

Non-invasive Monitoring of Cutaneous Hemodynamic Functions with a Multisensor System for Metabolic Monitoring

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Objective:

Monitoring of tissue metabolic status is important for the assessment of the conditions of e.g. patients with diabetes mellitus. It has also been reported that knowledge of the biophysical skin status in combination with measurements of the various metabolic parameters can improve the quality of the glucose estimation by the non-invasive glucose monitoring systems. The metabolic status of e.g. cutaneous tissue is to a large extent determined by the status of blood dynamics. A compact wearable multi-sensor system incorporating diffuse reflectance optical sensors has been developed for simultaneous and real-time assessment of the skin hemodynamic parameters such as pulse, blood perfusion, plethysmographic amplitude and tissue oxygenation, combined with activity monitoring using acceleration and skin temperature sensors.

Method:

Preliminary evaluation of the system was performed in the laboratory and a home-use setting in healthy subjects and in clinical settings in patients with type 1 diabetes mellitus (T1DM) undergoing hyperglycemic excursions. Reference measurements of arterial blood oxygenation and pulse were obtained with the clinical pulse oximeter. In the laboratory experiments cutaneous blood perfusion has been affected by standard protocols, such as local warming, venous and arterial occlusions.

Results:

The Multisensor system demonstrates high sensitivity to the changes in cutaneous blood perfusion and flow, as well as tissue oxygenation induced in laboratory settings. High stability of the measurements can be observed even in a home use setting, when movements are not restricted. Pulse estimates of the Multisensor system are in good agreement with reference oximetry with an accuracy of ± 3.5 beats per minute for a 5-seconds averaging interval. In the home use settings with unrestricted activities pulse and plethysmographic signals can be estimated from more than 61% of the recorded intervals. In the clinical setting the signal-to-noise ratio of the skin perfusion measurements is above 28 ± 3 dB (mean \pm SD). Observed body and skin hemodynamic reveal complex dependencies from the blood glucose level that will stimulate further investigation. Compared to hyperemia (max perfusion induced by local heating, set as 100%) skin perfusion during hypoglycemic challenges reached $35.2 \pm 11.6\%$ and during hyperglycemic challenges $21.2 \pm 6.4\%$, respectively.

Conclusion:

The Multisensor system can provide robust and reliable characterisation of the skin hemodynamical function. Additional studies are planned for the further evaluation of the system performance in the home-use setting on the patients with T1DM.