New Techniques in Impedance Imaging: MFEIT and MREIT

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Two different approaches in impedance imaging are addressed. One is the multi-frequency electrical impedance tomography (MFEIT) and the other is the magnetic resonance electrical impedance tomography (MREIT). MFEIT is to provide difference images of a complex conductivity distribution ($\sigma + i\omega\epsilon$) inside the human body with a low spatial resolution and high temporal resolution. Describing the design, construction and calibration of a new MFEIT system called the KHU Mark1, its performance is analyzed in terms of current source output impedance, signal-to-noise ratio, linearity, reciprocity error and other indices. Using the MFEIT system, difference images of σ and $\omega\epsilon$ are reconstructed from saline phantoms and human subjects. Observing that both σ and $\omega\epsilon$ affect both real and imaginary parts of measured complex boundary voltage data, we use a difference image reconstruction algorithm handling complex numbers. Time-difference images of σ and $\omega\epsilon$ at multiple frequencies are compared with complex conductivity spectra of imaging objects measured by using a bio-impedance spectroscopy (BIS). Frequency-difference images of σ and $\omega\epsilon$ are difference images reconstructed by using complex boundary voltage data at two different frequencies measured at the same time instant. Comparing with complex conductivity spectra of imaging objects, they show frequency-dependent changes of σ and $\omega\epsilon$. Unlike time-difference imaging, frequency-difference imaging can be improved by using an appropriate scaling of measured complex boundary voltage data at one frequency before we compute the difference of complex boundary voltages at two different frequencies. Future works on MFEIT including improvements in hardware performance, image reconstruction algorithm, image interpretation and possible clinical applications are discussed.

There have been numerous research works toward static image reconstructions of conductivity σ with a high spatial resolution. In order to overcome the inherent ill-posedness of the EIT image reconstruction problem, a new impedance imaging technique of combining MRI and EIT has been proposed in MREIT. When we inject current into an imaging object through a pair of electrodes, it produces a distribution of induced magnetic flux density inside the object. If we inject the current in such a way that its timing is synchronized with an MR imaging pulse sequence, we can obtain the induced internal magnetic flux density data from MR phase images. Sequentially injecting multiple imaging currents with at least two different directions, we can reconstruct static cross-sectional conductivity images with a high spatial resolution by using the corresponding magnetic flux densities and at least one boundary voltage data. Without using any boundary voltage measurement, conductivity image reconstructions can be performed to visualize only the conductivity contrast. Describing the relation between the induced magnetic flux density and the conductivity σ, MREIT image reconstruction algorithms are explained. High-resolution conductivity images of three-dimensional phantoms, postmortem canine brains and also *in vivo* canine brains are presented. Future research directions in MREIT are discussed including noise and artifacts, reduction of imaging current amplitude, improvement in image reconstruction algorithms, effects of anisotropic conductivity, possible applications and others.