Glycaemic Control in ICU: Stable Patients Tend to Remain Stable

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Background

Stress-hyperglycaemia is a common complication in intensive care patients. Glycaemic control (GC) has shown improved outcomes but was proven difficult to achieve safely, increasing risks of hypoglycaemia.

STAR is a model-based GC protocol with proven safety and performance. It uses a cohort-based 2D **stochastic model** of model-based, patient-specific **insulin sensitivity (SI)**. Given current SI, it predicts likely future distribution of SI values to dose insulin and nutrition based on specified risk of hypoglycaemia (**Figure 1**).

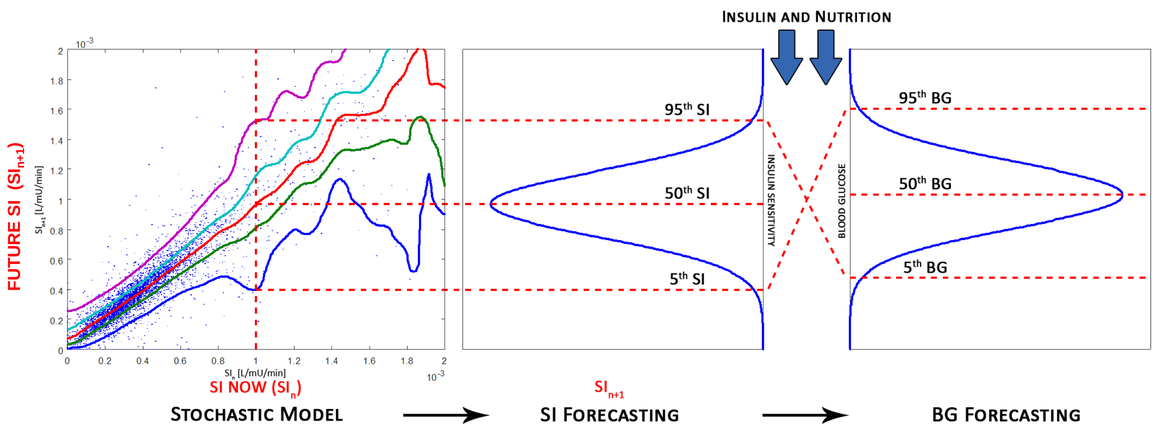

Figure 1 – Future insulin sensitivity (SI) is forecast from current SI. The distribution of future SI is used to predict likely BG outcomes for a given insulin-nutrition treatment intervention.

Objectives

- **Could we make the SI range prediction more patient-specific?**
  → Using more information can give additional information on future likely SI.
- **What separates different kinds of patients?**
  → Metabolic (SI) variability: more variable patients are harder to control than more stable patients.

Methods

Metabolic data from 3 clinical ICU cohorts (819 episodes and 68629 hours of treatment) are used in this study (**Table 1**).

Table 1 – Summary of patient demographics for three cohorts. Results are given as median [IQR] where relevant.

	SPRINT Christchurch	STAR Christchurch	STAR Gyula
# episodes	442	330	47
# hours	39838	22523	6268
% male	62.7	65.5	61.7
Age (years)	63 [48, 73]	65 [55, 72]	66 [58, 71]
APACHE II	19.0 [15.0,24.5]	21.0 [16.0,25.0]	32.0 [28.0,36.0]
LOS - ICU (days)	6.2 [2.7,13.0]	5.7 [2.5,13.4]	14.0 [8.0,20.5]

SI variability (%ΔSI) is defined as the hour-to-hour percentage change in SI:

$$\%\Delta SI_i = 100 \times \frac{SI_{i+1} - SI_i}{SI_i}$$

Data triplets ($\%\Delta SI_n$, SI_n, SI_{n+1}) are created and grouped together in bins of size %ΔSI = 10% and SI_n = 0.5e-4. CDFs are computed in each bin where data density reach 100 data triplets.

Outcomes are:

- **The percentage change in the 90% CI prediction width.**
- **The predictive power** (median [IQR] per-patient percentage prediction within the 5th-95th or 25th-75th percentile range).

Results

- The 2D model is **over-conservative for 77% of hours** mainly where %ΔSI is **within an absolute 25% change** (Figure 1).
  → **Indicates patients are stable more than 75% of the time.**
  → **Stable patients tend to remain stable.**
  → **51871 conservative** hours vs. **13180 non-conservative** hours.
- The percentage change in the 90% CI width in conservative regions is **reduced by 25-40%** (Figure 2).
  → **More aggressive dosing allowed for these patients.**

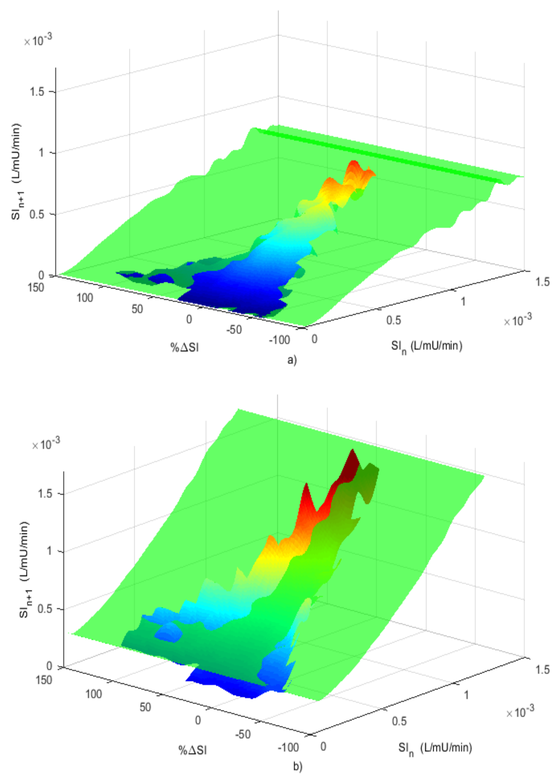

Figure 2 – Comparison between the 3D model (colour) and the original 2D model (green) for the 5th (a) and 95th (b) percentiles.

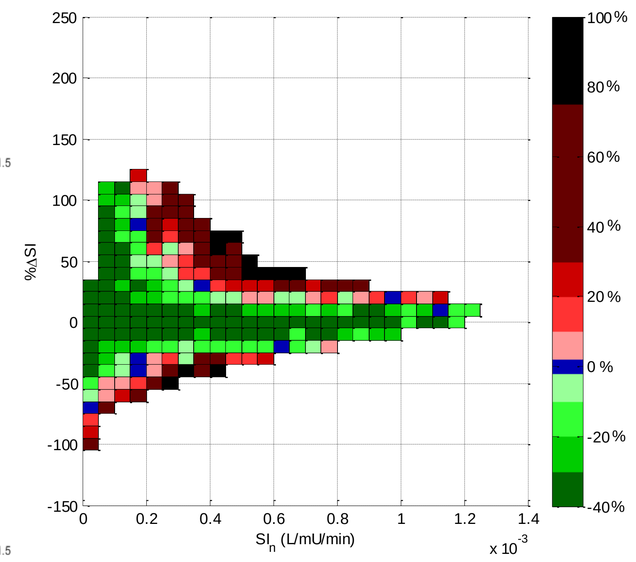

Figure 3 – Percentage change in the width of the 5th-95th percentile range when the new 3D model is compared to the previous 2D model. Green and red areas suggest over and under conservative behaviour respectively within the 2D model.

- **Similar predictive power for both models**, but closer to ideal value of 90% for 3D stochastic model (Table 2).
  → **Greater patient-specificity.**
- **Significant percentage reduction** of the 90% CI predictive range (Table 2, Figure 4).

Table 2 – Per-patient predictive power comparison between previous and new stochastic model. Results are given as median [IQR].

	2D Model	3D model
Median % prediction within 25th-75th range	63.1% [62.8%, 63.4%]	51.8% [51.5%, 52.1%]
Median % prediction within 5th-95th range	92.6% [92.5%, 92.7%]	89.7% [89.6%, 90.0%]
Median % reduction 90% CI width	30.8% [30.5%, 31.1%]	

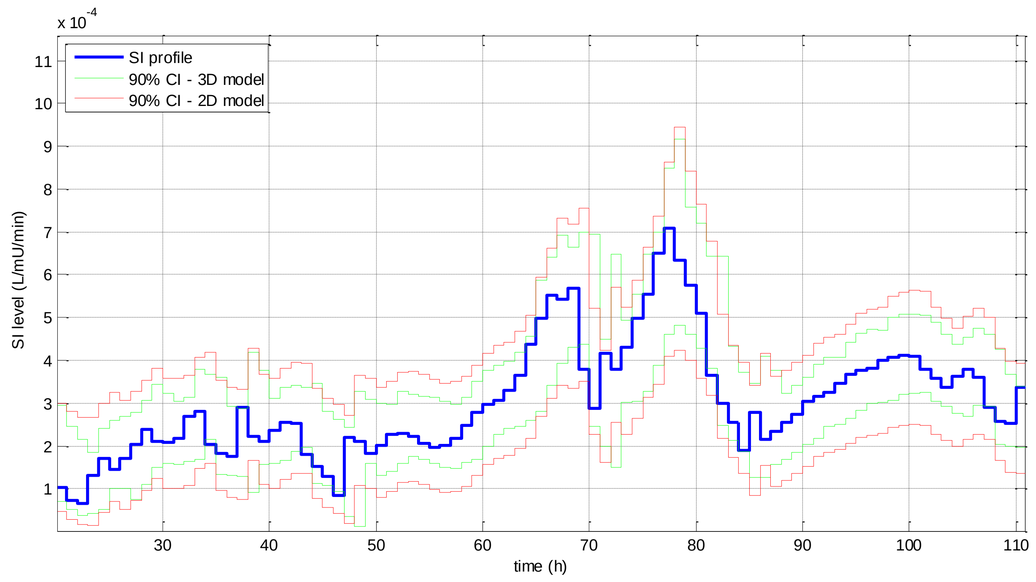

Figure 4 – Excerpt from a patient showing fitted SI (blue) as well as 5th and 95th percentile prediction for the new 3D model (green) and the previous 2D model (red). The new model predictive range is generally narrower than the old model.

Conclusions

- **By reducing prediction range for 77% of hours,** predominantly where SI is stable, **the new 3D model shows stable patients tend to remain stable in terms of %ΔSI, refuting the idea they are always very variable.**
- The 3D model **better characterises patient-specific response to insulin, allowing more optimal dosing** while ensuring safety.

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