Journal of Diabetes Science and Technology
Volume 3, Issue 5, September 2009

SYMPOSIUM

Probabilistic Evolving Meal Detection and Estimation of Meal Total Glucose Appearance

Fraser Cameron, M.Sc.,[1] Günter Niemeyer, Ph.D.,[2] and Bruce A. Buckingham, M.D.[3]

Abstract

Background:

Automatic compensation of meals for type 1 diabetes patients will require meal detection from continuous glucose monitor (CGM) readings. This is challenged by the uncertainty and variability inherent to the digestion process and glucose dynamics as well as the lag and noise associated with CGM sensors. Thus any estimation of meal start time, size, and shape is fundamentally uncertain. This uncertainty can be reduced, but not eliminated, by estimating total glucose appearance and using new readings as they become available.

Method:

In this article, we propose a probabilistic, evolving method to detect the presence and estimate the shape and total glucose appearance of a meal. The method is unique in continually evolving its estimates and simultaneously providing uncertainty measures to monitor their convergence. The algorithm operates in three phases. First, it compares the CGM signal to no-meal predictions made by a simple insulin–glucose model. Second, it fits the residuals to potential, assumed meal shapes. Finally, it compares and combines these fits to detect any meals and estimate the meal total glucose appearance, shape, and total glucose appearance uncertainty.

Results:

We validate the performance of this meal detection and total glucose appearance estimation algorithm both separately and in cooperation with a controller on the Food and Drug Administration-approved University of Virginia/Padova Type I Diabetes Simulator. In cooperation with a controller, the algorithm reduced the mean blood glucose from 137 to 132 mg/dl over 1.5 days of control without any increased hypoglycemia.

Conclusion:

This novel, extensible meal detection and total glucose appearance estimation method shows the feasibility, relevance, and performance of evolving estimates with explicit uncertainty measures for use in closed-loop control of type 1 diabetes.

J Diabetes Sci Technol 2009;3(5):1022-1030

Author Affiliations: [1]Department of Aeronautics and Astronautics, Stanford University, Stanford, California; [2]Department of Mechanical Engineering Stanford University, Stanford, California; and [3]Divisions of Pediatric Endocrinology and Diabetes, Stanford University, Stanford, California

Abbreviations: (A1C) glycated hemoglobin A1c, (BG) blood glucose, (CGM) continuous glucose monitor, (CHO) carbohydrate, (EGP) endogenous glucose production, (FDA) Food and Drug Administration, (ISG) interstitial glucose, (ITAP) insulin time action profile

Keywords: artificial pancreas, closed loop, meal detection, meal size estimation, simulation

Corresponding Author: Fraser Cameron, Department of Aeronautics and Astronautics, Stanford University, 212-101 Rosse Ln., Stanford, CA 94305; email address *fraser@stanford.edu*