the membrane structure to sensitivity of frequency-difference electrical impedance tomography.

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Summary: There have been numerous studies using multi-frequency electrical impedance tomography to image frequency-dependent admittivity spectra of biological tissues. Considering the fundamental drawback of the static EIT in recovering the absolute admittivity image at a certain frequency, we will focus on a difference imaging method using a currently available EIT system. We are particularly interested in the frequency-difference EIT (fdEIT) in this paper since it may provide spectroscopic admittivity images without requiring a time-reference data. Noting that non-negligible susceptibility values of biological tissues are attributed to thin cell membranes, we analyze the role of the membrane in terms of the sensitivity of the complex voltage data in fdEIT. Such an analysis requires one to study the frequency-dependent behavior of a complex potential in the framework of the elliptic partial differential equation (PDE) with a frequency-dependent complex coefficient representing the admittivity. Due to complicated coupling between the real and imaginary parts of the complex potential, there is little study on the complex elliptic PDE. Although there exist several previous studies using spherical models which allow the potential to be represented as trigonometric series, these approaches are not apt for biological tissues. In this paper, we decouple the real and imaginary parts via a key asymptotic analysis and approximate the real part as a solution of a well-established elliptic PDE with a real coefficient whose value changes with frequency. This more general approach provides a quantitative analysis of the role of the thin membrane in forming a fdEIT image. We perform numerical simulations and phantom experiments on a two-dimensional imaging object containing an anomaly with a thin insulating membrane. The results provide better understanding of the role of the thin membrane in the sensitivity of a multi-frequency current-voltage data.

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