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Personalized Glucose-Insulin Model based on Signal Analysis

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Abstract

Glucose plasma measurements for diabetes patients are generally presented as a glucose concentration-time profile with 15-60 min time scale intervals. This limited resolution obscures detailed dynamic events of glucose appearance and metabolism. Measurement intervals of 15 minutes or more could contribute to imperfections in present diabetes treatment. High resolution data from mixed meal tolerance tests (MMTT) for 24 type 1 and type 2 diabetes patients were used in our present modelling. We introduce a model based on the physiological properties of transport, storage and utilization. This logistic approach follows the principles of electrical network analysis and signal processing theory. The method mimics the physiological equivalent of the glucose homeostasis comprising the meal ingestion, absorption via the gastrointestinal tract (GIT) to the endocrine nexus between the liver, pancreatic alpha and beta cells. This model demystifies the metabolic 'black box' by enabling in silico simulations and fitting of individual responses to clinical data. Five-minute intervals MMTT data measured from diabetic subjects result in two independent model parameters that characterize the complete glucose system response at a personalized level. From the individual data measurements, we obtain a model which can be analyzed with a standard electrical network simulator for diagnostics and treatment optimization. The insulin dosing time scale can be accurately adjusted to match the individual requirements of characterized diabetic patients without the physical burden of treatment.

Keywords: Appearance profile, Model identification, Electrical network model, Simulation, Personalized target, Validation

1. Introduction

In healthy humans, glucose derangements like hyperglycemia and hypoglycemia are normally prevented by homeostatic control mechanisms of the precise antagonism between pancreatic insulin and glucagon secretion. Besides basal insulin secretion for maintenance of euglycemia under fasting conditions, additional prandial insulin response will occur when ambient glucose concentration exceeds a defined threshold level, G_B,