

Blood Glucose Monitors

Blood glucose monitors (BGMs) are electronic devices that measure blood glucose levels.

Numerous disease processes lead to derangements in blood glucose levels. The use of BGMs to rapidly identify such changes and help the clinician make appropriate therapeutic decisions is imperative to maximize patient outcome. Although most portable bedside rapid BGMs used in veterinary practice are designed for human use, 2 additional devices have been validated for veterinary patients—the i-STAT handheld clinical analyzer (heska.com) and the AlphaTRAK veterinary-specific handheld BGM (abbottanimalhealth.com).

To determine blood glucose levels, portable BGMs use enzymes, such as glucose oxidase, hexokinase, and glucose dehydrogenase, combined with reflectance photometry and electrochemical/amperometric technologies, to generate the blood glucose result. Continuous glucose monitors use an amperometric sensor and a glucose oxidase reaction to measure the glucose level in the subcutaneous interstitial fluid.

INDICATIONS

Blood glucose levels should ideally be measured in any sick patient presented to a veterinarian for care. In addition, serial blood glucose monitoring is imperative to:

- Generate a blood glucose curve and assess the dose of insulin therapy in diabetic patients



Courtesy Amanda Wright

- Monitor young, debilitated, anorexic, or insulinomic patients for hypoglycemia
- Guide dextrose supplementation
- Determine whether insulin therapy or an adjustment in nutritional formulation is necessary in hyperglycemic patients, such as those receiving parenteral nutrition. For these patients, the frequency of blood glucose monitoring often reflects the patient's overall stability, the magnitude of blood glucose derangements,

BGM = blood glucose monitor

CONTINUES

and the ease with which the blood sample can be safely obtained.

When appropriate equipment and trained personnel are available, continuous glucose monitoring can be considered, but requires the placement of a subcutaneous monitor that continuously measures interstitial fluid glucose level. Few veterinary studies have described the use of continuous glucose monitoring in both healthy and diabetic animals; however, possible indications include fractious patients, patients for which owner compliance is a concern, perioperative uses, and pediatric patients in which blood sampling and vascular access is a challenge. Further veterinary research with this technology may prove beneficial.

Contraindications to blood glucose monitoring include:

- Patients with severe anemia and the subsequent need to keep all blood sampling to a minimum
- Patients for which the stress of handling or restraint necessary to obtain the sample outweighs the benefit of knowing the current blood glucose level.

ADVANTAGES

Advantages of portable BGMs in veterinary practice include:

- Short amount of time needed to generate results
- Ease of use
- Availability
- Minimal amounts of blood needed to generate accurate results.

Time to Generate Results

Most human handheld BGMs produce a digital result within 15 to 60 seconds, depending on the device. Therefore, a patient's blood glucose level can be rapidly determined and the clinician can take immediate action, if indicated,

BGM = blood glucose monitor



A



B

Adding blood to a test strip of a blood glucose monitor (Accu-Chek Advantage, roche.com) (A) and the resulting blood glucose level in mg/dL (B).

rather than waiting hours or days for results from a clinical laboratory.

Handheld clinical analyzers, such as the i-STAT, produce blood glucose results as well as a variety of other biochemical measures within approximately 2 minutes. Depending on the selected cartridge, additional values might include acid-base status, electrolytes, blood urea nitrogen, and creatinine, which can help guide fluid therapy, assess oxygenation and ventilation, and determine treatment response and whether further diagnostic testing or therapies are indicated.

Ease of Use & Availability

Because portable BGMs are intended to be used frequently by humans with diabetes mellitus, they are small and designed for ease of operation. Both the monitors and test strips are readily available in most pharmacies. Because of these advantages, inclined owners with a cooperative diabetic patient can easily be

taught to measure blood glucose levels at home by using a lancet device to collect capillary blood from the inner pinna. This obviates the need for stressful, costly, and unnecessary visits to the veterinarian and may provide a more accurate blood glucose measurement.

Continuous glucose monitoring systems record interstitial fluid glucose level every 5 minutes, providing 288 results in 24 hours. After the monitoring system is set up, patients can be managed at home to more naturally reflect daily glucose variations; thus, confounding hyperglycemia in stressed patients can be avoided.

Amount of Blood

Human BGMs require between 3 and 15 mcL of blood to accurately determine glucose level. The AlphaTRAK veterinary-specific BGM uses only 0.3 mcL of blood and has been validated for veterinary patients, both diabetic and

nondiabetic; results are within 1% to 2% of measurements obtained by a clinical laboratory.

DISADVANTAGES

Validation in Veterinary Patients

The biggest disadvantage of portable BGMs is that many of the readily available devices are designed for human use and have not been validated for veterinary patients. Several studies have evaluated specific portable BGMs in veterinary patients, with variable results and correlation to clinical laboratory-generated values for blood glucose.

Portable BGMs designed for use in humans determine blood glucose levels from capillary blood samples. In veterinary patients, however, capillary blood is rarely used; instead, venous or arterial whole blood, serum, or plasma samples are analyzed. There are discrepancies between glucose levels from capillary, venous, and arterial samples in healthy and critically ill humans.

In addition, humans have approximately equal amounts of glucose in red blood cells and plasma, but dogs and cats have much higher percentages of glucose in plasma compared with red blood cells. This becomes clinically significant in anemic patients, when the red cell mass is decreased, and results in glucometer miscalculation of plasma displacement in whole-blood samples. Therefore, anemia results in an overestimation of blood glucose in all patients, and this error is magnified in veterinary patients that have naturally occurring higher plasma glucose percentages.

Influencing Factors

A variety of other factors may influence the reported blood glucose level by a portable BGM, including altitude, temperature, humidity, hyperbilirubinemia, increased serum acetaminophen level, increased triglyceride level, anemia, and

hemoconcentration. In humans, anemia (hematocrit < 20%), hyperbilirubinemia (total bilirubin level > 20 mg/dL), or elevated serum triglyceride levels (> 5000 mg/dL) produce erroneously increased blood glucose levels. Hemoconcentration (hematocrit > 55%), increased altitude, temperature, and high humidity produce falsely decreased blood glucose results.

Operator Error

Operator errors, such as inappropriately large or small blood samples for a given device's test strip, improper handling and storage of the test strips, improper device cleaning (for those requiring cleaning), and errors or inadequate frequency of calibration and coding, can all result in erroneous blood glucose levels.

Other Device Limitations

The i-STAT cartridge requires 300 mcL (0.3 mL) of blood; therefore, in small veterinary patients this device may not be practical for frequent assessments of blood glucose because of the comparatively large sample volume required.

Continuous glucose monitoring systems require 3 blood glucose samples per day for calibration, are more technically challenging to use, cannot record data if the sensor becomes dislodged from the subcutaneous space, and cannot read blood glucose levels less than 40 mg/dL and greater than 400 mg/dL.

CONCLUSION

Considering the frequency with which hospitalized veterinary patients require glucose monitoring, BGMs are practical, easy to use, cost-effective staples for any veterinary practice. Noninvasive blood glucose monitoring technologies of the future might include near-infrared detection, ultrasonography, and dielectric spectroscopy.

See Aids & Resources, back page, for references and suggested reading.

ECONOMIC IMPACT

- The price of human portable BGMs ranges from \$30 to \$100. Test strips for these meters are usually available in 50- or 100-count test strip packs and range in price from approximately \$60 to \$120.
- The AlphaTRAK system costs approximately \$100 for the meter and \$60 for a pack of 50 test strips.
- Continuous BGMs cost about \$1000, and the subcutaneous probes, which last 3 days each, cost about \$35.
- The price of an i-STAT machine (which offers multiple testing menus) ranges from \$3500 to \$5000, and cost of test cartridges ranges from \$6 to \$20 each, depending on the type and quantity purchased.