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SYMPOSIUM

Accuracy Requirements for a Hypoglycemia Detector: An Analytical Model to Evaluate the Effects of Bias, Precision, and Rate of Glucose Change

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Abstract

Background:
There has been considerable debate on what constitutes a good hypoglycemia (Hypo) detector and what is the accuracy required from the continuous monitoring sensor to meet the requirements of such a detector. The performance of most continuous monitoring sensors today is characterized by the mean absolute relative difference (MARD), whereas Hypo detectors are characterized by the number of false positive and false negative alarms, which are more relevant to the performance of a Hypo detector. This article shows that the overall accuracy of the system and not just the sensor plays a key role.

Methods:
A mathematical model has been developed to investigate the relationship between the accuracy of the continuous monitoring system as described by the MARD, and the number of false negatives and false positives as a function of blood glucose rate change is established. A simulation method with $N = 10{,}000$ patients is used in developing the model and generating the results.

Results:
Based on simulation for different scenarios for rate of change (0.5, 1.0, and 5.0 mg/dl per minute), sampling rate (from 1, 2.5, 5, and 10 minutes), and MARD (5, 7.5, 10, 12.5, and 15%), the false positive and false negative ratios are computed. The following key results are from these computations.

1. For a given glucose rate of change, there is an optimum sampling time.
2. The optimum sampling time as defined in the critical sampling rate section gives the best combination of low false positives and low false negatives.
3. There is a strong correlation between MARD and false positives and false negatives.
4. For false positives of <10% and false negatives of <5%, a MARD of <7.5% is needed.

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Abbreviations: (Hypo) hypoglycemia, (ISF) interstitial fluid, (MARD) mean absolute relative difference

Keywords: accuracy, alarm threshold, bias, calibration, critical sampling rate, coefficient of variation, continuous glucose monitor, critical threshold, drift, false positive ratio, false negative ratio, glucose monitoring system, hypoglycemia, hypoglycemia detector, hypoglycemia threshold, lag effect, linear regression, mean absolute relative difference, precision, random variation, rate of glucose change, relative bias, sampling rate, sampling time, slope, standard normal random variable, systematic bias, target area, variable sampling rate

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Abstract cont.

Conclusions:
Based on the model, assumptions in the model, and the simulation on $N = 10{,}000$ patients for different scenarios for rate of glucose change, sampling rate, and MARD, it is concluded that the false negative and false positive ratio will vary depending on the alarm Hypo threshold set by the patient and the MARD value. Also, to achieve a false negative ratio <5% and a false positive ratio <10% would require continuous glucose monitoring to have an MARD ≤7.5%.

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