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Statistical Hypoglycemia Prediction

Fraser Cameron,[1] Günter Niemeyer, Ph.D.,[1] Karen Gundy-Burlet, Ph.D., and Bruce Buckingham, M.D.[2]

Abstract

Background:
Hypoglycemia presents a significant risk for patients with insulin-dependent diabetes mellitus. We propose a predictive hypoglycemia detection algorithm that uses continuous glucose monitor (CGM) data with explicit certainty measures to enable early corrective action.

Method:
The algorithm uses multiple statistical linear predictions with regression windows between 5 and 75 minutes and prediction horizons of 0 to 20 minutes. The regressions provide standard deviations, which are mapped to predictive error distributions using their averaged statistical correlation. These error distributions give confidence levels that the CGM reading will drop below a hypoglycemic threshold. An alarm is generated if the resultant probability of hypoglycemia from our predictions rises above an appropriate, user-settable value. This level trades off the positive predictive value against lead time and missed events.

Results:
The algorithm was evaluated using data from 26 inpatient admissions of Navigator® 1-minute readings obtained as part of a DirecNet study. CGM readings were postprocessed to remove dropouts and calibrate against finger stick measurements. With a confidence threshold set to provide alarms that correspond to hypoglycemic events 60% of the time, our results were (1) a 23-minute mean lead time, (2) false positives averaging a lowest blood glucose value of 97 mg/dl, and (3) no missed hypoglycemic events, as defined by CGM readings. Using linearly interpolated FreeStyle capillary glucose readings to define hypoglycemic events provided (1) the lead time was 17 minutes, (2) the lowest mean glucose with false alarms was 100 mg/dl, and (3) no hypoglycemic events were missed.

Conclusion:
Statistical linear prediction gives significant lead time before hypoglycemic events with an explicit, tunable trade-off between longer lead times and fewer missed events versus fewer false alarms.

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Author Affiliations: [1]Stanford University, Palo Alto, California; and [2]Lucile Salter Packard Children's Hospital, Stanford Medical Center, Palo Alto, California

Abbreviations: (ADA) American Diabetes Association, (CGM) continuous glucose monitor, (FP) false positive, (OWL) observational window length, (PL) prediction length, (SD) standard deviation, (TP) true positive

Keywords: continuous glucose monitoring, estimation, hypoglycemia, linear regression, statistical prediction

Corresponding Author: Fraser Cameron, Stanford University, 216-202 Rosse Lane, Palo Alto, CA; email address *fraser@stanford.edu*