Urine Glucose Testing: Reliable Backup for Whole Blood Glucose Monitoring

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Urine glucose testing has been deemed by some to be nonessential in the management of diabetes mellitus since the technique and equipment for self-monitoring of blood glucose has become available. However, most physicians have experienced pitfalls in the management of diabetes mellitus when insulin dosage is adjusted daily based solely on the patient's monitoring of blood glucose. There have also been recent reports suggesting the use of urine glucose testing as a reliable and a reasonable alternative to monitoring of blood glucose in the management of diabetic subjects, including those using insulin as the mode of therapy.

In this report, we describe a patient in whom diabetic ketoacidosis occurred during hospitalization as a result of inadequate insulin administration due to inaccurate capillary blood glucose test results. Furthermore, urine glucose and ketone values obtained simultaneously had been disregarded. If insulin therapy had been adjusted according to urine glucose results rather than blood glucose readings, diabetic ketoacidosis could have been averted in this patient.

Urine glucose testing may provide a reliable backup for suspect whole blood glucose values and may prevent catastrophic events requiring expensive hospitalization. This report also delineates several potential procedural problems that exist in the technique of whole blood glucose monitoring and provides recommendations to overcome these deficiencies.

Key words. Diabetes mellitus; blood glucose; urine.
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Most practicing physicians have experienced pitfalls in the management of diabetes mellitus that have occurred as a result of erroneous readings obtained by whole blood glucose testing.[1,2] Nevertheless, many physicians do recommend self-monitoring by patients of blood glucose levels despite data showing the unreliability of patients' readings.[3-6] Inaccuracy of capillary blood glucose testing by paramedical hospital personnel has also been reported.[7-10] The accuracy of self-monitoring declines even further as neurovascular changes in the fingertips of patients with diabetes mellitus make it difficult to obtain an adequate amount of blood.

In our practice, we have noted that simultaneous urine glucose testing can prevent catastrophic events and reduce expensive hospitalizations. We describe an index case to exemplify the usefulness of urine glucose testing as a reliable second line of defense in patients using capillary blood glucose testing.

Case Report

A 32-year-old, white, male farmer with insulin-dependent diabetes mellitus of 15 years' duration was hospitalized with acute upper gastrointestinal bleeding. He was under fair metabolic control (HbA_{1c} 8.2% to 9.5%; normal range <8.2%) with the combination of NPH insulin (25 U and 15 U) and regular insulin (6 U and 4 U) administered twice daily, before breakfast and supper.

Usual therapeutic modalities were used to control the patient's gastrointestinal (GI) bleeding. Insulin, normal saline, dextrose, and blood transfusions were administered intravenously to the patient. Once the GI bleeding had stopped and oral intake was instituted, regular insulin was administered subcutaneously on a sliding scale according to capillary blood glucose levels obtained before each meal: no insulin was administered if the patient's blood glucose level was less than 8.3 mmol/L (<150 mg/dL), 4 U if his glucose level was from 8.3 mmol/L to 11.1 mmol/L (150 mg/dL to 200 mg/dL), 6 U if 11.2 mmol/L

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to 13.9 mmol/L (201 mg/dL to 250 mg/dL), 8 U if 14.0 mmol/L to 16.7 mmol/L (251 mg/dL to 300 mg/dL), and 10 U if greater than 16.7 mmol/L (300 mg/dL). At the same time, the house physician had also requested urine testing for glucose as well as acetone.

On the 6th day of hospitalization, the patient was scheduled to undergo an upper GI series; therefore, he was not given anything orally after midnight. On the morning that the GI series was to be done, the patient's capillary blood glucose level was 7.6 mmol/L (137 mg/dL); therefore, no insulin was administered. The patient returned from having the upper GI test series about 10 AM, and again, before lunch, no insulin was administered because the capillary blood glucose was 7.2 mmol/L (129 mg/dL). At about 4 PM, the patient complained of abdominal pain, nausea, vomiting, and mild respiratory distress. He was given an antacid, but this did not provide any relief.

At 6 PM, the patient reported that his symptoms were worse, and he was experiencing respiratory distress associated with tachypnea, suggestive of "Kussmaul's breathing." At this time, capillary blood glucose was again noted to be from 7.0 mmol/L to 8.5 mmol/L (125 mg/dL to 145 mg/dL) on repeated determinations. However, the bedside urine testing by "dipstick" tape (Ames Division of Miles Laboratories, Inc, Elkhart, Ind) showed marked glycosuria and ketonuria. Therefore, blood was drawn and sent to the clinical laboratory. The patient's plasma glucose level was 30.5 mmol/L (548 mg/dL), with an anion gap of 28 mmol/L and a moderately positive serum ketone concentration. The patient was transferred to the intensive care unit with the diagnosis of diabetic ketoacidosis. He was treated appropriately with insulin infusion and intravenous fluids, and recovered fully. On discharge, the patient was instructed to take NPH (24 U and 15 U) and regular insulin (8 U and 4 U) twice daily, before breakfast and supper, and instructed to alter the dosage depending on the results of whole blood glucose testing. Blood glucose testing was to be monitored, however, with at least once-daily simultaneous urine testing for glucose and acetone.

On later review of the hospital record, it was noted that the patient received no insulin for almost 36 hours prior to the time the GI series was done because all of his capillary blood glucose recordings were below 8.3 mmol/L (150 mg/dL). During this same period, urine glucose concentrations had ranged between 1% and 2% on all urine tests. Furthermore, urine acetone concentration was noted to be a trace on the morning of upper GI series and was moderate to large before lunch on the same day. Apparently, urine testing results had been disregarded in favor of blood glucose levels; hence, no insulin had been administered. On further investigation, it was found that the glucose testing meter (Glucometer, Ames Division of Miles Laboratories, Inc, Elkhart, Ind) used on the ward was functioning adequately when checked by the diabetes nurse educator. We believe that the problem arose because of the faulty technique of ward personnel who were only occasionally involved in using the equipment, and therefore not adequately trained.[7-10]

Table 1. Common Causes of Error in Values Obtained by Glucose Testing Meters

- Lack of quality control in hospital ward
- Fingertip not dry
- Insufficient blood sample because of inappropriate choice of site, faulty use of lancing device, or subcutaneous tissue atrophy due to extensive neurovascular changes in the fingertip
- Inappropriate or outdated reagent strips
- Instrument with dirty optical window
- Failure of the provider to reassess the patient's technique, of the patient to maintain equipment, or of the patient or provider to obtain further education about technique and equipment

Discussion

Although the technique of blood glucose testing has been simplified by reducing the number of procedural steps with the new generation of glucose testing meters, several potential problems (Table 1) resulting in erroneous glucose readings continue to occur.[1,2] The major reasons for errors in blood glucose values in hospital wards seem to be the lack of adequate training and experience in using the technique on the part of hospital personnel involved in blood glucose testing, and the absence of guidelines for quality control, such as frequent (at least 3 times a week) calibration and testing of the instrument, recurrent assessment of the reliability and accuracy of the technique used by personnel involved, and frequent, ongoing inservice instructions to overcome technical deficiencies.

Several other common problems may account for testing errors by hospital personnel and patients or their caretakers using the meters. Failure to wait for the fingertip to dry after cleansing it with an alcohol swab or washing it with soap and water before using the lancet device may dilute the blood sample and cause erroneous test results. This deficiency may be eliminated by using the second drop of blood from the pricked finger after wiping off the first drop. Lack of an adequate blood drop due to improper use of the lancing device or choice of an inappropriate point of insertion in the fingertip (lateral aspect as opposed to anterior part of the tip), as well as the extensive atrophy of the subcutaneous tissue because of neurovascular complications secondary to longstand-

ing diabetes, may also cause errors in the glucose values obtained. Furthermore, a faulty technique in bathing and blotting the reagent strip, the use of inappropriately stored or outdated reagent strips, the use of strips incompatible with the program of the instrument, a dirty optical window in the instrument, and inefficient activation of the timer on the instrument can cause inaccuracies in glucose readings. Finally, erroneous glucose readings may also be attributed to a decline in interest in effectively managing the disease on the part of the patient or health care worker. Unfortunately, this often results in the physician failing to reassess the patient's technique during follow-up visits; therefore, the patient is deprived of further education that may have improved his or her technique and thus enhanced the accuracy of the test results.

Our experience indicates that urine glucose testing may complement blood glucose testing as a reliable second source of information in patients who monitor their glucose levels. Another helpful tip may be to correlate the glucometer reading with the reading obtained using a visual color chart. The procedural problems responsible for errors in glucose levels remain, however, regardless of whether the readings are obtained by meters or by interpretation of color charts. Furthermore, some color charts that use different shades of the same color are confusing to patients, eg, the several shades of blue on the Chemstrip BG (Boehringer-Mannheim, Inc, Indianapolis, Ind). Urine test strips use different colors to indicate the degree of glycosuria.

The experience with the patient in this case prompted us to implement the following steps, similar to steps recommended in other studies,[1,2] to monitor the accuracy and reliability of the technique of personnel using whole blood glucose monitoring equipment as well as that of the equipment itself:

1. Urine glucose testing should be performed at least once daily using a double-voided urine sample. The results should then be compared with results obtained by finger capillary blood glucose testing performed within half an hour of the urine test. Any discrepancies between results obtained by the two methods (if noted repeatedly) should be reported to a member of the diabetes clinic team who should administer the appropriate therapeutic intervention.

2. Urinalysis and venous plasma glucose testing should be performed during each clinic visit to assess the correlation between urine and plasma glucose levels.

3. Finger capillary blood glucose testing should be performed by the patient with the patient's own equipment at the time the antecubital venous blood is withdrawn. If a gross discrepancy (>20%) is noted between the two glucose values obtained, then the glucose testing meter, the test strips, and the patient's technique should be assessed during the clinic visit. If inadequacies in the patient's technique are detected, further education and demonstration should be provided. Appropriate protocols for blood glucose monitoring should also be performed on a daily basis in hospital wards, including intensive care units, to ensure efficient functioning of equipment and personnel.

In conclusion, we suggest that urine glucose testing complements whole blood glucose monitoring in most subjects requiring insulin therapy to control diabetes mellitus. Moreover, urine glucose testing may be used as an acceptable alternative to whole blood glucose monitoring as indicated by certain recent studies[11-15] in subjects who shun whole blood glucose monitoring even after extensive education, as well as in those for whom blood glucose testing is not feasible owing to severe neurovascular changes in the fingertips.

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