

## A Bio-Inspired Glucose Controller Based on Pancreatic $\beta$ -Cell Physiology

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### Abstract

#### Introduction:

Control algorithms for closed-loop insulin delivery in type 1 diabetes have been mainly based on control engineering or artificial intelligence techniques. These, however, are not based on the physiology of the pancreas but seek to implement engineering solutions to biology. Developments in mathematical models of the  $\beta$ -cell physiology of the pancreas have described the glucose-induced insulin release from pancreatic  $\beta$  cells at a molecular level. This has facilitated development of a new class of bio-inspired glucose control algorithms that replicate the functionality of the biological pancreas. However, technologies for sensing glucose levels and delivering insulin use the subcutaneous route, which is nonphysiological and introduces some challenges. In this article, a novel glucose controller is presented as part of a bio-inspired artificial pancreas.

#### Methods:

A mathematical model of  $\beta$ -cell physiology was used as the core of the proposed controller. In order to deal with delays and lack of accuracy introduced by the subcutaneous route, insulin feedback and a gain scheduling strategy were employed. A United States Food and Drug Administration-accepted type 1 diabetes mellitus virtual population was used to validate the presented controller.

#### Results:

Premeal and postmeal mean  $\pm$  standard deviation blood glucose levels for the adult and adolescent populations were well within the target range set for the controller [(70, 180) mg/dl], with a percent time in range of  $92.8 \pm 7.3\%$  for the adults and  $83.5 \pm 14\%$  for the adolescents.

#### Conclusions:

This article shows for the first time very good glucose control in a virtual population with type 1 diabetes mellitus using a controller based on a subcellular  $\beta$ -cell model.

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**Abbreviations:** (ASIC) application-specific integrated circuit, (AUC) area under the curve, (BG) blood glucose, (BGRI) blood glucose risk index, (CGM) continuous glucose monitor, (CHO) carbohydrate, (CSII) continuous subcutaneous insulin infusion, (CVGA) control-variability grid analysis, (FDA) Food and Drug Administration, (HBGI) high blood glucose risk index, (IV) intravenous, (LBGI) low blood glucose risk index, (MPC) model predictive control, (PID) proportional-integral-derivative, (RRP) readily releasable pool, (SC) subcutaneous, (SD) standard deviation, (T1DM) type 1 diabetes mellitus

**Keywords:** artificial pancreas, bio-inspired technology, closed-loop, diabetes management, glycemic control

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