Journal of Diabetes Science and Technology
Volume 6, Issue 6, November 2012

ORIGINAL ARTICLE

Analysis: Continuous Glucose Monitoring in the Intensive Care Unit

W. Kenneth Ward, M.D.

Abstract

Control of glycemia in hospitalized patients is important; hypoglycemia is associated with increased mortality, and hyperglycemia is associated with adverse outcomes. For these reasons, though no such device is currently available, continuous glucose monitoring (CGM) is an attractive option, especially in the critical care setting. Schierenbeck and coauthors, in this issue of *Journal of Diabetes Science and Technology*, report on the use of a specialized central catheter designed to monitor glucose continuously in post cardiac surgery patients. This catheter, which was indwelled within the great veins, was specially designed with a separate lumen and membrane that allowed continuous glucose microdialysis. Accuracy was quite good, better than has been reported with the use of commercially-available CGM devices. Ideally, further development of this quite promising catheter-based device would allow it to be used also to deliver fluids and drugs, thus avoiding the need for a second catheter elsewhere.

J Diabetes Sci Technol 2012;6(6):1372-1374

The accuracy of glucose monitoring in hospitalized patients is important. Most workers in the field would agree that, in inpatients, it is crucially important to avoid hypoglycemia. A report from the NICE-SUGAR study found that, compared with controls, there was a 200% increase in mortality in subjects who experienced at least one blood glucose (BG) value under 41 mg/dl and an 81% increase in mortality in subjects with a BG value from 41–70 mg/dl. Hypoglycemia was quite common in this large study of approximately 6000 subjects; 45% experienced at least one BG between 41 and 70 mg/dl.[1]

Elevations of BG are also associated with adverse outcomes. One very interesting study found that, after an acute myocardial infarction, patients with diabetes whose average BG persistently exceeded 240 mg/dl experienced a 32% higher mortality rate compared with euglycemic patients. Even more striking was the finding that patients *without known diabetes* whose BG was in this range experienced approximately a 87% higher mortality rate.[2] The high complication and death rate in hyperglycemic patients without known diabetes (also noted in other studies) is almost certainly related to the severity of the underlying disease that causes hyperglycemia via marked elevations in stress hormones.

It is against this backdrop that Schierenbeck and coauthors[3] in this issue of *Journal of Diabetes Science and Technology* report on the use of a specialized central venous catheter (CVC) for continuous glucose monitoring in the post-cardiac surgery intensive care unit (ICU) setting. This catheter was specially designed with a

Author Affiliation: Oregon Health and Science University, Legacy Health, Portland, Oregon

Abbreviations: (BG) blood glucose, (CGM) continuous glucose monitor, (CVC) central venous catheter, (ICU) intensive care unit, (ISO) International Organization for Standardization, (MARD) mean absolute relative difference

Keywords: continuous glucose monitoring, critical care, diabetes mellittus, intensive care, microdialysis, post-operative

Corresponding Author: W. Kenneth Ward, M.D., Oregon Health and Science University, Legacy Health, 3181 SW Sam Jackson Park Road (mailstop OP05DC), Portland, OR 97239; email address wardk@ohsu.edu

separate lumen and distal membrane that allowed the investigators to carry out continuous glucose microdialysis in the great veins of these patients. As in any microdialysis system, a pump and receptacle were necessary, and these elements were incorporated into a bedside device that included a screen that displayed the real-time calibrated glucose value.

The system was prospectively calibrated by glucose measurements obtained from arterial blood gas sampling every 8 h (and to the authors' credit, these measurements during calibration were not included in the accuracy analysis). There was a 10 min delay due to dialysis perfusion. It is noteworthy that it was necessary for each subject to have at least one additional CVC in place for the purpose of administering usual postoperative fluids and medications. The devices were tolerated well, and the authors made specific mention of that fact that no thromboses or other complications were observed.

The accuracy of the system was quite good, although a limitation of the study was the lack of glucose values in the hypoglycemic range. Most of the patients (approximately 80%) did not have preexisting diabetes, and most of the BG values were accordingly in the mildly hyperglycemic range. Some values were quite hyperglycemic; the system accuracy appeared to be well maintained in this range. No systematic drift over time was observed, and 99% of the Clarke error grid values were in either the A or the B range. The Clarke grid is not well suited to measure accuracy in the hypoglycemic range, but as noted, no such values existed in this study. Mean absolute relative difference (MARD) was excellent at only 5%, and similarly, a very high percentage of glucose pairs (over 99%) met the International Organization for Standardization (ISO) accuracy criteria. A Bland–Altman plot was also provided, and these data showed little bias according to glycemic range, though there was a mild tendency to overestimate BG in the hyperglycemic range. It is not clear whether the calculations for accuracy were made after a 10 min delay correction. The authors state that, in some cases, glucose was infused through the dialysis CVC without causing a disturbance of glucose measurement.

Other workers have investigated competing technologies. For example, Skjaervold and coauthors[4] reported the use of a boronic acid sensor that was placed through the lumen of a CVC in anesthetized pigs. In a very clever manner, they were able to precisely measure the diameter of the sensor as it swelled and shrunk with changes in ambient glucose. Though their reported accuracy was quite good, my enthusiasm is tempered by the fact that the calibrations were carried out retrospectively, that there was substantial signal degradation over time, and that there was a need to compensate for several types of drift. A team from GluMetrics demonstrated preliminary success in a clinic setting with an intravascular boronic-acid-based sensor; the MARD was 8%.[5]

Others have investigated the use of commercially available continuous glucose monitors (CGMs) in the ICU (it should be noted that such a use of a CGM is not an approved indication; none of the devices discussed in this editorial are approved for hospital monitoring). In one study of critically ill children, Bridges and coauthors[6] found a MARD of 15.3% with the Medtronic CGM. Despite many different diagnoses and reasons for hospitalization, accuracy was generally similar to the standard outpatient setting. In another interesting study, Lorencio and coauthors[7] studied a real-time CGM in patients with a variety of diagnoses in the ICU setting, all of whom were receiving insulin treatment. The median absolute relative difference was generally satisfactory (13.5%), though the Bland–Altman revealed some very large errors. Of note is that only 68% met ISO accuracy criteria. Interestingly, patients with septic shock experienced more accurate CGM results than those without this diagnosis, with an absolute relative difference of 11.2% and with 75% meeting ISO criteria.[7] One presumes that the systemic vasodilation typical of septic shock may have improved system accuracy.

In summary, the glucose measurement accuracy of a CVC fitted with a microdialysis element was quite good, even in the challenging environment of an ICU. Though central catheters are associated with a variety of complications, including infection[8] and thrombosis,[9] the subjects in this study experienced no such misadventures. If this specially modified catheter can eventually also be used in the manner that such devices are usually intended (to deliver fluids and drugs), there would be no need for a second central catheter. Such an improvement would render this promising technology even more promising.

Acknowledgments:

This work was supported by the Juvenile Diabetes Research Foundation and the Legacy Good Samaritan Foundation.

References:

1. NICE-SUGAR Study Investigators, Finfer S, Liu B, Chittock DR, Norton R, Myburgh JA, McArthur C, Mitchell I, Foster D, Dhingra V, Henderson WR, Ronco JJ, Bellomo R, Cook D, McDonald E, Dodek P, Hébert PC, Heyland DK, Robinson BG. Hypoglycemia and risk of death in critically ill patients. N Engl J Med. 2012;367(12):1108–18.
2. Kosiborod M, Rathore SS, Inzucchi SE, Masoudi FA, Wang Y, Havranek EP, Krumholz HM. Admission glucose and mortality in elderly patients hospitalized with acute myocardial infarction: implications for patients with and without recognized diabetes. Circulation. 2005;111(23):3078–86.
3. Schierenbeck F, Franco-Cereceda A, Liska J. Evaluation of a continuous blood glucose monitoring system using central venous microdialysis. J Diabetes Sci Tech. 2012;6(6):1365–71.
4. Skjaervold NK, Solligård E, Hjelme DR, Aadahl P. Continuous measurement of blood glucose: validation of a new intravascular sensor. Anesthesiology. 2011 Jan;114(1):120–5.
5. Peyser T, Zisser H, Khan U, Jovanovič L, Bevier W, Romey M, Suri J, Strasma P, Tiaden S, Gamsey S. Use of a novel fluorescent glucose sensor in volunteer subjects with type 1 diabetes mellitus. J Diabetes Sci Technol. 2011;5(3):687–93.
6. Bridges BC, Preissig CM, Maher KO, Rigby MR. Continuous glucose monitors prove highly accurate in critically ill children. Crit Care. 2010;14(5):R176.
7. Lorencio C, Leal Y, Bonet A, Bondia J, Palerm CC, Tache A, Sirvent JM, Vehi J. Real-time continuous glucose monitoring in an intensive care unit: better accuracy in patients with septic shock. Diabetes Technol Ther. 2012;14(7):568–75.
8. Donelli G. Vascular catheter-related infection and sepsis. Surg Infect (Larchmt). 2006;7 Suppl 2:S25–7.
9. Wilson TJ, Stetler WR Jr, Fletcher JJ. Comparison of catheter-related large vein thrombosis in centrally inserted versus peripherally inserted central venous lines in the neurological intensive care unit. Clin Neurol Neurosurg. 2012. Epub ahead of print.