

The Compensation of Perturbation Effects in Glucose Monitoring Technologies Based on Impedance Spectroscopy

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Introduction: Several non-invasive glucose monitoring techniques are based on the realization that there is a correlation between the dielectric properties of the skin and underlying tissue, i.e., its impedance, and the glucose concentration. However, the impedance is not only affected by changes in the glucose concentration, but also by a variety of perturbation effects. Thus, in order to use the impedance as a measure of the glucose concentration, contributions from these perturbing effects need to be eliminated, requiring the knowledge of the functional relation between impedance and noise parameters.

Methods: For this purpose a clinical study with 7 non diabetic subjects (5 male, 2 female, 38.2±11.3 years, HbA1c 5.1±0.5%) and 13 diabetic patients (6 type 1, 7 type 2; 7 male, 6 female, 46.3±16.4 years, duration of diabetes 4.8±4.9 years, HbA1c 6.5±1.1%) was carried out in which each subject was exposed to a temperature profile ranging from 25°C to 9°C and back to 25°C. The temperature variation triggered fluctuations in a variety of other perturbation parameters such as moisture/sweat and the blood microcirculation. The perturbation parameters and impedance were closely monitored and the data collected were used to derive the desired functional relation via a statistical modelling procedure.

Results: This enables then the determination of the minimum required sensitivity of an impedance spectrometer to glucose in order to be operational in everyday conditions. Furthermore, the data can be used to determine if the compensations for the perturbing effects are universally applicable or if an individual calibration is required. For instance, to be operational in a temperature range of +/-7°C and to resolve glucose variations equivalent to 10 mg/dl the required sensitivity of the minimum frequency in a sensor-skin RLC circuit is 0.03 MHz/mg/dl and 0.07 MHz/mg/dl for type I and type II subjects, respectively. These sensitivities were derived under the assumption that no individual calibration is carried out.

Conclusion: The required sensitivities can be achieved by state-of-the-art technologies, suggesting that with a proper noise compensation, non-invasive glucose monitoring is feasible. To some extent, the problems addressed are typical for spectroscopic glucose monitoring techniques. Using an equivalent circuit diagram for the sensor-skin system, the results can be transformed to generic dielectric parameters pointing out the general relevance of the findings.