ON THE SENSITIVITY OF CONTINUOUS GLUCOSE MONITORING TO INSULIN INFUSION FAULTS

Konstanze Kölle1,2,3, Anders Fougner1,2,3, and Øyvind Stavdahl1,2

1Artificial Pancreas Trondheim – The APT research group (www.aptrondheim.com), Norwegian University of Science and Technology (NTNU), Trondheim, Norway
2Department of Engineering Cybernetics, Norwegian University of Science and Technology (NTNU), Trondheim, Norway
3Helie Midt-Norge – The Central Norway Regional Health Authority, Norway

MOTIVATION

Artificial pancreatic (AP) systems
- Continuous glucose monitoring (CGM)
- Fully automated insulin infusion
- No user input
- Increased safety and reliability requirements
- Need for automatic fault detection

Insulin infusion faults
- Insulin infusion sets are the Achilles heel of continuous insulin infusion [1]
- With in-line detection, occlusions may remain silent (for hours) [2]
- Alternative detection based on CGM, e.g. [3]
- Time delays and slow dynamics of insulin infusion and glucose sensing with the subcutaneous (SC) approach may compromise the detection based on CGM.

Variable insulin sensitivity
- Changing over time [4]
- Inter- and intraindividual variability
- Affects the glucose levels by variable insulin needs.

Aim: Distinguish insulin infusion faults from other disturbances in an artificial pancreas

METHODS

Simulation model
- In absence of clinical data on infusion faults, feed-forward simulations were used.
- UVa/Padova T1DM model [5]
- 10 adult subjects
- Glucose sensing, insulin absorption and meal digestion dynamics vary with subjects.

Comparison of perturbations with glucose-increasing effect
- Insulin infusion fault
  - Parameter $R_I$, rate of insulin appearance in plasma [5]
  - Time course of $R_I$ with subject’s insulin needs
  - Example of sudden stop:

- Meal disturbance
  - Parameter $R_M$, rate of glucose appearance in plasma [5]
  - Time course of $R_M$ from meal simulation
  - Example of step from 0 to 2 mg/kg/min:

- Decreased insulin sensitivity
  - Parameter $k_p$, insulin action on liver [5]
  - Nominal parameter value of each subject
  - Example of sudden change to 50% of nominal value:

RESULTS

Sensitivity to parameter changes over time
- Example of time course of a 3-meal-scenario for one subject
- Sensitivities of intravenous (IV) and SC CGM glucose

Sensitivity to parameter changes
- Mean local sensitivity after a meal of 25 g carbohydrates
- Normalized sensitivity coefficients

Insulin infusion fault $R_I$, Meal disturbance $R_M$, Decreased insulin sensitivity $k_p$

Interpretation:
- Especially low sensitivity to insulin infusion faults.
- SC CGM has lower sensitivity than blood measurements.
- Significant differences between subjects.

REFERENCES

[6] Hindmarsh AC and Serban R User Documentation for CVODE v2.9.0 (SUNDIALS v2.7.0), 2016.