# MATHEMATICAL MODELLING OF GLUCOSE-INSULIN SYSTEM BEHAVIOUR IN HOSPITAL TENGKU AMPUAN AFZAN INTENSIVE CARE UNIT PATIENTS

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**ABSTRACT**

Mathematical modelling of glucose-insulin system is significantly important to understand the body regulation control, to analyze experimental data based on clinical trials, to identify and quantify relevant physiological parameters, to design proper clinical trials and to assess diabetes therapies. In general, critically ill patients with blood glucose concentrations between 10.0 to 12.2 mmol/l is identified to develop an acute *hyperglycaemia* or high blood glucose (BG). Thus, to monitor *hyperglycaemia* among critically ill patients, this study is focused on observing the glucose-insulin system behaviour based on 40 patients' clinical data collected in Hospital Tengku Ampuan Afzan, Kuantan, Pahang with clinically validated mathematical glucose-insulin model. By using this model, a critical model-based parameter known as insulin sensitivity (*SI*) that illustrates patient's severity were identified hourly for all patients whose on insulin infusion therapy protocol for average four to six days. The results show that a BG normal distribution is attained with median kurtosis of 2.72. While, the 40 patient-specific *SI* indicate that an outliers-prone distribution occurred as kurtosis 3.96. Thus, abrupt changes in *SI* is basically due to chaotic interaction between blood glucose and insulin concentrations in bloodstreams. Also, the glucose-insulin behaviour pattern among these 40 critically ill patients might be varied due to their main diagnotics illness such as acute kidney failure, cardiovascular disease, etc. Overall, these results might assist clinicians and researchers to understand the glucose-insulin behaviour based on patient's severity illness and helps to inform glycaemic control protocol development in a larger group of critically ill patients.

**Keywords:** Glucose-Insulin system • Mathematical modelling • Insulin sensitivity • Blood glucose • Critical care

## INTRODUCTION

The glucose-insulin system is defined as interaction between insulin produced in pancreas once food is consumed. This system is important to maintain blood glucose levels in a stable condition (*homeostasis*). To sustain homeostasis, blood glucose concentrations are regulated by negative feedback where the concentrations are monitored by β-cells in the pancreas to produce insulin (Ferrannini & Mari, 2004). The production of insulin acts as the body's feedback signal to manage blood glucose storage (i.e. body fat) and transportation needs that determines the glucose utilisation as energy (Whyte et al., 2010).

Since 19$^{th}$ century, mathematical models have been developed to study glucose metabolism, insulin production and insulin-glucose system (Akerman, Gatewood, Rosevear, & Molnar, 1965; Insel et al., 1974). These models which defined by model parameters represent explicit physiology effects/processes of the true behaviour have been successfully simulated the mechanisms governing by glucose-insulin system (Chase, Le Compte, Suhaimi, et al., 2011). Thus, any changes in observed behaviour can be interpreted in terms of changing parameter values where the model can be used to provide a physiological explanation for the observed dynamic effects (Chase, Le Compte, Preiser, et al., 2011; Chee, Fernando, Savkin, & van Heeden, 2003; Mari, 2002). It also helps to understand the changes in physiological parameters can actually affect the changes in the uptake of substance by various organs in the body.

Nowadays, the potential of mathematical models in managing blood glucose levels in critically ill is becoming realized as these patients are sensitively prone to *hyperglycaemia* (high blood glucose) condition where extra cautions need to be taken during this stage. There are several mathematical model-based control protocols have