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ORIGINAL ARTICLE

A Simple Robust Method for Estimating the Glucose Rate of Appearance from Mixed Meals

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Abstract

Background:

Estimating the rate of glucose appearance (R_a) after ingestion of a mixed meal may be highly valuable in diabetes management. The gold standard technique for estimating R_a is the use of a multitracer oral glucose protocol. However, this technique is complex and is usually not convenient for large studies. Alternatively, a simpler approach based on the glucose-insulin minimal model is available. The main drawback of this last approach is that it also requires a gastrointestinal model, something that may lead to identifiability problems.

Methods:

In this article, we present an alternative, easy-to-use method based on the glucose-insulin minimal model for estimation of R_a. This new technique avoids complex experimental protocols by only requiring data from a standard meal tolerance test. Unlike other model-based approaches, this new approach does not require a gastrointestinal model, which leads to a much simpler solution. Furthermore, this novel technique requires the identification of only one parameter of the minimal model because the rest of the model parameters are considered to have small variability. In order to account for such variability as well as to account for errors associated to measurements, interval analysis has been employed.

Results:

The current technique has been validated using data from a United States Food and Drug Administration-accepted type 1 diabetes simulator [root mean square error (RMSE) = 0.77] and successfully tested with two clinical data sets from the literature (RMSE = 0.69).

Conclusions:

The presented technique for the estimation of R_a showed excellent results when tested with simulated and actual clinical data. The simplicity of this new technique makes it suitable for large clinical research studies for the evaluation of the role of R_a in patients with impairments in glucose metabolism. In addition, this technique is being used to build a model library of mixed meals that could be incorporated into diabetic subject simulators in order to account for more realistic and varied meals.

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Abbreviations: (AUC) area under the curve, (CV) coefficient of variation, (FDA) Food and Drug Administration, (MIA) model interval analysis, (MTT) meal tolerance test, (OGTT) oral glucose tolerance test, (R_a) glucose rate of appearance, (RMSE) root mean square error, (SD) standard deviation, (S_I) insulin sensitivity, (T1DM) type 1 diabetes mellitus, (UVa) University of Virginia

Keywords: artificial pancreas, diabetes management, glucose rate of appearance, insulin sensitivity, robust estimation

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