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New methodology to obtain a calibration model for noninvasive near-infrared blood glucose monitoring

Katsuhiko Maruo [1], Tomohiro Oota, Mitsuhiro Tsurugi, Takehiro Nakagawa, Hidenobu Arimoto, Mamoru Tamura, Yukihiro Ozaki, Yukio Yamada

Affiliations

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Abstract

This paper reports new methodology to obtain a calibration model for noninvasive blood glucose monitoring using diffuse reflectance near-infrared (NIR) spectroscopy. Conventional studies of noninvasive blood glucose monitoring with NIR spectroscopy use a calibration model developed by in vivo experimental data sets. In order to create a calibration model, we have used a numerical simulation of light propagation in skin tissue to obtain simulated NIR diffuse reflectance spectra. The numerical simulation method enables us to design parameters affecting the prediction of blood glucose levels and their variation ranges for a data set to create a calibration model using multivariate analysis without any in vivo experiments in advance. By designing the parameters and their variation ranges appropriately, we can prevent a calibration model from chance temporal correlations that are often observed in conventional studies using NIR spectroscopy. The calibration model (regression coefficient vector) obtained by the numerical simulation has a characteristic positive peak at the wavelength around 1600 nm. This characteristic feature of the regression coefficient vector is very similar to those obtained by our previous in vitro and in vivo experimental studies. This positive peak at around 1600 nm also corresponds to the characteristic absorption band of glucose. The present study has reinforced that the characteristic absorbance of glucose at around 1600 nm is useful to predict the blood glucose level by diffuse reflectance NIR spectroscopy. We have validated this new calibration methodology using in vivo experiments. As a result, we obtained a coefficient of determination, r2, of 0.87 and a standard error of prediction (SEP) of 12.3 mg/dL between the predicted blood glucose levels and the reference blood glucose levels for all the experiments we have conducted. These results of in vivo experiments indicate that if the parameters and their vibration ranges are appropriately taken into account in a numerical simulation, the new calibration methodology provides us with a very good calibration model that can predict blood glucose levels with small errors without conducting any experiments in advance to create a calibration model for each individual patient. This new calibration methodology using numerical simulation has promising potential for NIR spectroscopy, especially for noninvasive blood glucose monitoring.

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