Modeling the Effects of Subcutaneous Insulin Administration and Carbohydrate Consumption on Blood Glucose

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Abstract

Background:
Estimation of the magnitude and duration of effects of carbohydrate (CHO) and subcutaneously administered insulin on blood glucose (BG) is required for improved BG regulation in people with type 1 diabetes mellitus (T1DM). The goal of this study was to quantify these effects in people with T1DM using a novel protocol.

Methods:
The protocol duration was 8 hours: a 1–3 U subcutaneous (SC) insulin bolus was administered and a 25-g CHO meal was consumed, with these inputs separated by 3–5 hours. The DexCom SEVEN® PLUS continuous glucose monitor was used to obtain SC glucose measurements every 5 minutes and YSI 2300 Stat Plus was used to obtain intravenous glucose measurements every 15 minutes.

Results:
The protocol was tested on 11 subjects at Sansum Diabetes Research Institute. The intersubject parameter coefficient of variation for the best identification method was 170%. The mean percentages of output variation explained by the bolus insulin and meal models were 68 and 69%, respectively, with root mean square error of 14 and 10 mg/dl, respectively. Relationships between the model parameters and clinical parameters were observed.

Conclusion:
Separation of insulin boluses and meals in time allowed unique identification of model parameters. The wide intersubject variation in parameters supports the notion that glucose-insulin models and thus insulin delivery algorithms for people with T1DM should be personalized. This experimental protocol could be used to refine estimates of the correction factor and the insulin-to-carbohydrate ratio used by people with T1DM.


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Abbreviations: (AE) algebraic equation, (BG) blood glucose, (CF) correction factor, (CGM) continuous glucose monitoring, (CHO) carbohydrate, (CSII) continuous subcutaneous insulin infusion, (ICR) insulin-to-carbohydrate ratio, (IOB) insulin on board, (IV) intravenous, (ODE) ordinary differential equation, (pEGA) point error grid analysis, (rEGA) rate error grid analysis, (SC) subcutaneous, (T1DM) type 1 diabetes mellitus

Keywords: artificial pancreas, parameter estimation, physiological modeling, type 1 diabetes mellitus

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