A Closed-Loop Artificial Pancreas Using Model Predictive Control and a Sliding Meal Size Estimator

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Abstract

The objective of this article is to present a comprehensive strategy for a closed-loop artificial pancreas. A meal detection and meal size estimation algorithm is developed for situations in which the subject forgets to provide a meal insulin bolus. A pharmacodynamic model of insulin action is used to provide insulin-on-board constraints to explicitly include the future effect of past and currently delivered insulin boluses. In addition, a supervisory pump shut-off feature is presented to avoid hypoglycemia. All of these components are used in conjunction with a feedback control algorithm using model predictive control (MPC). A model for MPC is developed based on a study of 20 subjects and is tested in a hypothetical clinical trial of 100 adolescent and 100 adult subjects using a Food and Drug Administration-approved diabetic subject simulator. In addition, a performance comparison of previously and newly proposed meal size estimation algorithms using 200 in silico subjects is presented. Using the new meal size estimation algorithm, the integrated artificial pancreas system yielded a daily mean glucose of 138 and 132 mg/dl for adolescents and adults, respectively, which is a substantial improvement over the MPC-only case, which yielded 159 and 145 mg/dl.


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Abbreviations: (CHO) carbohydrate, (FDA) Food and Drug Administration, (IOB) insulin on board, (MPC) model predictive control, (MSE) meal size estimation, (PID) proportional-integral-derivative, (TDI) total daily insulin

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