# Insights into glucose monitoring for diabetes

## Developments in testing provide better outcomes for your patients.

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REFINEMENTS in glucose monitoring have opened a door to better glycemic management in patients with diabetes for both clinicians and patients. Clinicians are using the blood test glycated hemoglobin (A1c) as a surrogate to determine metabolic control, and both clinicians and patients are using more accurate glucose meters for monitoring blood glucose. A1c testing and self-monitoring of blood glucose have promoted better accuracy and timely results, allowing for more effective adjustments in diet, exercise, and insulin dosing.

This article provides insights into these two types of glucose monitoring.

### Dual role of the A1c

Standardization of A1c assays allows for accurate measurement, making it a tool for both diagnosing and monitoring. (See *Profile of the A1c*.) In 2009, the American Diabetes Association began using A1c as one diagnostic criteria for diabetes and prediabetes. (See *Diagnostic criteria*.)

A1c can be measured at any time of the day, eliminating patient fasting, and it provides valuable information about recent

glycemic control. Point of care (POC) A1c testing can be used in settings from acute care to long-term care, allowing for timely discussions between providers and patients about options for improving glycemic control.

Because A1c is a weighted value, the most recent 4 to 6 weeks of glucose levels make the greatest contribution to measurement. Keep this in mind when interpreting A1c values in patients who may have had a recent course of steroids or been hospitalized, which may acutely elevate glucose values.

## False highs and lows

Several conditions can cause A1c inaccuracies, including those characterized by unique hemoglobin variants such as sickle cell anemia, hemolytic anemias, fetal hemoglobin >25%, and carbamylated and acetylated hemoglobin. Early pregnancy can alter the value because of red blood cell production by the fetus and dilutional anemia from expanded blood volume. For those reasons, A1c shouldn't be used to diagnose gestational diabetes. End-stage renal disease can result in falsely low A1c values. And Whites have an absolute A1c reading 0.1% to 0.4% lower than Asian, African American, and Hispanic individuals, although the cause isn't well understood.

In individuals who may have falsely skewed A1c measures, using this test as a basis for clinical decisions may not be safe. Other options include self–blood glucose monitoring, which can help identify daily trends in glucose readings and any concerns about hypoglycemia. Fructosamine (glycated albumin) also provides information on glycemic control for the 2 weeks prior to testing. However, fructosamine measurements can be inaccurate in people with low albumin levels or severe liver disease.

# Profile of the A1c

The glycated hemoglobin test, commonly referred to as the A1c, is used widely as a clinical tool to diagnose diabetes and assess glycemic control. Dr. Samuel Rahbar first noted elevated HgbA1c (a minor hemoglobin component) in subjects with diabetes during his 1968 research on novel hemoglobin variants. He and his colleague, Dr. Anthony Cerami, also noted that the A1c was a surrogate for metabolic control in diabetes.
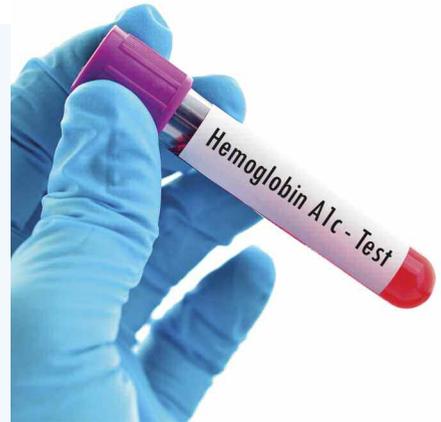
### What A1c tells us

The A1c reflects an individual's average blood glucose values in the 8 to 12 weeks before measurement. Glucose affixes to the hemoglobin protein in the oxygen-transporting red blood cells (RBCs), which are constantly turning over and have an average life span of 3 months. The A1c is the percentage of glycation during the life of the RBC and HgbA1c molecule. Interpretation of the A1c value correlates to the estimated average glucose (eAG), with higher A1c values indicating higher eAG. For example, a 6% A1c value reflects an eAG of 126 mg/dL and 12% A1c reflects an eAG of 298 mg/dL.

### Landmark trials

Measurement of the A1c was first used in research trials in the 1990s. The Diabetes Control and Complications Trial and the United Kingdom Prospective Diabetes Study instituted the A1c as a useful clinical marker for glycemic control. These trial outcomes also established target goals for A1c associated with fewer microvascular and macrovascular complications in patients with diabetes. Based on these landmark trials, the American Diabetes Association established its current A1c recommendation of 7% or lower.

# Diagnostic criteria

The following diagnostic criteria for diabetes were established by the American Diabetes Association.

- Fasting plasma glucose ≥126 mg/dL
- 2-hour plasma glucose ≥200 mg/dL during glucose tolerance test
- A1c ≥6.5% with testing done using standardized Diabetes Control and Complications Trial assay
- Random plasma glucose ≥200 mg/dL with symptoms of hyperglycemia (polyuria, polydipsia, and polyphagia)

American Diabetes Association. 2. Classification and diagnosis of diabetes. *Diabetes Care*. 2017;40(suppl 1):S11-S24.

## Glucose meters come of age

With the discovery of insulin by Banting and Best in 1921, insulin became a diabetes treatment option, but it required information about real-time glucose levels to allow for therapeutic insulin dosing. Urine glucose dipsticks, initially developed in the 1940s, were the only option for many years, but they were a better measure of retrospective glucose levels. Reagent strips introduced in the 1950s provided an estimation of blood glucose range but could be hindered by user technique error and variabilities in user color acuity.

Glucose meters, first introduced in the 1970s, were large, expensive, and subject to user error, so they were used primarily by clini-

cians in hospitals. With improved technology, meters got smaller, less expensive, and more accurate. People not hospitalized were now able to titrate insulin based on pre-meal glucose readings and to identify hypoglycemia early so that insulin dosing could be modified. As a result, self-monitoring of blood glucose became much more effective, an important development because it's associated with improved glycemic control and with helping patients identify how exercise, insulin dosing, various foods, and portion sizes may affect glucose levels. Self–blood glucose monitoring, used in conjunction with medication therapy to treat hyperglycemia, facilitates the identification of trends that allow for medication titration and improved safety.

### Accuracy of today's meters

Today's glucose meters use capillary blood samples, usually from a finger stick, to measure glucose. The meters must be maintained to International Organization for Standardization (ISO) accuracy standards, including accuracy within 15 mg/dL for glucose levels below 75 mg/dL, and no more than 20% variability for glucose levels ≥75 mg/dL. Meters must meet these requirements for 95% of readings.

However, these standards can still result in variability that may be clinically significant. For example, variability of 15 mg/dL in a glucose reading of 75 mg/dL could be associated with actual glucose levels ranging from 90 mg/dL to 60 mg/dL and could result in lack of recognition of hypoglycemia and delayed treatment. Also, accuracy variability exists between the various commercially available meters, with a mean absolute relative difference from 5.6% to 20.8% when comparing readings in the hypoglycemic range.

Although today's commercial

## False highs and lows

Various conditions and patient characteristics can falsely raise or lower glucose levels, impacting the accuracy of A1c tests.

| Conditions and characteristics | False high | False low |
|---|---|---|
| Asplenia | X | |
| Chronic alcohol ingestion | X | |
| Chronic opioid use | X | |
| End-stage renal disease | | X |
| Hemolytic anemia | | X |
| High-dose vitamin E (600-1,200 mg/day) | | X |
| High hematocrit (>50%) | | X |
| High uric acid (>20 mg/dL) | X | |
| HIV | | X |
| Icodextrin (used in peritoneal dialysis solution) | X | |
| Impaired peripheral perfusion (such as during hypovolemic shock) | | X |
| Iron-deficiency, pernicious (vitamin B12 deficiency), or folic acid deficiency anemia | X | |
| Low hematocrit (<35%) | X | |
| Pregnancy | | False lows first and second trimester |
| Recent red blood cell transfusion | X | X |
| Ribavirin and interferon alpha | | X |
| Severe hypertriglyceridemia (>1,750 mg/dL) | X | |
| Uremia | X | |
| Very high triglycerides (>1,750 mg/dL) | | X |

American Diabetes Association. 14. Diabetes care in the hospital. *Diabetes Care*. 2017;40(suppl 1):S120-S127.

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Yalamanchi S, Brown T, Dobs A. HIV infection and diabetes. Living Reference Work Entry. Principles of Diabetes Mellitus. Springer International Publishing. 2016. http://link.springer.com/referenceworkentry/ 10.1007%2F978-3-319-20797-1_38-1

glucose meters are user friendly, several factors can affect reading accuracy, resulting in either false low or false high readings. Patient education can help reduce user error and erroneous readings.

A common error leading to false high readings is the presence of glucose on the user's hands (for example, from peeling an orange before self-testing). Teach patients to wash their hands before and after glucose meter testing. Exposing testing strips to temperature extremes can lead to erroneous results, although this seems to be mitigated if the strips are allowed time to revert to room temperature. In addition, elevations higher than 6,500 feet can lead to false readings. Individual patient characteristics, such as low or high hematocrit, also can alter readings. (See *False highs and lows*.)

The American Diabetes Association and the Food and Drug Administration (FDA) have specific concerns about the use of POC meters using capillary blood samples in critically ill patients because of changing volume status, hemoglobin variants, and low hematocrit. These confounders have led to undetected hypoglycemic events in the hospital. For these patients, alternative measurements from a blood gas analyzer or use of a central laboratory is recommended. Blood samples should be taken from arterial or venous lines; capillary blood samples shouldn't be used. The FDA now recommends that POC meters be developed for critically ill patients with stringent quality-control measures.

## Nursing considerations
Measuring daily and long-term glycemic trends helps improve diabetes management. Because the A1c serves as a marker for glycemic control and can prompt changes in the diabetes care plan, patients need education on how

**B**lood samples should be taken from *atrial* or *venous* lines; capillary blood samples shouldn't be used.

these results are used in caring for their diabetes. And patient teaching on proper glucose testing techniques with a return patient demonstration for performance can help ensure accurate results. Elements of this teaching include handwashing before and after testing, troubleshooting the meter, and proper storage of testing strips. Providing this information will help ensure patients avoid complications and enjoy the best quality of life possible. ★

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