Modelling Insulin and Glucose Dynamics in Diabetes Mellitus Type 1: Intravenous, Subcutaneous and Intraperitoneal Approach

Konstanze Kölle[1,2], Anders Fougner[1,2], Hans Erik Frøyen[1,2] and Øyvind Stavdahl[1,2]

[1] Artificial Pancreas Trondheim – The APT research group (www.apt-norway.com), Norwegian University of Science and Technology, Trondheim, Norway;
[2]Department of Engineering Cybernetics, Norwegian University of Science and Technology, Trondheim, Norway; Correspondence: konstanze.koelle@itk.ntnu.no

NTNU – Trondheim Norwegian University of Science and Technology
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Motivation

Diabetes mellitus type 1 (DM1)

- Normal glucose regulation by insulin
- Destructed insulin secretion in DM1
- Exogenous insulin infusions

State-of-the-art treatment

- Sensor-augmented insulin pumps
- Subcutaneous insulin delivery
- Subcutaneous glucose sensing
- Manual interventions required

Long-term aim

- Artificial Pancreas (AP)
- Fully automated insulin delivery

Strategy

- Easily extendable modular model
- Open- and closed-loop scenarios
- AP algorithm development based on simulation
- Validation by animal and clinical trials

Model

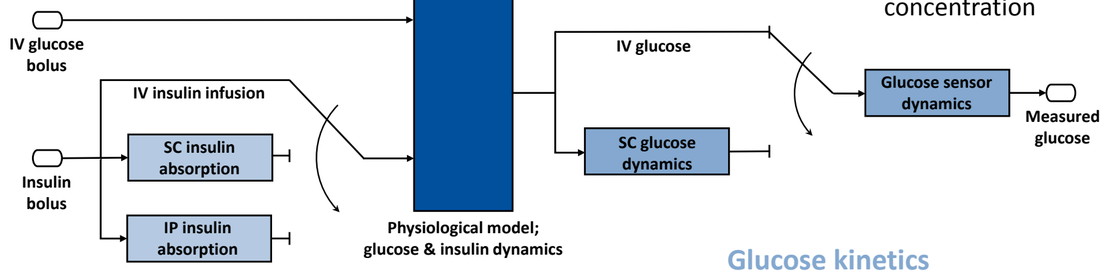
Input

- Intravenous glucose bolus
- Insulin bolus

Physiological glucose-insulin model [1]

Output

- Measured glucose concentration



Insulin absorption kinetics

- Intravenous (IV) [1]
- Subcutaneous according to Wilinska at al. ($SC_{Wil.}$) [2]
- Subcutaneous according to Dalla Man et al. ($SC_{D.M.}$) [1]
- Intraperitoneal (IP) [3]

Glucose kinetics

- Intravenous (IV) [1]
- Subcutaneous (SC) [4]

- Sensor dynamics

Simulation

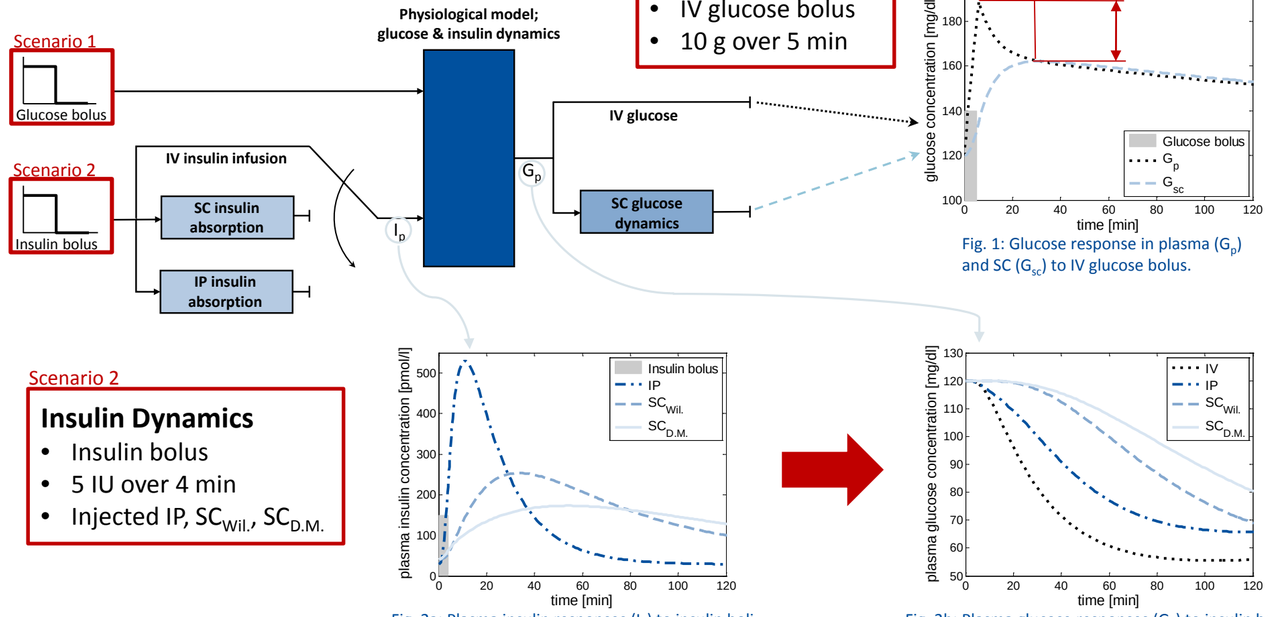


Fig. 1: Glucose response in plasma (G_p) and SC (G_{sc}) to IV glucose bolus.

Fig. 2a: Plasma insulin responses (I_p) to insulin boli.

Fig. 2b: Plasma glucose responses (G_p) to insulin boli.

Conclusion

Insulin infusion

- SC: common but large time constants
- IV: fastest but not practical for safety reasons
- IP: promising

Glucose sensing

- SC: significant time delays/constants
- No other options available for outpatient use
- Faster sensing techniques highly desired

References

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