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ORIGINAL ARTICLE

Dynamic Insulin on Board: Incorporation of Circadian Insulin Sensitivity Variation

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Abstract

Background:

Insulin-on-board (IOB) estimation is used in modern insulin therapy with continuous subcutaneous insulin infusion (CSII) as well as different automatic glucose-regulating strategies (i.e., artificial pancreas products) to prevent insulin stacking that may lead to hypoglycemia. However, most of the IOB calculations are static IOB (sIOB): they are based only on approximated insulin decay and do not take into account diurnal changes in insulin sensitivity.

Methods:

A dynamic IOB (dIOB) that takes into account diurnal insulin sensitivity variation is suggested in this work and used to adjust the sIOB estimations. The dIOB function is used to correct the dosage of insulin boluses in light of this circadian variation.

Results:

Basal–bolus as applied by pump users and model predictive control therapy with and without dIOB were evaluated using the University of Virginia/Padova metabolic simulator. Three protocols with four meals of 1 g carbohydrate/kg body weight were evaluated: a nominal scenario and two robustness scenarios, one in which insulin sensitivity was 15% greater than estimated and the other where the lunch is 30% less than announced. In the nominal and robustness scenarios, respectively, the dIOB led to 6% and 24% and 40% less hypoglycemia episodes than approaches without IOB. The new approach was also compared with the sIOB to evaluate the improvements with respect to the previous approach.

Conclusions:

Improved glucose regulation was demonstrated using the dIOB where circadian insulin sensitivity is used to adjust IOB estimation. Use of diurnal variations of insulin sensitivity appears to promote effective and safe insulin therapy using CSII or artificial pancreas. Clinical trials are warranted to determine whether nocturnal hypoglycemia can be reduced using the dIOB approach.

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Abbreviations: (BB) basal–bolus, (BG) blood glucose, (BW) body weight, (CL) closed loop, (CR) carbohydrate ratio, (CSII) continuous subcutaneous insulin infusion, (CVGA) control-variability grid analysis, (dIOB) dynamic insulin on board, (IOB) insulin on board, (MPC) model predictive control, (sIOB) static insulin on board, (T1DM) type 1 diabetes mellitus

Keywords: artificial pancreas, circadian rhythm, continuous subcutaneous insulin infusion, diabetes, insulin on board, insulin sensitivity

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