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SYMPOSIUM

Closed-Loop Artificial Pancreas Using Subcutaneous Glucose Sensing and Insulin Delivery and a Model Predictive Control Algorithm: Preliminary Studies in Padova and Montpellier

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Abstract

New effort has been made to develop closed-loop glucose control, using subcutaneous (SC) glucose sensing and continuous subcutaneous insulin infusion (CSII) from a pump, and a control algorithm. An approach based on a model predictive control (MPC) algorithm has been utilized during closed-loop control in type 1 diabetes patients. Here we describe the preliminary clinical experience with this approach.

Six type 1 diabetes patients (three in each of two clinical investigation centers in Padova and Montpellier), using CSII, aged 36 ± 8 and 48 ± 6 years, duration of diabetes 12 ± 8 and 29 ± 4 years, hemoglobin A1c 7.4% ± 0.1% and 7.3% ± 0.3%, body mass index 23.2 ± 0.3 and 28.4 ± 2.2 kg/m^2, respectively, were studied on two occasions during 22 h overnight hospital admissions 2–4 weeks apart. A Freestyle Navigator® continuous glucose monitor and an OmniPod® insulin pump were applied in each trial. Admission 1 used open-loop control, while admission 2 employed closed-loop control using our MPC algorithm.

In Padova, two out of three subjects showed better performance with the closed-loop system compared to open loop. Altogether, mean overnight plasma glucose (PG) levels were 134 versus 111 mg/dl during open loop versus closed loop, respectively. The percentage of time spent at PG > 140 mg/dl was 45% versus 12%, while postbreakfast mean PG was 165 versus 156 mg/dl during open loop versus closed loop, respectively. Also, in Montpellier, two patients out of three showed a better glucose control during closed-loop trials. Avoidance of nocturnal hypoglycemic excursions was a clear benefit during algorithm-guided insulin delivery in all cases.

This preliminary set of studies demonstrates that closed-loop control based entirely on SC glucose sensing and insulin delivery is feasible and can be applied to improve glucose control in patients with type 1 diabetes, although the algorithm needs to be further improved to achieve better glycemic control.

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Abbreviations: (BG) blood glucose, (BMI) body mass index, (CGM) continuous glucose monitoring, (CHO) carbohydrate, (CSII) continuous subcutaneous insulin infusion, (HbA1c) hemoglobin A1c, (IG) interstitial glucose, (MPC) model predictive control, (PG) plasma glucose, (PID) proportional integrative derivative, (SC) subcutaneous

Keywords: continuous glucose monitoring, control algorithm, glucose sensor, insulin pump, modeling, simulation, type 1 diabetes

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