Glucagon-glucose dynamics for in-silico testing of an adaptive control bi-hormonal artificial pancreas

Ravi K. Reddy[1], Navid Resalat[1], Peter G. Jacobs[1], Joseph El Youssef[1], Jessica Castle[1], Deborah Branigan[1], Nicholas Preiser[1], W. Kenneth Ward[1,2]

[1]Oregon Health and Science University, Portland, OR, [2]Legacy Health, Portland, OR

Pancreatic cancer ranks as 4th among cancer related deaths in the United States. Pancreatic resection is the treatment of choice for long term survival of the patient; an important goal for the surgery is to prolong the quality of life of the patient. The complete or near-complete removal of the pancreas leads to pancreoprivic diabetes, a condition similar to type 1 diabetes. In such cases, an artificial endocrine pancreas with a dual-hormone closed-loop delivery would provide a higher quality of life for the patient. The current system addresses the replacement of the endocrine hormones needed for glucose metabolism. Closed loop control of the blood glucose in the patients could be achieved using the dual hormonal control algorithm shown here. An adaptive proportional derivative control algorithm with a fading memory (FMPD) senses the glucose measurements and along with meal announcements entered by the patient; calculates and delivers the hormones as needed. The system integrates off-the-shelf subcutaneous glucose sensor and pumps to maintain euglycemia. The coordinated secretion of glucagon and insulin from the alpha and beta cells respectively in the pancreas provides the principal level of control on glycaemia. To create an optimal dual-hormone closed loop system, in-silico validation and testing environments are needed. As the insulin and glucose kinetics are very well understood, here we present a mathematical model for the glucagon action system. Extending a minimal model of glucose and insulin dynamics we incorporate the action of glucagon on the underlying model. Model parameters are identified based on the physiological data collected.