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Simulations of the bio-impedance of the human thigh by the finite element method in 3D

INTRODUCTION

Electrical impedance tomography (EIT) is used to reconstruct the complex conductivity distribution in a region by injecting electrical currents via electrodes and simultaneously measuring the resulting potential distribution on the surface [1]. The complex conductivity of biological tissue is closely related to the hydration state. Therefore EIT is a very promising method to determine the hydration state [2]. Since the injected currents spread out in three dimensions, simulations in 3D are inevitable. The partial differential equation to be solved describing a quasi-static electric field in the time harmonic case using the electric scalar potential V is shown in (1). The corresponding boundary value problem is simulated by nodal tetrahedral finite elements of second order [3]. The aim is to study the agreement between measurements and simulations of the basic forward problem.

$$\nabla\left([\sigma + j\omega\varepsilon]\nabla V\right) = 0\,. \tag{1}$$

SIMULATION MODEL AND MEASUREMENT

The finite element models of the human thighs were made with a commercial mesh-generator from 41 magnetic resonance (MR) images covering the whole thigh (see Fig. 1). Electrodes of gel (conductivity of 11.0 S/m, relative permittivity of 80.0, diameter of 10.0 mm, thickness of 1.0 mm) completed with a metal layer represented as surfaces of constant potentials are incorporated in the models. Measurements are carried out by the Sheffield Mk3a system consisting of 8 interleaved drive and 8 voltage measuring electrodes. Data are collected by the adjacent- adjacent strategy. Impedances obtained by the measurements are compared with simulated ones when drive one is on.

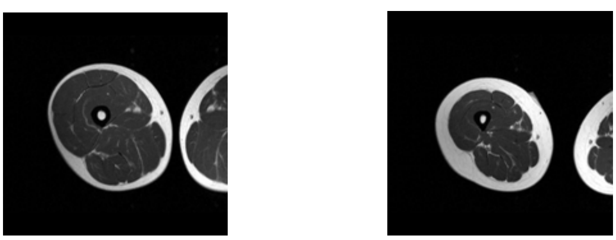

Fig. 1: Axial MR images in a central region of the thigh of test person A (left, male) and B (right, female).

RESULTS

A comparison of the impedances of the test persons are carried out in Fig. 2. An overall qualitative agreement is evident. The frequency has been chosen with 9.6 kHz. Due to the limited measuring range of the system (maximal 50.0 Ω) the noticeable deviation of large impedances of test person B occurs. The material properties used are taken from the literature and are summarized in Tab. I. Anisotropic conductivity and permittivity have been considered for muscle.

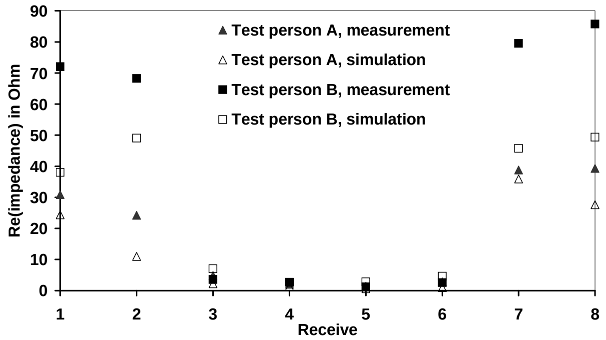

Fig. 2: Real part of the impedances of test person A and B.

	Relative permittivity	Specific conductivity (S/m)
Bone	1 742	0.0826
Muscle parallel	30 650	0.5391
Muscle transverse	31 320	0.3615
Fat	1 188	0.0238

Tab. I: Electrical properties of biological tissues selected at a frequency of 9.6 kHz.

To study the influence of the material properties selected extreme values are used within the limits of measured data by different authors. It can be easily seen in Fig. 3 that the measured values are within the simulated results.

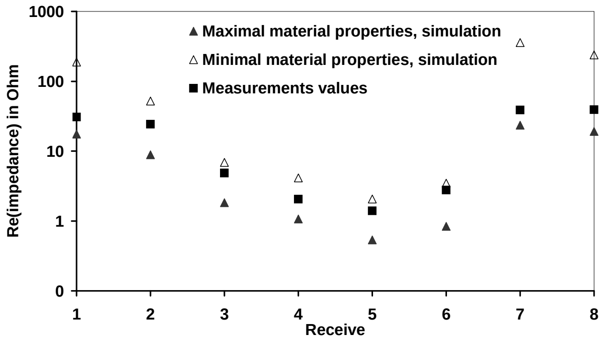

Fig. 3: Real part of the impedances of test person A for varying material properties.

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