



# Advances in Glucose Monitoring

Susan A. Meeking, DVM, Animal Medical Center, New York, New York

## **P** Profile

### DEFINITIONS

Glucose is frequently measured in the blood and urine of veterinary patients. Blood glucose monitors are used to quickly provide accurate measurements of blood glucose levels; they are commonly used in the hospital to monitor severely ill patients and at home for patients with diabetes mellitus. In the hospital, interpretation of how well blood glucose measurement reflects control of diabetes is notoriously difficult because of both the high level of stress experienced by animals in the hospital environment and the handling and restraint required for blood sampling.

### Blood Glucose

Recent advances in blood glucose monitoring techniques have been designed to minimize stress and to allow owners to perform serial blood glucose monitoring at home. These less-invasive techniques should more accurately reflect blood glucose levels by decreasing the stress experienced by the animal.

### Urine Glucose

Urine glucose is commonly measured as part of routine urinalysis in healthy pets, for screening patients for diabetes mellitus, and for monitoring glycemic control in patients being treated for diabetes mellitus. Urine glucose test strips are easy to use and interpret and require only a small amount of urine, so they can be used by owners at home. Urine dipsticks often combine glucose indicators with ketone indicators to detect glucosuria and ketonuria in diabetics.

### PATHOPHYSIOLOGY

Accurate measurement of blood glucose is important for monitoring diabetes control because treatment decisions, such as altering the type or amount of insulin administered, may be based on these measurements. The technique used to measure blood glucose must minimize stress on the animal because increased levels of catecholamines released during stress cause a rapid increase in blood glucose levels that can exceed 300 mg/dl. Advances in glucose monitoring include measurement of glucose levels in body fluids other than blood, as glucose in

circulation is distributed quickly through most body compartments due to capillary permeability.

Glucose should be undetectable in the urine of normoglycemic patients. In these patients, all glucose filtered at the glomerulus is reabsorbed in the tubules; as a result, no glucose is excreted in the urine. Any elevation in glucose can cause glucosuria, including transient stress-related hyperglycemia. In hyperglycemic patients, the amount of glucose filtered in the glomerulus exceeds the amount that can be reabsorbed by the tubules, resulting in glucose spilling into the urine and positive results on urine glucose tests. Glucosuria can also occur with proximal tubular damage or defects, resulting in decreased reabsorptive capacity in the tubules, such as in Fanconi's syndrome, heavy metal toxicity, and aminoglycoside toxicity.

### PAIN INDEX

The degree of pain associated with sample collection for blood glucose measurement varies with the type of sample required for

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## Capillary Ear-Prick Sampling Technique



1 Hold warm gauze against the ear to increase circulation.



2 Use a 25-gauge needle or lancet device to prick the ear margin (protect your finger on the back of the ear with a gauze sponge). Allow a drop of blood to form. Massage the ear to increase the size of the drop.



3 Apply the test strip from the portable blood glucose monitor directly to the drop of blood. The blood will enter the strip through capillary action.

the monitor used and the skill and experience of the person collecting the sample. Collection of venous samples requires restraint and venipuncture, whereas capillary blood collection and sample collection through an indwelling sampling catheter can often be done without restraint and is barely noticed by many patients (see technique description on page 9). Pain should be minimized because it contributes to stress hyperglycemia and patient aversion to restraint and handling. Minimally invasive and noninvasive sampling methods are current areas of focus for human diabetes research.

## **Diagnosis**

### **BLOOD GLUCOSE MONITORS**

The most common types of blood glucose monitors currently used in veterinary medicine include PBGMs, POC analyzers, color test strips, and automated chemistry analyzers.

#### **Portable Blood Glucose Monitors (PBGMs)**

Recent publications have compared the suitability of various PBGMs in veterinary medicine (see **Table**). In general, these monitors have the advantage of using small quantities of blood, have a low cost per test, and quickly yield results. They can work well with capillary samples. Many clients are able to use PBGMs at home.

#### **Point-of-Care (POC) Analyzers**

The POC monitors are in-clinic analyzers that typically use cartridges and small quantities of blood to measure blood glucose as well as blood gases, blood pH, electrolytes, and coagulation and other biochemical variables. The iSTAT (HESKA Corporation, Fort Collins, CO) is a POC monitor currently used in many practices. These monitors are more expensive than PBGMs and are designed for use by health care professionals, but also require a small sample size and give quick, accurate results.

#### **Color Test Strips**

Color test strips have a square on which blood is placed. A colorimetric reaction occurs, and the blood is rinsed from the test square. The color change is compared with a color chart, and the blood glucose level is estimated according to the closest color match. These tests are cheap and fast. However, they provide only a ballpark measurement of the blood glucose level—not a numerical read-out—and are subject to interpretation.

#### **Automated Chemistry Analyzers**

Automated chemistry analyzers are not available in many clinic settings; these analyzers are most commonly used by diagnostic laboratories. They require larger quantities of blood and are more expensive than PBGMs. Automated chemistry analyzers have the advantage of being able to perform other biochemical assays.

Blood glucose monitors in most veterinary settings typically use venous, capillary, or arterial blood for measurement. It is important to read the equipment insert to ensure that the type of sample and anticoagulant are appropriate for the equipment being used. The clinician should be familiar with the factors that can affect the monitor's accuracy.

Blood glucose readings can be artificially low in samples from polycythemic animals because of the decreased fluid portion of the blood. They can also be artificially low in whole blood samples not used immediately after collection due to continued glucose use by red blood cells.

Glycemic control over a long period (weeks) as opposed to immediate blood glucose determination is best assessed through use of laboratory tests, such as serum fructosamine and glycosylated hemoglobin measurement. Limitations of these tests include the inability to assess the response of blood glucose levels to insulin administration on an hour-to-hour basis and inability to determine glucose nadir.

### **URINE GLUCOSE**

Urine glucose is most often measured with dipsticks. Granules that change color in the presence of glucose are also available for placement in the litter for detection of glucosuria at home.



## **Follow-up**

### **INPATIENT OR OUTPATIENT**

Owners can easily and successfully perform the capillary ear prick technique at home to evaluate blood glucose levels over a longer period than is practical in the clinic. Capillaries yield an acceptable blood sample for glucose determination by PBGMs.

**Blood glucose** levels have been shown to vary considerably on a daily basis. Single measurements or multiple measurements made on a single day in the hospital may not accurately depict the animal's glycemic control in its normal environment. Owners can assist in evaluation of their animal's glycemic control through measurement of blood glucose levels at home.

**Urine glucose** is easily measured at home through the use of urine dipsticks or glucose-detecting granules placed in the litter. Some clients collect urine through use of an empty litterbox, a plastic layer placed over the litter, or free catch. Urine dipsticks can also be placed in the litter, but timing of the test is important so the cat must be watched so the dipstick can be retrieved immediately after urination.

### **CLIENT EDUCATION**

Clients who are monitoring blood glucose levels at home for diabetic animals must be instructed never to adjust insulin doses based on their results. They should communicate frequently with their veterinarian for appropriate adjustments to be made.

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## Comparison of Portable Blood Glucose Monitors

<i><b>Glucometer DEX</b></i>	<i><b>Glucometer Elite &amp; Elite XL</b></i>	<i><b>Accu-Chek Compact</b></i>	<i><b>Accu-Chek Advantage</b></i>	<i><b>Accu-Chek Complete</b></i>	<i><b>Accu-Chek Active</b></i>
Rating	+	++	+	++	+
Ease of use	Easy	Easy	Easy	Easy	Easy
Precision	Less consistent	Consistent	Consistent	Consistent	Consistent
Accuracy	± 20%	±20%	±20%	±20%	±20%
Cost	\$68	\$40, XL \$53	\$45	\$60	\$70
For pets	Yes	Yes	Yes	Yes	Yes
Blood (µl)	3–4	2	3	3	3
Time (sec)	30	30	8	Up to 40	15
Test Strips	Dex sensors (ct 50), \$40; (ct 100), \$70	Elite (ct 50), \$37	Accu-Chek Compact (ct 50), \$40	Comfort Curve (100 ct), \$63 Accu-Chek Advantage (ct 50), \$40	Accu-Chek Complete (ct 50), \$40 Accu-Chek Active (ct 50), \$40
Pros	Convenient for frequent testers; meter can be hand held in any orientation; positive reports from consumers	Touchable strips; meter can be held in any orientation	Touchable strips; can be held in any orientation; second drop w/in 15 sec	Touchable strips; can be held in any orientation; second drop w/in 15 sec	5-second read-out; touchable strips; can be held in any orientation; any orientation; second drop w/in 15 sec
Cons	Inadequate sample size yields false-positive results	Inadequate sample size yields false-positive results	Inadequate sample size yields false-positive results	Inadequate sample size yields false-positive results	
Maker	Bayer	Bayer	Roche	Roche	Roche
Contact	800-348-8100	800-348-8100	800-858-8072	800-858-8072	800-858-8072

Key: + = good; ++ = excellent

Clients may need frequent communication and support when beginning home glucose monitoring.



## Future Considerations

Current advances in human glucose monitoring that may have future applications in veterinary medicine include continuous glucose monitoring systems, minimally invasive sampling, and noninvasive monitoring of blood glucose.

### CONTINUOUS MONITORING SYSTEMS

Continuous glucose monitoring systems involve subcutaneous placement of a sensor that is attached to a cord and a recording device. The system detects glucose levels in the venous blood or interstitial fluid and records hundreds of measurements taken minutes apart. This technique avoids multiple venipunctures and/or intravenous catheter placement for multiple blood collections. The system can be temporarily attached to the patient with a halter, harness, or bandage for monitoring and data

collection in the patient's home environment, or the data can be transmitted with wireless technology. These systems must be calibrated to whole blood glucose measurements on an individual basis.

A recent study has shown that these devices are valid for use in cats, dogs, and horses and that they are well tolerated. They essentially perform a glucose curve with minimal stress on the animal and can be used to determine the effect of insulin therapy on blood glucose levels and glucose nadir. The devices can also be used for data collection in oral and intravenous glucose tolerance tests and in critically ill patients. Limitations include the animal's tolerance of placement of the system, current availability, cost, and range of glucose measurements.

### MINIMALLY INVASIVE SAMPLING TECHNIQUE

Reverse iontophoresis is a minimally invasive sampling technique that measures glucose levels in interstitial fluid by extracting small amounts of fluid transdermally without pain or tissue disruption. This has been

studied to a limited extent in veterinary patients but will probably be the subject of future studies and discussions. This method is currently used for monitoring glucose in human diabetic patients.

### NONINVASIVE TECHNOLOGY

Near infra-red spectroscopy is the most-studied noninvasive glucose monitoring technology in humans. Glucose absorption peaks are measured through transmission or reflectance of light through tissues, such as the fingertip. Currently, precision has not been proven accurate enough for routine clinical use, although a system is currently marketed for veterinary use in the United States.

Other current monitoring techniques under development for humans include a contact lens with glucose monitoring capability. ■

#### ACKNOWLEDGMENT

The author thanks Dr. Deborah Greco for the opportunity to write this article, her assistance in its preparation, and for providing the table on portable monitors.

See Aids & Resources, back page, for references, contacts, and appendices.

## Comparison of Types of Glucose Monitoring Equipment

Type of Monitor	Accuracy	Availability	Cost	Speed	Small Sample Size	Noninvasiveness of Sampling	Home Use
Portable glucose monitor	+++ / ++++	++++	\$	++++	Yes	+	++++
Color strips	+	++++	\$	++++	Yes	+	+
Point-of-care analyzer	++++	+++	\$\$\$	++	Yes	+	NA
Automated chemistry analyzer	++++	+++	\$\$\$	+	No	+	NA
Minimally invasive monitor	?	+	?	+++	Yes	+++	++++
Continuous monitor	?	+	?	++++	Yes	+	+/-
Noninvasive monitor	?	+	?	+++	NA	++++	+
Urine dipsticks	++	++++	\$	++++	Yes	++++	++++
Key: + = worst; ++++ = best    \$ = least expensive; \$\$\$ = most expensive    NA = not applicable    ? = data unknown							