Journal of Diabetes Science and Technology
Volume 4, Issue 5, September 2010

SYMPOSIUM

Use of Subcutaneous Interstitial Fluid Glucose to Estimate Blood Glucose: Revisiting Delay and Sensor Offset

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Abstract

Background:
Estimates for delays in the interstitial fluid (ISF) glucose response to changes in blood glucose (BG) differ substantially among research groups. We review these findings along with arguments that continuous glucose monitoring (CGM) devices used to measure ISF delay contribute to the variability. We consider the impact of the ISF delay and review approaches to correct for it, including strategies pursued by the manufacturers of these devices. The focus on how the manufacturers have approached the problem is motivated by the observation that clinicians and researchers are often unaware of how the existing CGM devices process the ISF glucose signal.

Methods:
Numerous models and simulations were used to illustrate problems related to measurement and correction of ISF glucose delay.

Results:
We find that (1) there is no evidence that the true physiologic ISF glucose delay is longer than 5–10 min and that the values longer than this can be explained by delays in CGM filtering routines; (2) the primary impact of the true ISF delay is on sensor calibration algorithms, making it difficult to estimate calibration factors and offset (OS) currents; (3) inaccurate estimates of the sensor OS current result in overestimation of sensor glucose at low values, making it difficult to detect hypoglycemia; (4) many device companies introduce nonlinear components into their filters, which can be expected to confound attempts by investigators to reconstruct BG using linear deconvolution; and (5) algorithms advocated by academic groups are seldom compared to algorithms pursued by industry, making it difficult to ascertain their value.

continued →

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Abbreviations: (BG) blood glucose, (CF) calibration factor, (CGM) continuous glucose monitoring, (FIR) finite impulse response, (IIR) infinite impulse response, (ISF) interstitial fluid, (OS) offset, (SC) subcutaneous, (SG) sensor glucose

Keywords: algorithms, artificial pancreas, closed-loop control, diabetes, interstitial fluid

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Abstract cont.

Conclusions:

The absence of any direct comparisons between existing and new algorithms for correcting ISF delay and sensor OS current is, in part, due to the difficulty in extracting relevant details from industry patents and/or extracting unfiltered sensor signals from industry products. The model simulation environment, where all aspects of the signal can be derived, may be more appropriate for developing new filtering and calibration strategies. Nevertheless, clinicians, academic researchers, and the industry would benefit from collaborating when evaluating those strategies.

J Diabetes Sci Technol 2010;4(5):1087-1098