Clinical Data Validation of an Improved, Physiologically Relevant Critical Care Glycaemic Control Model

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Background

Stress-induced hyperglycaemia is prevalent in critical care. Tight glycaemic control can significantly improve clinical outcomes. Model-based and model-derived methods, such as SPRINT in Christchurch, have shown significant mortality reductions. This research used prediction validation on an improved metabolic control model for real-time glycaemic control.

A stochastic insulin sensitivity variability model is derived to capture patient dynamics hour to hour. The BG distribution resulting from a given intervention can thus be derived, enabling better control and safety.

Methods & Methods

Data: N=270 patients (≥ 24 hour stay) and 47,326 hours from patients on SPRINT in Christchurch Hospital.

Population Parameters:
- EGP = 1.16 mmol.min⁻¹
- αG = 0.0017 l.mU⁻¹
- βG = 3.15 l
- k = 0.0198 min⁻¹
- n = 0.16 min⁻¹
- δ = 0.0347 min⁻¹
- α = 0.0098 min⁻¹
- β = 0.0347 min⁻¹
- δ = 0.0069 min⁻¹

Time-Varying Parameters: Insulin Sensitivity (S(t))

Cohort-Specific Parameters: EGP and pG identified using a grid search, based on minimal prediction and fitting errors, while held constant over the entire cohort.

ID Method: An Integral-based method is used to identify time-varying insulin sensitivity for virtual patient trials.

Virtual Patients are created by identifying time-varying S(t) profiles for each patient to be used with different interventions. Prediction errors are the error using the known intervention.

Stochastic Model: The 64 586 hourly S(t) values are used to estimate the BG hour to hour using PNSG. A 2D kernel density estimation method is used to construct the model. Given a cohort identified S(t) value, the glucose levels can be calculated over the last hour for a given intervention.

Results

Parameter identification: The pG and EGP values fixed agreed well with literature. Patient-specific values resulted in a performance improvement.

Model Validation: Fitting and prediction errors (median, IQR, 90% CI) are:

- Model 1: EDF = 1.16 mmol.min⁻¹
- Model 2: EDF = 1.16 mmol.min⁻¹

All errors are well within the measurement error of 7-12%. Predictions outside measurement error are primarily due to outlying measurement errors or sensor failures.

Conclusions

Model-based tight glycaemic control is proving to be a function of model quality. A new, more physiologically relevant control model is presented and validated over a 270 patient data set. Prediction and fitting errors lie within measurement error, indicating suitability for clinical use.

A stochastic model is developed and shows the same trends expected in the dynamic, critically ill patient who gets well slowly, can decline quite rapidly in some (more rare) cases. The combination of these models is suitable for use in acute and critical care settings.

The deterministic + stochastic model combination has already been applied successfully in 24-hour ICU trials.