Institutionen för klinisk vetenskap, intervention och teknik (CLINTEC), Enheten för medicinsk bild, funktion och teknologi

Electrical impedance of human skin and tissue alterations: Mathematical modeling and measurements.

AKADEMISK AVHANDLING
som för avläggande av teknologie doktorsexamen vid Karolinska Institutet offentligen försvaras i 3-221, Alfred Nobels Allé 10, plan 2, KI Campus Huddinge

Torsdagen den 10 Januari, 2013, kl 10.00

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Stockholm 2012

Abstract

The overall aim of the studies in this thesis is twofold. One is oriented towards calibrating a classifier in differentiating between malignant melanoma and benign nevi of the skin. The other concerns the development of a mathematical model to ascertain the validity of the electrical properties found in literature and to aid in the design and operation of electrodes as well as to broaden the knowledge of the signal distribution in skin.

In the pursuit of calibrating a classifier in the distinction between benign and malignant cutaneous lesions, an international, multicenter, prospective, non-controlled, clinical study is conducted, where a total of 1807 subjects are enrolled. When the observed accuracy, although significant, is found not to be sufficient for the device to be used as a stand-alone decision support tool for the detection of malignant melanoma, the study is put on hold. The study is then re-initiated after hardware updates and redesign of both probe and electrode are implemented.

The resulting classifier demonstrates that EIS can potentially be used as an adjunct diagnostic tool to help clinicians differentiate between benign and malignant cutaneous lesions, although further studies are needed to confirm the validity of the classification algorithm.

In Paper III the literature values of the electrical properties of stratum corneum obtained by Yamamoto et al. are adjusted, and the impact of both the soaking time and sodium chloride concentration of the applied solvent is shown to significantly alter the measured electrical properties. Thereafter, in Paper IV, more realistic median electrical properties of both the stratum corneum and the underlying skin is inverse engineered from experimental measurements on a large cohort of subjects, by using a mathematical model considering the conservation of charge in combination with an optimization algorithm.

Previously it was thought that the electrical impedance of intact skin is dominated by the stratum corneum at low frequencies ($\lesssim$1 kHz) and by the underlying layers at higher frequencies ($\gtrsim$1 MHz). In Paper V, it is shown that the stratum corneum heavily dominates the electrical impedance of intact skin up to frequencies of approximately 100kHz, and that the influence of the stratum corneum is not negligible even at 1MHz.

Key Words: Electrical impedance, diagnostics, sensitivity and specificity, skin cancer, melanoma, epidermis, dermis, subcutaneous fat, mathematical modeling, optimization, finite element analysis