Journal of Diabetes Science and Technology
Volume 7, Issue 6, November 2013

SYMPOSIUM

Periodic-Zone Model Predictive Control for Diurnal Closed-Loop Operation of an Artificial Pancreas

Ravi Gondhalekar, Ph.D., Eyal Dassau, Ph.D., Howard C. Zisser, M.D., and Francis J. Doyle III, Ph.D.

Abstract

Background:

The objective of this research is an artificial pancreas (AP) that performs automatic regulation of blood glucose levels in people with type 1 diabetes mellitus. This article describes a control strategy that performs algorithmic insulin dosing for maintaining safe blood glucose levels over prolonged, overnight periods of time and furthermore was designed with outpatient, multiday deployment in mind. Of particular concern is the prevention of nocturnal hypoglycemia, because during sleep, subjects cannot monitor themselves and may not respond to alarms. An AP intended for prolonged and unsupervised outpatient deployment must strategically reduce the risk of hypoglycemia during times of sleep, without requiring user interaction.

Methods:

A diurnal insulin delivery strategy based on predictive control methods is proposed. The so-called "periodic-zone model predictive control" (PZMPC) strategy employs periodically time-dependent blood glucose output target zones and furthermore enforces periodically time-dependent insulin input constraints to modulate its behavior based on the time of day.

Results:

The proposed strategy was evaluated through an extensive simulation-based study and a preliminary clinical trial. Results indicate that the proposed method delivers insulin more conservatively during nighttime than during daytime while maintaining safe blood glucose levels at all times. In clinical trials, the proposed strategy delivered 77% of the amount of insulin delivered by a time-invariant control strategy; specifically, it delivered on average 1.23 U below, compared with 0.31 U above, the nominal basal rate overnight while maintaining comparable, and safe, blood glucose values.

continued →

Author Affiliations: University of California, Santa Barbara, Santa Barbara, California; and Sansum Diabetes Research Institute, Santa Barbara, California

Abbreviations: (AP) artificial pancreas, (APS) artificial pancreas system, (CGM) continuous glucose monitor, (CVGA) control variability grid analysis, (gCHO) gram carbohydrates, (LTI) linear time-invariant, (MPC) model predictive control, (PZMPC) periodic-zone model predictive control, (T1DM) type 1 diabetes mellitus

Keywords: artificial pancreas, automated insulin delivery, automatic control, model predictive control, outpatient care, periodic control

Corresponding Author: Francis J. Doyle III, Department of Chemical Engineering, University of California, Santa Barbara, Santa Barbara, CA 93106-5080; email address *doyle@engineering.ucsb.edu*

Abstract cont.

Conclusions:

The proposed PZMPC algorithm strategically prevents nocturnal hypoglycemia and is considered a significant step toward deploying APs into outpatient environments for extended periods of time in full closed-loop operation.

J Diabetes Sci Technol 2012;6(2):1446–1460