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SYMPOSIUM

A Controlled Study of the Effectiveness of an Adaptive Closed-Loop Algorithm to Minimize Corticosteroid-Induced Stress Hyperglycemia in Type 1 Diabetes

Joseph El Youssef, M.B.B.S.,[1] Jessica R. Castle, M.D.,[1] Deborah L. Branigan, B.A.,[2] Ryan G. Massoud, B.S.,[2] Matthew E. Breen, B.S.,[1,2] Peter G. Jacobs, M.S.E.E., Ph.D.,[3] B. Wayne Bequette, Ph.D.,[4] and W. Kenneth Ward, M.D.,[1,2]

Abstract

To be effective in type 1 diabetes, algorithms must be able to limit hyperglycemic excursions resulting from medical and emotional stress. We tested an algorithm that estimates insulin sensitivity at regular intervals and continually adjusts gain factors of a fading memory proportional-derivative (FMPD) algorithm. In order to assess whether the algorithm could appropriately adapt and limit the degree of hyperglycemia, we administered oral hydrocortisone repeatedly to create insulin resistance. We compared this indirect adaptive proportional-derivative (APD) algorithm to the FMPD algorithm, which used fixed gain parameters. Each subject with type 1 diabetes (n = 14) was studied on two occasions, each for 33 h.

The APD algorithm consistently identified a fall in insulin sensitivity after hydrocortisone. The gain factors and insulin infusion rates were appropriately increased, leading to satisfactory glycemic control after adaptation (premeal glucose on day 2, 148 ± 6 mg/dl). After sufficient time was allowed for adaptation, the late postprandial glucose increment was significantly lower than when measured shortly after the onset of the steroid effect. In addition, during the controlled comparison, glycemia was significantly lower with the APD algorithm than with the FMPD algorithm. No increase in hypoglycemic frequency was found in the APD-only arm.

An afferent system of duplicate amperometric sensors demonstrated a high degree of accuracy; the mean absolute relative difference of the sensor used to control the algorithm was 9.6 ± 0.5%. We conclude that an adaptive algorithm that frequently estimates insulin sensitivity and adjusts gain factors is capable of minimizing corticosteroid-induced stress hyperglycemia.

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Author Affiliations: [1]Oregon Health & Science University, Portland, Oregon; [2]Legacy Health System, Portland, Oregon; [3]Jacobs Technologies, Portland Oregon, and [4]Rensselaer Polytechnic Institute, Troy, New York.

Abbreviations: (AD) absolute difference, (APD) adaptive proportional-derivative, (ARD) absolute relative difference, (CGM) continuous glucose monitoring, (DE) derivative error, (EGP) endogenous glucose production, (FDA) Food and Drug Administration, (FMPD) fading memory proportional-derivative, (HbA1c) hemoglobin A1c, (HC) hydrocortisone, (IIR) insulin infusion rate, (IOB) insulin-on-board, (NIMGU) noninsulin-mediated glucose uptake, (NS) not significant, (PE) proportional error, (PID) proportional-integral-derivative, (SD) standard deviation, (SEM) standard error of the mean, (T1DM) type 1 diabetes mellitus, (TDIR) total daily insulin requirement, (VBG) venous blood glucose

Keywords: algorithms, artificial pancreas, corticosteroids, glucose sensor, insulin resistance, type 1 diabetes

Corresponding Author: W. Kenneth Ward, M.D., Legacy Health System, 1225 NE 2nd Avenue, Portland, OR 97232; email address *kward@legacyglucosesensor.org*