

## BLOOD GLUCOSE MONITORING: DETERMINING THE ACCURACY OF METERS

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*The author, expert reviewers and Pharmacy Post magazine have each declared that there is no real or perceived conflict of interest with the sponsor company.*

### STATEMENT OF OBJECTIVES

*Upon successful completion of this lesson, the pharmacist should be able to*

1. describe the different features of the blood glucose meters on the market today.
2. review the factors that affect the accuracy of blood glucose monitoring devices.
3. discuss the relevance of meter calibration and the implications of miscoded meters.
4. apply the knowledge learned in this lesson to practice scenarios.

### INSTRUCTIONS

1. After carefully reading this lesson, study each question and select the one answer you believe to be correct. Circle the appropriate letter on the attached reply card.
2. Indicate if you are already registered as an annual CE Club Member or if you would like to become a member.
3. Complete the card and mail, or fax to (416) 764-3937.
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5. To pass this lesson, a grade of 70% (14 out of 20) is required. If you pass, your CEU(s) will be recorded with the relevant provincial authority(ies). (Note: Some provinces require individual pharmacists to notify them.)

### INTRODUCTION

With the release of the 2003 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada, many health professionals are adapting their practices to help meet the needs of our Canadian population with diabetes. Current estimates have the number of individuals with diabetes at two million in Canada. Demographic trends that will contribute to an increased prevalence of diabetes in Canada include aging population, increasing migration from high-risk populations and the growth in the aboriginal population.<sup>1</sup>

It is relevant to start any discussion of the potential pitfalls of self-monitoring of blood glucose (SMBG) with a review of the practice guidelines, as they relate specifically to SMBG. The guidelines begin their discussion of monitoring glycemic control by stating: "The Diabetes Control and Complications trial (DCCT) and the United Kingdom Prospective Diabetes Study (UKPDS) clearly demonstrated that poor glycemic control (as measured by glycosylated hemoglobin [A1C]) and the development of long-term complications are correlated in both Type 1 and Type 2 diabetes" and that "everyone with diabetes can benefit from SMBG."<sup>2</sup> The

guidelines also state that these benefits, which include improved A1C, avoidance of hypoglycemia and increased lifestyle flexibility, are further enhanced when individuals are prepared to adjust their dietary choices, physical activity and medications in response to blood glucose values.<sup>3</sup>

Furthermore, the guidelines have defined a state described as "prediabetes." This is a practical and convenient term for impaired fasting glucose (IFG) and impaired glucose tolerance (IGT), which places individuals at risk of developing diabetes and its complications.<sup>4</sup> Many people with prediabetes will not progress to diabetes, but the guidelines suggest that these individuals would benefit from cardiovascular risk factor modification. Since there is evidence that lifestyle modification and medication interventions prevent the onset of diabetes mellitus (DM),<sup>5</sup> these individuals will be identified earlier and are very likely to initiate SMBG. People identified as being in this category will likely be motivated to avoid the progression to DM, and as such may see SMBG as a valuable tool to chart their progress.

The optimal frequency of SMBG for the majority of patients with Type 2 diabetes who are treated with lifestyle modification alone or in combination with oral



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antihyperglycemic agents is unclear.<sup>6</sup> Some research has shown that in people with Type 2 diabetes who are treated with medications, testing at least once daily is associated with a reduction in A1C of 0.6% compared to less frequent monitoring.<sup>2</sup> The same study found that for those on lifestyle modification alone, any monitoring is associated with a lower A1C. Although promising and positive, these findings were not statistically significant.

As a result of recent guideline recommendations, pharmacists can expect to interact with even more patients seeking information and expertise on SMBG. Pharmacists can play a crucial role in counselling patients to help them find an appropriate monitor for themselves.

There are many important considerations in the selection of blood glucose meters (see Table 1).<sup>7</sup>

While blood glucose meters offer different features, most meters are still very similar. To facilitate meter selection, this lesson will review the importance of proper calibration and the many factors that can have an effect on meter accuracy.

## ACCURACY OF BLOOD GLUCOSE MONITORS

The gold standard for blood glucose results is laboratory measurement. Blood glucose monitors use capillary blood while the laboratory uses venous blood. Since some blood glucose is transferred to cells from the capillaries before it enters the venous system, venous blood has less glucose in it than capillary blood. The difference

**TABLE 1**  
**Important Considerations in Meter Selection**

- Overall size and weight of monitor
- Cost of meter
- Size of visual field and display characters
- Size of strip (handling by patient)
- Amount of blood needed for each test
- Simplicity of use
- Computer download ability
- Alternate site testing option
- Calibration requirements
- Testing speed
- Ability to store test results in memory
- Cost of test strips used and coverage by insurance plans
- Battery requirements
- Ease of strip handling

between the two is very small if a fast of eight hours or more has occurred. However, this difference can be significant after a meal because glucose levels rise and glucose-transfer into tissues accelerates.<sup>8</sup> Laboratories test venous samples of blood and measure only the plasma portion (whole blood with the formed elements of red, white and platelet cells removed). Since the glucose content of the red blood cells is 20% less than that of plasma, and whole blood is about equal parts red blood cells and plasma, measuring whole blood provides a lower glucose concentration compared to measuring only the plasma portion. For example, if the plasma glucose concentration is 10 mmol/L, the red blood cell glucose concentration would be 20% less or about 8 mmol/L. Testing whole blood provides a concentration of 9 mmol/L. A meter that tests whole blood

would already differ by 10% compared to the laboratory test, without accounting for patient error. Fortunately, many meters on the Canadian market use a whole blood sample (i.e., blood drop) but only test the plasma portion, or account for this difference in the readout. A meter that reads plasma glucose levels will provide results that are closer to laboratory results. These meters often claim “lab-like results.” For an indication “acceptable error” when testing blood glucose levels, see Table 2.

The CDA clinical practice guidelines recommend that this accuracy should be verified by comparison of the home glucose monitor to laboratory measurement of plasma glucose at least annually, and when indicators of glycemic control do not match meter readings.<sup>10</sup>

Many factors come into play when determining the accuracy of results from home blood glucose monitors (see Table 3).

All of these factors impact accuracy. However, a review of some key factors will illustrate the differences between meters currently on the market.

## SUFFICIENT BLOOD SAMPLE

Many meters available today possess “underfill” detection technology. Simply put, this is the ability of the meter to detect when it has not received enough blood to provide an accurate reading. Meters with the underfill technology provide an error message or will not register a result without the necessary amount of blood. Without the underfill feature, the meter reading can be inaccurate. When meters lack this fea-

## CE FACULTY

**This Month:** Blood Glucose Monitoring: Determining the Accuracy of Meters

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**Reviewers:**

All lessons are reviewed by pharmacists for accuracy, completeness and relevance to current pharmacy practice.

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**TABLE 2**

**Acceptable Error with Blood Glucose Meters<sup>9</sup>**

ADA Criteria  
± 15%

CDA Criteria  
>4.2 mmol/L ± 20%  
<4.2 mmol/L with less than ±20% recommended

ADA = American Diabetes Association  
CDA = Canadian Diabetes Association

**TABLE 3**

**Factors Affecting Accuracy of Blood Glucose Monitors**

- Quality of the blood drop (no alcohol) (wipe away first drop)
- Sufficient blood sample
- Quality of strips - not expired
- Quality of meter electronics
- Alternate site testing
- Sample detection method
- Hematocrit range
- Temperature of meter
- Storage of strips - shelf-life closed and open
- Concurrent medications
- Testing technique
- Correct calibration (coding)

ture, the manufacturer will often provide a warning that inaccurate results may be obtained if the strip is not completely filled.

### SAMPLE DETECTION METHOD

All test strips on the market use an enzyme system that produces an electrical charge (electrochemical system) or a colour change (colorimetric system) that is analyzed and a corresponding numeric value displayed as a reading. Colorimetric systems have the disadvantage of requiring that the sample window be cleaned to ensure accurate readings. Electrochemical systems have the advantage of not requiring the blood application area of the test strip to be in close proximity to the meter. Longer electrode leads prevent meter contamination. The blood application method does differ between meters, but the majority of meters use the “sip in” or “sip up” method. Neither method has a particular advantage.

### ALTERNATE SITE TESTING

This feature seems to have received the most attention over the last few years as a feature that differentiates one meter from another. The arm and thigh have less perfusion of blood than the finger. This physiologic difference alone places restrictions on any values obtained from these alternate sites. During periods of rapid change in blood glucose levels (e.g., after meals or exercise), fingertip testing has been shown to reflect glycemic status more accurately than forearm testing.<sup>11,12</sup> As a result, fingertip testing may be preferred after meals (less than 90 minutes), when medication is peaking, or when hypoglycemia is suspected. Any meter can give a reading on the arm, given a large enough sample of blood. Because of low perfusion rates to the arm compared to the fingertip, it is often hard to get a large blood sample. For this reason, meters that allow for alternate site testing have very small blood volume requirements in their strips.

### HEMATOCRIT RANGE

As discussed earlier, a blood sample is comprised of plasma and formed elements. These formed blood cells are often expressed as a percentage of the total blood volume and called hematocrit. Because the glucose concentration is different in the formed elements versus the plasma, it is important to have a meter that is accurate over a wide hematocrit range. The normal hematocrit range is usually 35 to 50%. Conditions such as anemia can cause low hematocrit. High hematocrit can be seen in neonates and those individuals at high altitudes. In general, high hematocrit levels cause lower than normal readings, while low hematocrit causes readings to be higher than average. In Canada we do not see large fluctuations due to elevation, but in the general population conditions such as anemia can be frequent enough to make hematocrit a consideration. Meters on the Canadian market will range (on average) from 20 to 60% with some as low as 0% and some as high as 70% at the upper limit. Unless a patient with diabetes has an abnormal hematocrit, most meters do not differ significantly in this feature.

### TEMPERATURE OF THE METER

Chemical reactions occur on the strip during blood glucose testing, and temperature can affect that reading. Meter programming includes the ability to adjust for changes in temperature when a reading is being calculated. Most meters will not report a test outside their temperature range. All meters have a stated temperature range of at least 15 to 40° C, with some as low as 5° C but none over 40° C. If the meter is being used outside a stated range, it will notify the user that the reading is being given outside the desired temperature range, or will not give a reading until the user moves to an area where the ambient temperature is either warmer or cooler than the current temperature. While meter selection will often not be determined by this factor alone, participation in outdoor exercise and activities such as hockey, skiing and snowmobiling may be significant to a meter user. This factor should be considered when selecting an appropriate meter.

### INTERFERENCE FACTORS

To understand how meters on the market respond to some of the more common interference factors, such as oxygen and maltose, pharmacists need to understand the enzyme systems used. In electrochemical blood glucose monitoring systems, an enzyme in the test strip facilitates a chemical reaction between glucose and a mediator molecule. This reaction involves passing electrons from glucose to the mediator. At the end of the test time, the meter applies an electrical potential to the working electrode. The electrons built up in the mediator are drawn into the electrode and are measured by the meter as an electrical current.

Meters that use a glucose oxidase enzyme system have a competing reaction that involves passing the electrons from glucose to the mediator and to oxygen. Since only those electrons on the mediator are used in determining a reading, the amount of oxygen can affect the final reading. This factor will affect the choice of meter used in the hospital environment

where venous blood is often used (lower oxygen than fingerstick blood) or for patients on oxygen therapy (which creates very high oxygen concentrations in the blood).

The presence of sugars in the sample, other than glucose, may be of concern. Systems using the glucose oxidase enzyme react only with B-D-(+) glucose. Glucose dehydrogenase systems (PQQ-GDH) are less specific and can bind with sugars other than glucose, such as maltose. Patients with maltose in their system will obtain a blood sugar reading higher than the actual glucose concentration. Icodextrin, sometimes used in patients undergoing renal dialysis, breaks down to maltose in the blood. Patients undergoing dialysis, or who have diets high in foods containing maltose, need to use a glucose oxidase system to test their blood sugars.

Other more commonly encountered interference factors include ascorbic acid, uric acid, acetaminophen and bilirubin.

**Ascorbic acid** levels in the body are usually 1 to 2 mg/dL, even in people who take large doses of vitamin C, because it is readily excreted from the body in the urine. At this physiologic level, few if any meters will have significant errors.

**Uric acid** levels can be up to 10 mg/dL (0.59 mmol/L) in many asymptomatic hyperuremic individuals. Blood uric acid levels above 10 mg/dL are common in renal failure. Normal physiologic levels, even those at the high end in an asymptomatic individual with hyperuricemia, do not often produce significant errors. Individuals having a gout attack and those in renal failure have the potential for significant error with some meters. Again, refer to each manufacturer's recommendations for their specific limits with respect to uric acid concentration.

**Acetaminophen**, (or paracetamol in some literature) levels in the blood can vary among individuals based on the person's particular physiological characteristics. The therapeutic range for acetaminophen (paracetamol) is 1 to 2 mg/dL (60 to 130 mmol/L) and at therapeutic dosing levels acetaminophen concentrations as high as 4

mg/dL (265 mmol/L) have been found.<sup>13</sup> Many meters function within acceptable limits at therapeutic dosages of acetaminophen, but at extremely high levels some meters will give a significant bias.

**Bilirubin** will only cause problems at levels that cause symptomatic jaundice. Individuals who experience jaundice should be cautioned that readings may show a significant bias at extreme levels of bilirubin concentration.

Does the reading go higher or does it show lower than actual? These are important questions that you may be asked by a patient. The effect of acetaminophen, bilirubin and uric acid in high concentrations is to increase blood glucose readings. This is not due to the enzyme but rather to the electric potential that is applied at the end of the test time. When the potential is applied, ferrocyanide that has built up due to the reaction with glucose is oxidized, creating a current that is measured and used to calculate the glucose concentration. However, other oxidizable molecules in the blood may also be oxidized to some extent, increasing the total signal that is measured. Acetaminophen, bilirubin, ascorbic acid and uric acid are all oxidizable and therefore increase the signal when they are present in high concentrations

Pharmacists should determine whether or not a patient is taking large amounts of these drugs or has a condition that may affect their uric acid or bilirubin levels, when assisting in the selection of an appropriate meter.

### TEST STRIP STABILITY

The reactivity of blood glucose test strips can shift over time due to changes in the chemistry that occurs spontaneously.<sup>14</sup> These performance shifts can decrease the accuracy of the system and may, when severe enough, result in clinical risk to the patient. It is important to know how resistant the test strip chemistry is to these spontaneous changes. For pharmacists and patients, shelf-life stability and open-bottle stability are critical factors.

A study performed by one meter manufacturer provided insight into how these

spontaneous changes affect the strips patients with diabetes use every day.<sup>14</sup> To determine shelf-life stability, the manufacturer compared strips from four different companies currently on the market. The strips were exposed to varying temperatures (30, 40 and 50° C) over 20 weeks to speed up any chemical changes that might occur in the strips. These altered strips were then compared to a control strip stored at 5° C, which, it was assumed, did not undergo spontaneous change during the duration of the study period (20 weeks). The results showed that two of the four strips had significant variations from the control strips at the 40 and 50° C categories. Specifically, low sugar readings were affected. It is important to note that the study did not look at all test strips on the market and the study results do not indicate that the strips are unstable or inferior when used inside their determined expiry date. This experiment did show that if strips are used outside the expiry date, results can be inaccurate. The strips that fared better are stable longer and allow for a longer expiry date on the packaging. The fact that many of these strips can sit in a warehouse or at a patient's home for long periods of time before being opened is an important consideration. In addition, some patients receive chronic or long-term medications through mail-order pharmacies where larger quantities are often dispensed.

Open-bottle stability is determined by the expiry date on the package. However, many companies state on the packaging that the product must be used within three months of opening, irrespective of the expiry listed on the package. This is because spontaneous chemistry changes in test strips can result when they are subjected to humidity, which occurs when a patient opens the bottle to retrieve a strip. Strips individually packaged in foil are less likely to be affected by humidity. Desiccants are also being used inside multi-strip vials to address this concern. To determine the stability of four different brands of bottled strips, researchers exposed them to a relative humidity of 80% and tested the strips at 12-hour intervals to

**TABLE 4A**  
**Medications that can cause hyperglycemia**<sup>\*15</sup>

- |                    |                       |
|--------------------|-----------------------|
| • Beta-blockers    | • Diuretics           |
| • Corticosteroids  | • Ethanol             |
| • Sympathomimetics | • Pentamidine         |
| • Cyclosporine     | • Protease Inhibitors |
| • Diazoxide        |                       |

\* Adapted from: Koda Kimball and Young.  
*Applied Therapeutics: The Clinical Use of Drugs*  
- 7th edition.

**TABLE 4B**  
**Medications that can cause hypoglycemia**

- |           |                 |
|-----------|-----------------|
| • Ethanol | • Pentamidine   |
| • Insulin | • Sulfonylureas |

a maximum of 96 hours (four days).<sup>14</sup> The researchers acknowledged that if test strips are kept sealed when not in use, and not used after the expiry date, all test strips should provide clinically consistent results. Unfortunately, patients often store strips with the lid removed (for easier access) or in a plastic bag or other container. The results of this study showed that after 96 hours, three of the four strips tested showed a significant variation (>20%) from control. One strip even showed a change after 12 hours. This result was seen for all three meters, only in the low blood sugar (2.2 mmol) samples. The fact that this change only occurred at low sugar values is important to note since inaccurate results at this glucose concentration can lead to mistreatment of a potential low sugar reading. The strip that showed no significant variation incorporated a built-in desiccant system. This study highlights the importance of proper instruction on the storage and handling of strips for accurate testing, and shows that strips either packaged in foil or those systems incorporating a built-in desiccant in the bottle have the potential to reduce the number of errors caused by humidity.

### CONCURRENT MEDICATIONS

Some medications can interfere with glucose utilization within the body as a function of an adverse reaction. This will differ from the interference factors discussed

above in that they affect the body's blood glucose concentration directly and do not interfere with the functionality of a given blood glucose monitor. It may be useful to keep these medications in mind when trying to problem-solve a suspect reading. If the patient presents with a reading that is way off normal (expected) values, then these concurrent medications could be considered to help explain the variation. Keep in mind though, even in the absence of these medications, the meter accuracy needs to be verified versus the lab when any doubt exists.

These medications are numerous, and this lesson will only consider those that have been shown to have a clinically significant effect (based on potential prevalence and/or magnitude) (see Tables 4a and 4b).

### PITFALLS TO PROPER TECHNIQUE

Self-monitoring of blood glucose, as a physical process carried out by an individual, can create the potential for error and inaccurate results. These errors are often a result of poor technique or lack of knowledge by the user. The importance of proper training, not only of technique for a particular meter but of training as a whole, cannot be understated. The meter may accurately read the glucose concentration at that particular time from a given site, but that reading may lead to an error in management (for example, failure to treat a hypoglycemic reaction based on an arm-test that reads in the normal range due to timing and lack of perfusion to the site). See Table 5 for the most common user errors.

### ISSUES OF CODING/CALIBRATION

Coding or calibration refers to the electronic adjustment required to correct for manufacturing differences between strip lots. This electronic adjustment is accomplished by manually entering a code number, inserting a computer chip, or by automatic calibration. Since a chemical reaction produces the electrical response, which in turn produces the glucose reading on a meter, manufacturers assign a code number

to similarly reacting strips. The reacting chemicals may give an erroneous result at high or low glucose levels but, when calibrated or given a certain code number, the meter will make an adjustment before the result is displayed on the meter. Many meters on the market are self-calibrating, and they do not need the manual code number input. This may help decrease the number of errors that can occur during daily testing.

An example of the need for proper coding comes from a study done at a diabetes clinic of 201 patients with Type 1 and Type 2 diabetes.<sup>16</sup> Each patient was trained by a pharmacist, diabetes educator or clinic nurse. Of these participants, 32 (16% or one in six) had incorrect or non-matching codes. These results could be indicative of two things: 1) the training given needs to be reassessed, and 2) manual coding in itself may be an issue. Both of these factors have the potential to affect the use of oral medications and insulin dosages when the readings are used to alter management of a diabetes regime.

A small study comparing two manually coded meters with an auto-calibration feature showed the impact of coding errors on blood glucose readings.<sup>17</sup> Of special note,

**TABLE 5**  
**Common User Errors**<sup>16</sup>

- Failure to store glucose strips properly
- Failure to set the glucose meter code to match the strip code accurately
- Failure to apply sufficient blood on the meter strip
- Failure to use control solutions
- Use of date-expired strips and/or control solutions
- Failure to clean the optics surface of some meters
- Testing too soon after a meal
- Arm-testing too soon after a meal (<90 minutes)
- Testing potential hypoglycemia using the arm-testing method
- Squeezing fingertip rather than milking the hand
- Testing the same time each day, day after day

**TABLE 6 Summary of available blood glucose meters**

Enzyme System Used	Meter / company	Reference	Sample Size	Underfill Technology	Calibration	Hematocrit	Temperature range °C	Strip packaging**	Alt Site (if claimed)*	Detection method
Glucose Dehydrogenase	Accu-check Aviva / Roche	Plasma	0.6µL	yes	chip	20-70%	2-32	Bottle	yes	Electro-chemical
Glucose Dehydrogenase	Accu-check Advantage / Roche	Plasma	4µL	yes	chip	20-65% (<11mmol/L)	14-40	Bottle	no	Electro-chemical
Glucose Dehydrogenase	Accu-check Compact / Roche	Plasma	1.5µL	yes	auto	20-65%	10-40	Drum	yes	Coloro-metric
Glucose Dehydrogenase	Ascensia Contour - Bayer	Plasma	0.6µL	yes	auto	20-60% (<11mmol/L)	10-40	Bottle	yes	Electro-chemical
Glucose Dehydrogenase	Precision Extra - Abbott	Plasma	1.5µL	yes	strip	20-70% (<16mmol/L)	15-40	Foil	yes	Electro-chemical
Glucose Dehydrogenase	Therasense Freestyle - Abbott	Plasma	0.3µL	yes	manual	0-60%	5-40	Bottle	yes	Electro-chemical
Glucose Oxidase	Ascensia Breeze - Bayer	Plasma	2.5-3.5µL	yes	auto	20-55% (<16mmol/L)	10-40	Disc	yes	Electro-chemical
Glucose Oxidase	Ascensia Dex - Bayer	Plasma	2.5-3.5µL	yes	auto	20-55% (<16mmol/L)	10-40	Disc	yes	Electro-chemical
Glucose Oxidase	Ascensia Elite - Bayer	Plasma	2µL	no	strip	20-60% (<16mmol/L)	10-40	Foil	yes	Electro-chemical
Glucose Oxidase	BD Logic - BD	Plasma	0.3µL	yes	manual	25-60%	15-39	Bottle	yes*	Electro-chemical
Glucose Oxidase	BD Latitude - BD	Plasma	0.3µL	yes	manual	25-60%	15-39	Bottle	yes*	Electro-chemical
Glucose Oxidase	One Touch Fastake - Lifescan	Plasma	2.5µL	no	manual	30-55%	15-35	Bottle	yes	Electro-chemical
Glucose Oxidase	One Touch Ultra - Lifescan	Plasma	1µL	yes	manual	30-55%	6-44	Bottle	yes	Electro-chemical
Glucose Oxidase	One Touch Ultrasmart - Lifescan	Plasma	1µL	yes	manual	30-55%	6-44	Bottle	yes	Electro-chemical

\* Manufacturer may not claim alt site even if strip is able to perform the test based on low volume needed.

\*\* Some bottles utilize a drying agent or built-in desiccant - contact manufacturer for details.

The information in this table is based on a review of 2005 Consumers Guide to Diabetes Products from the Canadian Diabetes Association, the manufacturers' websites, product literature and customer service centres.

when all meters were coded correctly, similar precision was seen and no difference from laboratory results was observed. When certain discordant combinations of meter code number settings and test strip code numbers was used for the "codeable" meters, statistically and clinically significant inaccuracies of blood glucose results were seen. Some of the differences seen with these miscoded meters when compared to laboratory values for the same sample varied by

greater than plus/minus 30%. When these numbers were analyzed by error grid analysis, the erroneous values accounted for altered clinical action in >90% of cases. Therefore, potentially, 90% of all clinical decisions based on results obtained from miscoded meters could be in error. These changes could include increasing or decreasing medications or insulin dosages, which could result in poor control or, more importantly, hypoglycemia in some individuals.

## CONCLUSION

In conclusion, factors such as strip stability and proper coding of meters can have very significant effects on the accuracy of blood glucose readings done at home. Pharmacists can help minimize the potential for inaccuracy in many ways, but especially through:

- Selection of meters that employ an auto-calibration feature
- Careful demonstration of the proper

handling and storage of strips

- Use of strips that are less affected by environmental conditions (e.g., humidity), such as foil-wrapped strips or those that employ a built-in desiccant
- Careful consideration of the more common interference factors
- Follow-up with patients after they start using their meter

Table 6 summarizes the attributes of various meters. Pharmacists are often the only professionals that patients with diabetes see other than their primary care physician. It is practical to apply the pharmaceutical care model to the selection of a meter for these patients. The rule should be: The right meter for the right patient for the right (accurate) results.

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## QUESTIONS

**1. Venous blood has more glucose in it than capillary blood.**

- a) True
- b) False

**2. When the lab tests blood, only the plasma portion is used to obtain a reading. Considering that home blood glucose monitors use whole blood (plasma and formed elements), how does whole blood compare to a plasma sample with respect to glucose concentration?**

- a) Plasma has a higher glucose concentration than whole blood.
- b) Whole blood has a higher glucose concentration than plasma blood.
- c) Both contain the same glucose concentration.

**3. To account for this difference in glucose concentration between plasma and whole blood, modern blood glucose monitors**

- a) take a whole sample but only test the plasma portion.
- b) account for the difference electronically before displaying the reading.
- c) both a and b.
- d) There is no difference in glucose concentration between plasma and whole blood.

### Case #1

*AJ is a 66-year-old male patient who presents to your pharmacy with newly diagnosed Type 2 diabetes. His physician has scheduled an appointment to visit your local diabetes education centre in three weeks. The physician has recommended that AJ get a blood glucose monitor and record the results for at least two weeks before coming to the centre.*

*AJ also suffers from arthritic pain in his hands and is currently being treated for hypertension and hypercholesterolemia, and is on home and portable oxygen for emphysema. At this time the doctor wants to see what a dietitian consult can accomplish before starting on medications for diabetes. AJ is to be reassessed in three months for weight loss and blood sugar control.*

**4. With respect to demographic trends, the number of individuals with diabetes will increase dramatically over the next decade due to**

- 1. the aging population**
  - 2. stringent diagnostic criteria**
  - 3. increased migration from high-risk populations**
  - 4. growth of aboriginal population**
- a) 1 and 2
  - b) 1 and 3
  - c) 1, 2 and 3
  - d) 1, 3 and 4

**5. The Diabetes Control and Complications Trial (DCCT) and the United Kingdom Prospective Diabetes Study (UKPDS) demonstrated that glycemic control and the development of long-term complications are correlated in which diabetes populations?**

- a) Type 1
- b) Type 2
- c) Type 1 and Type 2
- d) neither Type 1 nor Type 2

**6. Considering AJ's history, which feature will immediately influence your selection of meter?**

- a) Patient's age
- b) Medical condition of hypertension
- c) Treatment with oxygen for his emphysema
- d) Motivation to test

**7. AJ asks you to recommend the easiest meter on the market. When you ask him what he means by the "easiest," he says that he wants the least number of steps possible. Which feature decreases the number of steps a meter user needs to complete to obtain a reading?**

- a) Auto-calibration
- b) Wide hematocrit range
- c) Underfill technology
- d) Alternate site testing

## QUESTIONS

**8. AJ mentions that he has an old meter that his mom used years ago, and he tried to get some readings, but it seemed like the readings were all over the map.**

**Which common user errors might contribute to these erroneous readings?**

1. Failure to store glucose strips properly.
2. Failure to set glucose meter code to match the strip code accurately.
3. Use of date expired strips and/or control solution.
4. Failure to apply sufficient amount of blood.

- |            |                     |
|------------|---------------------|
| a) 1 and 3 | d) 1 and 4          |
| b) 2 and 3 | e) all of the above |
| c) 2 and 4 |                     |

*Upon inspecting the unit you notice that the code number of the strips does not match the code number of the meter. You also notice that his strips are expired.*

**9. A meter that is coded improperly, but uses strips within the expiry listed on the package, has the potential to provide readings that are in excess of 30% of the true blood value.**

- |         |          |
|---------|----------|
| a) True | b) False |
|---------|----------|

**10. Considering AJ's arthritis, what type of packaging of strips might be easier to handle?**

1. flip top
2. screw top
3. foil wrapped

- |                                      |  |
|--------------------------------------|--|
| a) 1                                 |  |
| b) 1 and 2                           |  |
| c) 1 and 3                           |  |
| d) All of the above would be alright |  |

**Case #2**

*CS is a 70-year-old female patient. She suffers from poor eyesight and, from her history, you note she has requested easy-open or "snap caps" because of occasional stiffness or pain in her hands. CS is currently on levothyroxine for hypothyroidism and celecoxib on a prn basis to control the occasional pain in her hands.*

**11. Considering CS's poor eyesight, which meter feature would NOT be important to her in selecting a blood glucose meter?**

- a) Autocalibration
- b) Large reading display
- c) Speed of results
- d) Underfill technology

**12. CS states that she wants a meter with a memory "just in case," because she seems to be forgetting things a little more lately. Based on what CS has just revealed to you, what other features may help avoid inaccurate readings for her in the future?**

- a) Strips with "lab like" results
- b) Auto calibration
- c) Foil wrapped strips or those with a built-in desiccant
- d) Alternate site testing

**13. A single training session when first buying a meter is sufficient to avoid user errors.**

- |         |          |
|---------|----------|
| a) True | b) False |
|---------|----------|

**Case #3**

*MN is a busy middle-aged male patient. He comes in and says that he wants to know if there is anything new on the market in home blood glucose monitors. He was diagnosed with Type 2 diabetes about 10 years ago and he likes to keep up-to-date and wants cutting-edge equipment. He is currently taking metformin and glyburide along with an exercise regimen to control his sugars.*

**14. Which are the newest features on the market for blood glucose monitors?**

1. Alternate site testing
2. Autocalibration
3. Fast test results
4. Strips with built-in desiccant

- |            |                     |
|------------|---------------------|
| a) 1 and 2 | c) 1, 2 and 4       |
| b) 2 and 3 | d) all of the above |

*MN has an old meter that he has had for about six years. The meter still reads accurately when last compared to the lab results at his last visit with his doctor.*

**15. To be considered accurate, what is the acceptable maximum percentage difference from lab results?**

- |        |        |
|--------|--------|
| a) 20% | c) 5%  |
| b) 10% | d) 30% |

**16. A meter should be exchanged irrespective of new features on the market every five years to maintain accurate results.**

- |         |          |
|---------|----------|
| a) True | b) False |
|---------|----------|

*MN shows you his meter and test strips. You question him about his technique and storage of strips. He has been testing more frequently lately and says that he leaves the lid*

*off the strips to be able to access them more easily.*

**17. As the pharmacist, you should counsel MN about**

- a) the importance of trading in his meter regularly.
- b) the importance of properly storing his strips.
- c) the importance of testing regularly.

**18. Considering MN specifically, what is the optimal frequency of blood glucose testing?**

- a) 2 times per day
- b) 3 times per day
- c) once daily
- d) unclear as to how many

**19. When compared to less frequent monitoring in people with Type 2 diabetes treated with medications, testing at least once daily**

- a) is associated with a lowering in A1C by 0.6%.
- b) is associated with a lowering in A1C by at least 1.0%.
- c) is not associated directly to a change in A1C.
- d) is no better than three times a week in reducing complications.

*MN states that he usually has no problem getting blood to do his test, but sometimes he has to test at work outdoors, where it is a little colder. Because of the cold, he has a hard time getting a good blood drop.*

**20. Which statement is TRUE about meters currently on the market?**

- a) All meters will display a reading even with an insufficient blood sample.
- b) All meters on the market have underfill technology.
- c) Some meters will give a reading even with an insufficient blood sample.
- d) All meters will warn the user if an insufficient amount of blood was given.

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