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ORIGINAL ARTICLE

Use of a Food and Drug Administration-Approved Type 1 Diabetes Mellitus Simulator to Evaluate and Optimize a Proportional-Integral-Derivative Controller

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Abstract

Background:

Clinical studies have shown that the Medtronic proportional-integral-derivative (PID) control with insulin feedback (IFB) provides stable 24 h glucose control, but with high postprandial glucose. We coupled this algorithm to a Food and Drug Administration-approved type 1 diabetes mellitus simulator to determine whether a proportional-derivative controller with preprogrammed basal rates (PD_{BASAL}) would have better performance.

Methods:

We performed simulation studies on 10 adult subjects to (1) obtain the basal profiles for the PD_{BASAL} controller; (2) define the pharmacokinetic/pharmacodynamic profile used to effect IFB, (3) optimize the PID and PD_{BASAL} control parameters, (4) evaluate improvements obtained with IFB, and (5) develop a method to simulate changes in insulin sensitivity and assess the ability of each algorithm to respond to such changes.

Results:

PD_{BASAL} control significantly reduced peak postprandial glucose [252 (standard error = 11) versus 279 (14) mg/dl; $p < .001$] and increased nadir glucose [102 (3) versus 92 (3) mg/dl; $p < .001$] compared with PID control (both implemented with IFB). However, with PD_{BASAL} control, fasting glucose remained elevated following a 30% decrease in insulin sensitivity [156 (6) mg/dl; different from the target of 110 mg/dl; $p < .001$] and remained below target following a 30% increase in insulin sensitivity [84 (2) mg/dl; $p < .001$]. In both cases, PID control returned glucose levels to target.

Conclusions:

PD_{BASAL} provides better postprandial glucose control than PID but is not appropriate for subjects whose basal requirements change with insulin sensitivity. Simulations used to compare different control strategies should assess this variability.

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Abbreviations: (BG) blood glucose, (GF) gain factor, (IFB) insulin feedback, (PD) pharmacodynamic, (PD_{BASAL}) proportional-derivative controller with preprogrammed basal rates, (PID) proportional-integral-derivative, (PK) pharmacokinetic, (UVA) University of Virginia

Keywords: blood glucose, closed-loop control, insulin delivery, insulin feedback, proportional gain, safe operating region, type 1 diabetes mellitus simulator

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