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SYMPOSIUM

Closed-Loop Artificial Pancreas Using Subcutaneous Glucose Sensing and Insulin Delivery and a Model Predictive Control Algorithm: The Virginia Experience

William L. Clarke, M.D.,[1] Stacey Anderson, M.D.,[2] Marc Breton, Ph.D.,[3] Stephen Patek, Ph.D.,[4] Laurissa Kashmer, M.D.,[1] and Boris Kovatchev, Ph.D.[3]

Abstract

Background:

Recent progress in the development of clinically accurate continuous glucose monitors (CGMs), automated continuous insulin infusion pumps, and control algorithms for calculating insulin doses from CGM data have enabled the development of prototypes of subcutaneous closed-loop systems for controlling blood glucose (BG) levels in type 1 diabetes. The use of a new personalized model predictive control (MPC) algorithm to determine insulin doses to achieve and maintain BG levels between 70 and 140 mg/dl overnight and to control postprandial BG levels is presented.

Methods:

Eight adults with type 1 diabetes were studied twice, once using their personal open-loop systems to control BG overnight and for 4 h following a standardized meal and once using a closed-loop system that utilizes the MPC algorithm to control BG overnight and for 4 h following a standardized meal. Average BG levels, percentage of time within BG target of 70–140 mg/dl, number of hypoglycemia episodes, and postprandial BG excursions during both study periods were compared.

Results:

With closed-loop control, once BG levels achieved the target range (70–140 mg/dl), they remained within that range throughout the night in seven of the eight subjects. One subject developed a BG level of 65 mg/dl, which was signaled by the CGM trend analysis, and the MPC algorithm directed the discontinuance of the insulin infusion. The number of overnight hypoglycemic events was significantly reduced ($p = .011$) with closed-loop control. Postprandial BG excursions were similar during closed-loop and open-loop control

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Author Affiliations: [1]Division of Pediatric Endocrinology, Department of Pediatrics, University of Virginia Health Sciences Center, Charlottesville, Virginia; [2]Department of Internal Medicine, University of Virginia, Charlottesville, Virginia; [3]Diabetes Technology Program, University of Virginia, Charlottesville, Virginia; and [4]Department of Systems and Information Engineering, University of Virginia, Charlottesville, Virginia

Abbreviations: (BG) blood glucose, (CGM) continuous glucose monitor, (FDA) Food and Drug Administration, (MPC) model predictive control, (PID) proportional integrative derivative

Keywords: artificial pancreas, closed-loop control, continuous glucose monitoring, model predictive control algorithms

Corresponding Author: William L. Clarke, M.D., Box 800386, Department of Pediatrics, University of Virginia Health Sciences Center, Charlottesville, VA 22908; email address wlc@virginia.edu

Abstract cont.

Conclusion:

Model predictive closed-loop control of BG levels can be achieved overnight and following a standardized breakfast meal. This "artificial pancreas" controls BG levels as effectively as patient-directed open-loop control following a morning meal but is significantly superior to open-loop control in preventing overnight hypoglycemia.

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