Home Monitoring of Glucose and Blood Pressure

JAMES R. TAYLOR, PharmD, CDE, and KENDALL M. CAMPBELL, MD, *University of Florida, Gainesville, Florida*

Home monitoring of blood glucose and blood pressure levels can provide patients and physicians with valuable information in the management of diabetes mellitus and hypertension. Home monitoring allows patients to play an active role in their care and may improve treatment adherence and clinical outcomes. Glucose meters currently on the market produce results within 15 percent of serum blood glucose readings and offer a variety of features. Although the data are somewhat conflicting, home glucose monitoring has been associated with improved glycemic control and reduced long-term complications from diabetes. These effects are more pronounced in patients who take insulin. Home blood pressure values predict target organ damage and cardiovascular outcomes better than values obtained in the office. Home blood pressure measurements are also effective at detecting borderline hypertension and monitoring the effectiveness of antihypertensive drugs. Validated arm cuffs are the preferred blood pressure devices for home use. Information from home monitoring should always be used in conjunction with that from regular office visits and other data to make appropriate therapeutic decisions. (Am Fam Physician 2007;76:255-60, 261, 262. Copyright © 2007 American Academy of Family Physicians.)

AGF This article exemplifies the AAFP 2007 Annual Clinical Focus on management of chronic illness.

▶ **Patient information:** A handout on home monitoring of blood pressure, written by the authors of this article, is provided on page 261.

▶ **Patient information:** A handout on home monitoring of blood sugar, written by the authors of this article, is provided on page 262.

Home monitoring of blood glucose and blood pressure levels can provide the patient and physician with valuable information for disease management. Because a variety of home monitoring devices are available, appropriate selection and use can be a daunting task. This article reviews devices for home monitoring of glucose and blood pressure and discusses their clinical utility.

Glucose Monitoring

Although there is no universal standard for accuracy of glucose meters, several groups have defined acceptable ranges.[1-4] The U.S. Food and Drug Administration (FDA) requires glucose meters to produce self-monitoring results within 20 percent of a reference measurement but recommends results within 15 percent[4]; the FDA has stated that future meters should achieve results within 10 percent of reference at serum glucose concentrations of 30 to 400 mg per dL (1.7 to 22.2 mmol per L). The American Diabetes Association (ADA) recommends that meters produce readings within 5 percent of laboratory values.[1] All meters currently on the market are considered to be clinically accurate in that they at least meet the FDA standard, although it is important to remember that they are not as accurate as a standard laboratory test.[5,6] Given this broad range of possible error, making treatment decisions based solely on self-monitoring of blood glucose (SMBG) is not advised.

Glucose meters are most accurate when used properly.[7] Thus, educating patients on proper use and what to do with the results is vital. Although the exact procedure for using a meter varies by product, potential pitfalls are similar. Common errors include poor maintenance (e.g., soiled meter), using expired test strips, obtaining an inadequate sample size, and failing to calibrate the meter.

CLINICAL UTILITY

Uses of SMBG data include identifying and treating hyper- and hypoglycemia; making decisions about food intake or medication adjustment when exercising; determining the effect of ingested food on blood glucose; and managing glucose fluctuations resulting from illness.[8] Although the data are somewhat conflicting, larger, better-designed trials have shown that SMBG improves glycemic control when the results are used to adjust therapy.[6] However, the data for reducing long-term complications are more conclusive for patients on insulin therapy.

SORT: KEY RECOMMENDATIONS FOR PRACTICE

Clinical recommendation	*Evidence rating*	*References*
Patients with type 1 diabetes should self-monitor blood glucose three or more times a day.	C	9
Glucose should be monitored more frequently during insulin dose adjustments.	C	8
Patients with hypertension should monitor their blood pressure at home because it correlates well with target organ damage and cardiovascular mortality. It also can be used to monitor drug effectiveness.	B	17
Home blood pressure measurement should be performed twice in the morning and twice in the evening for at least three days to determine the patient's usual blood pressure.	C	17

A = consistent, good-quality patient-oriented evidence; B = inconsistent or limited-quality patient-oriented evidence; C = consensus, disease-oriented evidence, usual practice, expert opinion, or case series. For information about the SORT evidence rating system, see page 176 or http://www.aafp.org/afpsort.xml.

Although the optimal frequency of monitoring is unknown, the ADA recommends SMBG three or more times a day for patients with type 1 diabetes.[9] Patients with type 2 diabetes still benefit from at least periodic monitoring. Ultimately, the frequency and timing of SMBG should be determined by how the data will be used.[8] SMBG can assist the patient and physician with adjusting diet and medications and maintaining appropriate glucose control. More frequent monitoring is beneficial during insulin dose adjustments.[8] Postprandial monitoring is important to identify the effect of various foods on glucose levels and to monitor the effects of preprandial medications. Other factors, such as desire for tight control and current degree of control, will influence frequency of monitoring.

METER SELECTION

A number of glucose meters are available, with new models being released each year. Although home glucose meters use whole-blood samples, nearly all are plasma calibrated so that the results reflect plasma glucose. This allows home values to be compared directly to laboratory values. Glucose meters are largely differentiated based on their features. These include blood sample size required, test time, memory capability, ability to download results into data management software, and ability to perform alternate site testing (e.g., forearm). Meter selection should be based primarily on features desired by the patient *(Table 1)*.

Newer technology has led to the development of continuous glucose meters that measure glucose in subcutaneous interstitial fluid and reflect changes relatively quickly. However, continuous monitors are not easily used on a long-term basis, and their current clinical utility is somewhat limited. *Table 2* provides a comparison of commonly used glucose meters. Prices of most glucose meters and strips are comparable. However, patients often can purchase the meter for little or no cost after rebates. The long-term expenses come from the strips and other supplies. A few meters offer more advanced features, such as the ability to enter information (e.g., medication doses, carbohydrate intake, exercise) and voice prompts for the visually impaired.

Table 1. Considerations for Glucose Meter Selection

Feature	*Clinical advantages*
Smaller sample size requirement	Less painful, permits alternate site testing
Alternate site testing	Less discomfort for patients who use fingertips regularly (e.g., for typing)
Results in less than 15 seconds	Increased convenience

Blood Pressure Monitoring

Electronic devices are available to measure blood pressure at the arm, wrist, or finger. Published data evaluating the accuracy of specific electronic blood pressure monitors are limited. However, several organizations have established standards for accuracy.[10-13]

Table 2. Common Glucose Meters

Glucose meter	*Approximate cost ($)*†*	*Sample size*	*Comments*
Alternate site testing, test time ≤ 15 seconds			
Accu-Chek Active	20 (meter) 0.60 (per test)	1 µL	Able to download, memory
Accu-Chek Aviva	75 (meter) 1.00 (per test)	0.6 µL	Able to download, memory, larger test strip for easier handling
Accu-Chek Compact Plus	78 (meter) 1.00 (per test)	1.5 µL	Able to download, memory, uses 17-strip drum to avoid handling strips
Ascensia Contour	75 (meter) 0.93 (per test)	0.6 µL	Able to download, memory
FreeStyle	77 (meter) 0.97 (per test)	0.3 µL	Able to download
FreeStyle Flash	75 (meter) 0.97 (per test)	0.3 µL	Able to download, compact meter
OneTouch InDue	110 (meter) 0.98 (per test)	1 µL	Combination meter and insulin pen for use with Novo PenFill
OneTouch Ultra2	70 (meter) 0.98 (per test)	1 µL	Able to download, memory
OneTouch UltraSmart	91 (meter) 0.98 (per test)	1 µL	Combination meter and electronic logbook
ReliOn Ultima (sold only at Wal-Mart stores)	9 (meter) 0.43 (per test)	0.6 µL	Memory
TrueTrack Smart (sold as generic meter at pharmacies under pharmacy name)	18 (meter) 0.52 (per test)	1 µL	Memory
Alternate site testing, test time > 15 seconds			
Ascensia Breeze	60 (meter) 0.88 (per test)	2.5 to 3.5 µL	Able to download, memory, uses 10-strip disk to avoid handling strips
Ascensia DEX 2	88 (meter) 0.88 (per test)	2.5 to 3.5 µL	Able to download, memory, uses 10-strip disk to avoid handling strips
Ascensia Elite and Elite XL	50 (Elite meter) 70 (Elite XL meter) 0.88 (per test)	2 µL	No buttons, easy to use, XL meter has larger memory
No alternate site testing, test time ≥ 30 seconds			
Accu-Chek Advantage	69 (meter) 0.90 (per test)	4 or 9 µL (depending on strip used)	Able to download, memory
Accu-Chek Complete	120 (meter) 0.90 (per test)	4 or 9 µL (depending on strip used)	Able to download, memory, stores information on insulin doses, carbohydrates, exercise, laboratory results
Accu-Chek Voicemate	480 (meter) 0.90 (per test)	4 µL	Memory, voice prompts
OneTouch Basic	57 (meter) 0.92 (per test)	10 µL	Memory, reports whole blood glucose
OneTouch SureStep	78 (meter) 1.00 (per test)	10 µL	Able to download, memory

**—Prices from http://www.walgreens.com, http://www.cvs.com, and http://www.drugstore.com.*

†—Price per test reflects test strip cost only and does not include additional items such as control solutions and lancets.

Devices available in the United States that are known to meet these criteria are listed in *Table 3.* Clinical evaluations of wrist and finger devices have revealed that these instruments are considerably less accurate than their arm (brachial artery) counterparts, with finger monitors being the least accurate.[14-16] Thus, arm monitors are preferred over wrist or finger monitors.

CLINICAL UTILITY

Office-based blood pressure measurements have been shown to result in higher values than those recorded at home.[17] Studies have found variations of 9 to 23 mm Hg in systolic blood pressure and diastolic differences of 3 to 10 mm Hg.[18] The most recent report from the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7) defines home blood pressure values consistently greater than 135/85 mm Hg as hypertensive.[19] The differences in systolic pressure between home and office blood pressure measurements increase with age and degree of anxiety during office visits (known as "white coat" hypertension). These differences also tend to be greater in men and in patients not taking antihypertensive medication.

A systematic review concluded that, compared with office monitoring, home monitoring is better at predicting target organ damage and cardiovascular mortality, predicting sustained hypertension in patients with borderline hypertension, and can be used to monitor drug effectiveness.[17] This

Table 3. Validated Electronic Arm Home Blood Pressure Monitors

Monitor	*Approximate cost ($)*†*	*Use if patient has arrhythmia?*	*Memory feature?*	*Comments*
Basic models				
LifeSource UA-704	25	No	No	Semiautomatic, compact
Omron HEM-432C	25	No	Yes	Semiautomatic
LifeSource UA-767	50	No	No	Automatic
LifeSource UA-767 Plus	58	Yes	Yes	Automatic, latex free
Models with extra features‡				
LifeSource UA-787AC	62	Yes	Yes	Reminder alarms, latex free
LifeSource UA-787EJ	65	Yes	Yes	Averages, reminder alarms, easy-fit cuff
LifeSource UA-774	67	Yes	Yes	Dual memory for two users, latex free
Omron HEM-712C	70	Yes	Yes	Compact
LifeSource UA-767T	75	No	Yes	Voice announcement of results
Omron HEM-711AC	80	Yes	Yes	Includes AC adapter
Omron HEM-705CP	100	Yes	Yes	Includes printer
Omron HEM-780	100	Yes	Yes	Includes AC adapter, contoured cuff
Omron HEM-773AC	120	Yes	Yes	Includes AC adapter, contoured cuff

**—Prices obtained from http://www.lifesourceonline.com, http://www.drugstore.com, and http://www.walgreens.com.*

†—Prices given are for medium-size cuff; large cuffs, where available, are slightly more expensive.

‡—All are automatic.

Table 4. Recommended Protocol for Home Blood Pressure Monitoring

Avoid exercise, caffeine, and other stimulants 30 minutes before measurement
Avoid restrictive clothing
Use an appropriately sized cuff
Rest quietly before and during blood pressure measurement
Position arm at heart level
Do not talk while the machine is measuring the blood pressure

evidence is based on the use of validated blood pressure monitors. Although there are no evidence-based recommendations on frequency of home blood pressure measurements, it has been suggested that the minimal number of measurements to obtain an accurate assessment of a patient's usual blood pressure should be four times per day (twice in the morning and twice in the evening) for three consecutive days.[17]

MONITOR SELECTION

Although there are limited comparative data on specific blood pressure monitors, home monitoring offers several advantages in addition to its correlation with outcomes and drug effectiveness. It eliminates the white coat effect, allows for multiple readings, and may improve patient awareness and compliance with treatment. There are, however, a few limitations. Some home devices may not be appropriate in obese patients (because of limited cuff sizes), patients with arrhythmias or preeclampsia, and patients in whom vascular stiffening is suspected.[17] In a recent randomized controlled trial, adjustment of antihypertensive medications based solely on home monitoring led to less-intensive drug treatment and poorer blood pressure control than usual care.[20] Medication adjustments should incorporate values from home and office monitoring.

Electronic blood pressure models are relatively easy to use and display a digital readout. They may be semiautomatic (i.e., patient inflates and deflates cuff) or fully automatic (i.e., cuff inflates and deflates with the press of a button), although both types automatically measure the blood pressure. Electronic blood pressure readings correlate well with the auscultatory method.[21] Despite the relative ease of using electronic blood pressure monitors, failure to follow protocol can lead to erroneous results. *Table 4* outlines the recommended protocol for home blood pressure measurement.

The Authors

JAMES R. TAYLOR, PharmD, CDE, is a clinical assistant professor in the Department of Pharmacy Practice at the University of Florida College of Pharmacy, Gainesville. He received his pharmacy degree from Ohio Northern University, Ada, and completed a pharmacy practice residency at the Veterans Affairs Medical Center, Huntington, W.Va., and a family medicine residency at the University of Florida.

KENDALL M. CAMPBELL, MD, is a clinical assistant professor in the Department of Community Health and Family Medicine and assistant dean for minority affairs at the University of Florida College of Medicine, Gainesville. He received his medical degree from the University of Florida, and completed his residency training at Tallahassee (Fla.) Memorial Healthcare.

Address correspondence to James R. Taylor, PharmD, CDE, University of Florida College of Pharmacy, P.O. Box 100486, Gainesville, FL 32610-0486 (e-mail: jtaylor@cop.ufl.edu). Reprints are not available from the authors.

Author disclosure: Nothing to disclose.

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