Abstract for ESCTAIC 2010

"Glucosafe - A model-based medical decision support system for tight glycemic control in critical care"

Ulrike Pielmeier[a]

[a]*Center for Model-based Medical Decision Support, Aalborg University, Fredrik-Bajers-Vej 7, 9220 Aalborg, Denmark*

Introduction

Hyperglycemia during critical illness is common and is associated with increased mortality, morbidity and prolonged stay in intensive care [1][2]. The past decade has seen many attempts to improve survival by regulating blood glucose using intensive insulin therapy (IIT) protocols [3][4]. However, consistent control has proven elusive, not least because typical IIT protocols ignore the carbohydrate intake of patients [5]. An effective method that achieves and maintains "tight" blood glucose levels (i.e. in the range from 4 to 6 mmol/l) without high glucose variances and without increasing insulin-induced severe hypoglycemia (<2.2 mmol/l) has yet to emerge [6].

This work assesses the effectiveness of the computerized decision support system "Glucosafe" for tight glycemic control in critical care. This system advises insulin therapy and infusion rates of enteral and parenteral nutrition, based on blood glucose predictions with a physiological insulin-glucose model and patient-specific data [7]. Pilot testing shows significant improvements of glycemic control in a prospectively controlled cohort of intensive care patients [8]. In a retrospective analysis of the pilot study data the model is assessed with regard to how accurately blood glucose was predicted, and whether the predictive accuracy can be improved by two physiological model extensions, regarding the decreased delivery rate of nutrients that is often observed in critical care patients with delayed gastric emptying [9], and the dependency of pancreatic insulin secretion on the blood glucose level [10].

Methods

The blood glucose concentrations of 10 hyperglycemic patients admitted to a neuro- and trauma intensive care unit were retrospectively predicted using a) the original Glucosafe model [7] b) the Glucosafe model including a feedback loop between blood glucose and pancreatic insulin secretion rate c) the Glucosafe model and a reduced rate of appearance of enterally administered nutrition in the intestinal reservoir d) both extensions as described in b) and c). Prediction errors were expressed as absolute percent error (APE) from measured concentrations; the comparison was based on median APEs for different prediction time lengths, reflecting intervals between measurements of up to 5 hours.

Results

The model predictive accuracy improved modestly for each one of the two model extensions. The greatest reduction in prediction error was achieved when both model extensions were included in the

Glucosafe model. For predictions time lengths (in hours) of 0.5-1.5h, 1.5-2.5h, 2.5-3.5h, 3.5-4.5h and 4.5-5.5h, the median APE was 9.7%, 11.2%, 14.8%, 15.1% and 17.7% with the Glucosafe model, compared to 9.2%, 10.1%, 12.3%, 13.2% and 16.6% with both of the model extensions included, for the same prediction time lengths.

Discussion

Predicted blood glucose concentrations with the Glucosafe model in its original form [7] are sufficiently accurate for typical time intervals between two measurements. The pilot trial results [8] showed that glycemic control was significantly improved, while no hypoglycemic event was observed. Thus, model-based predictive control based on the Glucosafe model may be a step towards a consistent reduction of elevated blood glucose levels. This retrospective analysis also explored two physiological model extensions, which modestly improved the model's predictive accuracy. However, as the data used in this study were from a small cohort of patients with similar admission diagnosis, groups of other patients with a different disease background should be used to verify these preliminary results.

References

[1] Falciglia M, Freyberg RW, Almenoff PL, et al. Hyperglycemia-related mortality in critically ill patients varies with admission diagnosis. Crit Care Med 37 (12): 3001-3009, 2009.

[2] Krinsley JS: Association between hyperglycemia and increased hospital mortality in a heterogeneous population of critically ill patients. Mayo Clinic Proceedings 78 (12): 1471-1478, 2003.

[3] Meijering S, Corstjens AM, Tulleken JE, et al.Towards a feasible algorithm for tight glycaemic control in critically ill patients: a systematic review of the literature. Critical Care 10 (1): R19, 2006.

[4] Chase JG, Hann CE, Shaw GM, et al. An overview of glycemic control in critical care - relating performance and clinical results. Journal of Diabetes Science and Technology 1 (1): 82-91, 2007.

[5] Kalfon P, Preiser JC. Tight glucose control: should we move from intensive insulin therapy alone to modulation of insulin and nutritional inputs? Crit Care 12:156, 2008.

[6] Dossett LA, Collier B, Donahue R, et al. Intensive insulin therapy in practice: Can we do it? J Parenter Enteral Nutr 33 (1): 14-20, 2009.

[7] Pielmeier U, Andreassen S, Nielsen BS, et al. A simulation model of insulin saturation and glucose balance for glycemic control in ICU patients. Computer Methods and Programs in Biomedicine 97 (3): 211-222, 2010.

[8] Pielmeier U, Andreassen S, Juliussen B, et al. The Glucosafe system for tight glycemic control in critical care: A pilot evaluation study. J Crit Care 25 (1): 97-104, 2010.

[9] Chapman M, Fraser R, Matthews G, et al. Glucose absorption and gastric emptying in critical illness. Crit Care 13 (4): R140, 2009.

[10] Polonsky KS, Given BD, Van Cauter E. Twenty-four-hour profiles and pulsatile patterns of insulin secretion in normal and obese subjects. J Clin Invest 81: 442-448, 1988.