Evaluation of five portable blood glucose meters for use in dogs

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Objective—To evaluate clinical and analytical accuracy of 5 portable blood glucose meters (PBGM) used to measure blood glucose concentrations in dogs and to determine potential sources of error.

Design—Prospective study.

Animals—221 dogs.

Procedure—Venous blood samples were obtained, and results of the 5 PBGM were compared with results of a hexokinase reference method. Agreement among methods was determined by use of error grid analysis and statistical methods.

Results—Accuracy of the PBGM varied with glucose concentration of the sample. The largest differences between results of the PBGM and results of the reference method were obtained with samples with high glucose concentrations; 4 PBGM tended to underestimate and 1 PBGM tended to overestimate the true glucose concentration. Absolute differences between results of the PBGM and results of the reference method were small for samples with low glucose concentrations and samples with concentrations in the reference range. None of the PBGM yielded measurements that would result in clinically unacceptable errors. Within-run and between-day precision was good for all PBGM, and results were not affected by use of EDTA or heparin to anticoagulate blood. Readings of the PBGM were significantly higher for blood samples with low Hct than for samples with normal Hct. For 3 PBGM, samples < 3 µl resulted in inaccurate measurements.

Conclusions and Clinical Relevance—Results suggest that currently available PBGM are sufficiently accurate for use in clinical practice to determine blood glucose concentrations in dogs. (J Am Vet Med Assoc 2000;216:203–209)

Portable blood glucose meters (PBGM) are small, pocket-sized devices used for rapid, easy, and inexpensive determination of blood glucose concentrations. In people with insulin-dependent diabetes mellitus, better regulation of blood glucose concentration can significantly reduce the onset and progression of microvascular and neuropathic complications. Thus, regular monitoring of blood glucose concentration using a PBGM has become an integral part of the management of diabetes mellitus in humans. In addition, physicians routinely use PBGM to screen patients for hyperglycemia and to manage and provide follow-up care for diabetic patients.

In recent years, many new PBGM from various manufacturers have appeared on the market. Proclaimed improvements include greater precision, faster measurements, decreased blood volume requirements, and reduced dependence on operator technique. However, studies using PBGM to measure blood glucose concentrations in humans have shown that accuracy can vary greatly. In addition, other factors, such as low Hct or small sample size, can influence values obtained with PBGM. Although PBGM are used with increasing frequency in small animal medicine to determine blood glucose concentration curves or to measure individual blood glucose concentrations, to our knowledge, only 1 study evaluated accuracy of PBGM when used to measure blood glucose concentrations in dogs, and that study involved only 3 first-generation meters. The purposes of the study reported here were to evaluate clinical and analytical accuracy of 5 newer-model PBGM used to measure blood glucose concentrations in dogs and to determine potential sources of error.

Materials and Methods

Dogs—The study was conducted at the University of Zurich Clinic for Small Animal Internal Medicine. Jugular vein blood samples were collected from 221 client-owned dogs of various breeds. Dogs had been brought to the clinic for a variety of medical reasons, and blood samples were collected as part of the routine diagnostic testing for each dog.

Blood glucose meters—Five PBGM were evaluated: the Glucometer Elite (Elite), the Glucometer DEX (DEX), the SureStep, the Precision QID (QID), and the Accu-Chek Simplicity (Accu-Chek). Devices used an electrochemical or photometric method for measuring blood glucose concentrations, and manufacturers of each device had established a measurement range for that device (Table 1). All devices displayed a result of “LO” or “HI” for concentrations less than or greater than the limits of the established measurement range. For the Elite and DEX meters, blood samples are drawn into the reaction chamber of test strips by capillary action, whereas for the other meters, a drop of blood must be applied to the application zone of the test strip.

For comparison, blood glucose concentrations were also measured by use of a hexokinase reference method, using heparinized plasma. Concentrations were measured with the reference method within 30 minutes after concentrations were measured with the PBGM. The hexokinase method is the generally accepted reference method for determination of glucose concentration in body fluids.

Quality control—For quality control and for determination of between-day precision, the manufacturers’ control solutions were used. Two solutions were used for the Elite meter, 3 were used for the DEX meter, 1 was used for the SureStep meter, 2 were used for the QID meter, and 2 were

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This work represents a portion of Gerhard Wess’ dissertation presented to the Clinic for Small Animal Internal Medicine, University of Zurich, Zurich, Switzerland.

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used for the Accu-Chek meter. Quality control tests were performed once a week and whenever a new box of test strips was used. Meters were calibrated according to the manufacturers’ instructions whenever a new box of test strips was opened.

Effect of anticoagulants—Blood samples from 10 euglycemic dogs and 10 hyperglycemic dogs were used to assess the effect of anticoagulation and type of anticoagulant on measurements. From each blood sample, the following aliquots were prepared: fresh blood without anticoagulant; blood anticoagulated with either EDTA, fluoride, or lithium-heparin; and serum.

To determine the effect of type of anticoagulant on measurements from the 5 PBGM, results for aliquots of each anticoagulated blood sample were compared with results for fresh blood samples without anticoagulant. To determine effects of anticoagulation on measurements from the reference method, aliquots of each blood sample anticoagulated with EDTA, fluoride, or lithium-heparin were centrifuged at 3,000 X g for 5 minutes. Measurements obtained with plasma were then compared with measurements obtained with serum.

Because fresh blood without anticoagulant and heparinized blood samples are most often used in clinical practice, another 130 blood samples were obtained. For each sample, glucose concentrations in an aliquot of fresh blood and in an aliquot of blood anticoagulated with heparin were measured with each of the 5 PBGM. Plasma was obtained from aliquots of each blood sample anticoagulated with heparin, and glucose concentrations in serum and in plasma were measured by use of the reference method. Of the 130 samples, 65 were in the mid-glycemic range (4.0 to 7.9 mmol/L) and 65 were from hyperglycemic dogs (> 7.9 mmol/L).

Effect of blood drop size—To determine the effect of the size of the blood drop on the accuracy of glucose measurements, test strips were covered with 1, 2, 3, 5, 8, 10, and 15 µl aliquots of a heparinized blood sample with glucose concentrations within the reference range and of a heparinized blood sample with glucose concentration greater than the upper limit of the reference range. Samples of each volume were tested in triplicate.

Effect of Hct—Heparinized blood samples from 14 euglycemic dogs with a low Hct (12 to 28%) were used to evaluate the effect of Hct on glucose measurements. Differences between values obtained with the PBGM and values obtained with the reference method were calculated, and mean differences were compared with mean differences between PBGM values and reference method values for blood samples from 65 euglycemic dogs with a normal Hct (43 to 56%).

Within-run precision—To evaluate within-run precision, glucose concentrations in heparinized blood samples from 15 dogs were measured 10 times within 15 minutes, using the 5 PBGM and the reference method. Five of the samples had low glucose concentrations, 5 had concentrations within the reference range, and 5 had high concentrations.

Between-day precision—Between-day precision of the PBGM was assessed by testing each manufacturer's glucose control solution in duplicate on 10 consecutive days.

Agreement among methods—All 5 PBGM and the reference method were used to measure blood glucose concentrations in 170 blood samples. Forty of these samples had low glucose concentrations (< 4.0 mmol/L), 65 had glucose concentrations within the mid-glycemic range (4.0 to 7.9 mmol/L), and 65 had high glucose concentrations (> 7.9 mmol/L). Of the 40 samples with low glucose concentrations, only 15 were from dogs with hypoglycemia for medical reasons. To increase the number of samples with low glucose concentration, 25 euglycemic blood samples that had been left at room temperature (approx 20°C) for 2 to 4 hours to allow anaerobic glycolysis also were used. For technical reasons, it was necessary to use heparinized whole blood samples for the PBGM and plasma obtained from heparinized blood samples for the reference method for all 170 samples.

Statistical analyses—Data were analyzed by use of standard statistical software. To determine the effect of type of anticoagulant and anticoagulation, mean differences between results of the PBGM and reference method values were calculated. One-way ANOVA was then used to compare mean differences. One-way ANOVA was also used to test for an effect of blood drop size on measurements. Mean differences between results of PBGM and reference method values for dogs with low Hct were compared with mean differences for dogs with normal Hct by use of a t-test. Mean, SD, and coefficients of variation were calculated to assess within-run and between-day precision. For all analyses, a value of P < 0.05 was considered significant.

Agreement between results of the PBGM and results of the reference method was evaluated by use of statistical and clinically oriented approaches. For the method of residuals, the absolute values of the differences between results of the PBGM and results of the reference method were plotted against results of the reference method. Relationships between variables were examined by use of Pearson correlation coefficients. Clinical accuracy of PBGM values was examined by use of error grid analysis. This analysis divided the plot of predicted (PBGM, y-axis) versus actual (reference method, x-axis) blood glucose concentrations into 5 zones (A through E) and is based on the assumption that the clinical goal is to maintain blood glucose concentration between 3.9 and 10.0 mmol/L. Measurements in zones A and B are considered clinically accurate in that they would lead to clinically correct treatment decisions. Results of the PBGM that fall in zone A deviate from the reference method value by no more than 20%, or the PBGM value and the reference method value are both < 3.9 mmol/L. Results of the PBGM that fall in zone B deviate from reference method values by more than 20% but would lead to benign treatment decisions. Results of the PBGM that fall in zone C, D, and E would lead to treatment errors or a failure to treat. Results of the PBGM that fall in zone C would lead to overcorrection of an acceptable glucose concentration and would cause the actual blood glucose concentration to fall to < 3.9 mmol/L or to rise to > 10.0 mmol/L. Results of the PBGM that fall in zone D would lead to potentially dangerous error of failing to treat actual glucose concentrations outside the target
range. Results of the PBGM that fall in zone E are opposite to the actual glucose values, and therapeutic actions based on these values would be opposite to those indicated.

**Results**

**Effect of anticoagulation**—For all 5 PBGM, values obtained with fresh blood, blood anticoagulated with EDTA, and blood anticoagulated with lithium-heparin were not significantly different from each other. For 4 of the PBGM, values obtained with blood anticoagulated with fluoride were not significantly different from values obtained with fresh blood or blood anticoagulated with EDTA or lithium-heparin. However, for the SureStep, glucose concentrations of euglycemic and hyperglycemic blood samples anticoagulated with fluoride were underestimated to a significantly larger degree than were glucose concentrations in fresh blood and in blood samples anticoagulated with EDTA or lithium-heparin. For euglycemic samples, differences between reference method values and values obtained with the SureStep for samples anticoagulated with fluoride, fresh blood samples, samples anticoagulated with EDTA, and samples anticoagulated with lithium-heparin were –1.65, –0.66, –0.78, and –0.74 mmol/L, respectively. For hyperglycemic samples, the respective differences were –8.62, –3.35, –3.52, and –3.23 mmol/L.

With the reference method, results for serum were not significantly different from results for any of the anticoagulated blood samples. Subsequently, plasma obtained from heparinized blood samples was used for the reference method.

**Effect of blood drop size**—Minimum volume of blood required to consistently initiate the measuring process differed among the 5 PBGM. For the Elite meter, it was 1 µl, and values were displayed for all drop sizes tested. For the DEX and Simplicity meters, minimum drop size was 3 µl. In 8 of 12 instances when smaller drops were used, the measuring process was initiated, but an error message was displayed in 3 of these 8 instances. For the SureStep and QID meters, minimum drop sizes were 3 and 5 µl, respectively. When drops of ≥ 3 µl (5 µl for the QID meter) were used, glucose measurements did not differ among the 5 instruments (Fig 1). For the Elite and DEX meters, values obtained when drops < 3 µl were used were significantly lower than values obtained when larger drops were used. The same was true for the Simplicity meter, although the discrepancy was less pronounced. On the basis of these findings, blood samples in all subsequent experiments were delivered with a 2 ml syringe and a 22-gauge hypodermic needle, which produced a blood volume of 10 to 15 µl.

**Effect of Hct**—For all 5 PBGM, mean difference between values obtained with the PBGM and reference method values was significantly higher for blood samples with a low Hct than for samples with a normal Hct (Table 2).

**Within-run precision**—All coefficients of variations were < 7% (Table 3). For all PBGM, coefficients of variation were lower for samples with high glucose concentrations than for samples with concentrations in the reference range and samples with low concentrations. For the Elite, SureStep and Accu-Chek meters, coefficients of variation were < 5% for euglycemic and hyperglycemic samples. For the DEX and QID meters, coefficients of variation were < 5% only for hyperglycemic samples.

**Table 2**—Mean ± SD difference between blood glucose concentrations obtained using various PBGM and concentration obtained using a reference method for dogs with low (12 to 28%; n = 14) or normal (43 to 56%; 65) Hct

<table>
<thead>
<tr>
<th>Meter</th>
<th>Normal Hct</th>
<th>Low Hct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucometer Elite</td>
<td>–1.2 ± 0.5</td>
<td>0.1 ± 0.7</td>
</tr>
<tr>
<td>Glucometer DEX</td>
<td>0.6 ± 0.6</td>
<td>1.1 ± 1.2</td>
</tr>
<tr>
<td>SureStep</td>
<td>–0.9 ± 0.6</td>
<td>0.3 ± 0.6</td>
</tr>
<tr>
<td>Precision QID</td>
<td>–1.0 ± 0.8</td>
<td>0.3 ± 0.3</td>
</tr>
<tr>
<td>Accu-Chek Simplicity</td>
<td>–1.0 ± 0.5</td>
<td>–0.5 ± 0.3</td>
</tr>
</tbody>
</table>

Figure 1—Effect of blood drop size on results of 5 portable blood glucose meters (PBGM) used to measure glucose concentrations in dogs. Meters were tested with aliquots of a heparinized blood sample with glucose concentration within the reference range (top) or greater than the upper limit of the reference range (bottom). ▼ = Glucometer Elite; + = Glucometer DEX; × = SureStep; Δ = Precision QID; □ = Accu-Check Simplicity.
Between-day precision—In all cases, coefficient of variation was < 8% (Table 3).

Agreement among instruments—Blood glucose concentrations determined by use of the reference method ranged from 1.3 to 28.3 mmol/L for the 170 samples. When all samples were considered, the correlation coefficient was 0.98 for the DEX instrument and 0.99 for the 4 other PBGM. For hyperglycemic samples, correlation coefficients ranged from 0.91 to 0.95 for the 5 meters, whereas for the mid-glycemic samples, the correlation coefficient was 0.35 for the QID meter and ranged from 0.63 to 0.71 for the other 4 meters; for the hypoglycemic samples, correlation coefficients ranged from 0.68 to 0.81.

The Bland Altman difference plots (Fig 2) indicated that the largest deviations between reference method values and values obtained with the PBGM were recorded for samples with higher glucose concentrations. For hyperglycemic samples, correlation coefficients ranged from 0.91 to 0.95 for the 5 meters, whereas for the mid-glycemic samples, the correlation coefficient was 0.35 for the QID meter and ranged from 0.63 to 0.71 for the other 4 meters; for the hypoglycemic samples, correlation coefficients ranged from 0.68 to 0.81.

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Table 4—Error grid analysis for results of blood glucose measurements obtained with 5 PBGM

<table>
<thead>
<tr>
<th>Glucose concentration of samples</th>
<th>Percentage of measurements</th>
<th>Zone A</th>
<th>Zone B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (&lt; 4.0 mmol/L; n = 40)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucometer Elite</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Glucometer DEX</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SureStep</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Precision QID</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Accu-Chek Simplicity</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Normal (4.0 to 7.9 mmol/L; n = 65)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucometer Elite</td>
<td>29</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Glucometer DEX</td>
<td>82</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>SureStep</td>
<td>57</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Precision QID</td>
<td>49</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Accu-Chek Simplicity</td>
<td>48</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>High (&gt; 7.9 mmol/L; n = 65)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucometer Elite</td>
<td>89</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Glucometer DEX</td>
<td>91</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>SureStep</td>
<td>74</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Precision QID</td>
<td>57</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Accu-Chek Simplicity</td>
<td>89</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>All samples</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucometer Elite</td>
<td>69</td>
<td>31</td>
<td></td>
</tr>
<tr>
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<td>11</td>
<td></td>
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<td>26</td>
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<tr>
<td>Precision QID</td>
<td>64</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Accu-Chek Simplicity</td>
<td>76</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

Measurements were assigned to a zone by comparing concentration obtained using the PBGM with concentration obtained using a reference method. Results of the PBGM that fall in zone A deviate from the reference method value by no more than 20%, or the PBGM value and the reference method value are both < 3.9 mmol/L. Results of the PBGM that fall in zone B deviate from the reference method value by more than 20%, but reliance on results of the PBGM to make treatment decisions would not cause unacceptable treatment errors. None of the PBGM yielded measurements that were in zones C (reliance on the PBGM value would result in unnecessary corrections), D (reliance on the PBGM value would result in a failure to detect glucose concentrations outside the target range), or E (reliance on the PBGM value would result in erroneous treatment).

Discussion
Results of this study suggest that all 5 PBGM tested were sufficiently accurate for use in clinical practice. However, to avoid misinterpretation of results, clinicians should be aware of variations in performance of these PBGM and of potential sources of errors. In human medicine, numerous factors that can potentially influence the accuracy of measurements obtained with PBGM, including sample volume, Hct, blood incubation time, color stability of the test strips, altitude, hemolysis of blood samples, blood temperature, room humidity, and blood samples, prandial state, and blood source (ie, venous, arterial, or capillary blood), have been tested.8,9,18-22 To our knowledge, however, no previous study has evaluated potential sources of errors associated with using PBGM in small animal medicine.

For clinical purposes, it is important to determine whether blood samples that do or do not contain an anticoagulant can be used in a PBGM. Although manufacturers of meters used in this study recommend that certain anticoagulants not be used, we did not find that type of anticoagulant had any significant effect on blood glucose measurements, with the inclusion of measurements for samples anticoagulated with fluoride when the SureStep is used. Therefore, we recommend that blood samples anticoagulated with fluoride not be used with this particular instrument. In addition, on the basis of the manufacturer’s recommendations, it might be preferable to avoid these types of samples for all 5 PBGM.

The minimum sample volume required for these PBGM was 3 to 5 µL, which represents a drop that is barely visible to the naked eye. Use of smaller blood drops can cause problems, especially with the Elite and, to a lesser extent, the DEX and Accu-Chek meters, and may lead to erroneous readings. The DEX and Accu-Chek meters sometimes displayed an error message when the sample volume was too small, but the Elite meter did not. Therefore, the test strip chamber of the Elite meter must be filled to the mark. Use of too small a sample volume did not appear to be a problem with the QID and SureStep meters, because the measuring process was not started when the sample volume was too small. Generally, the size of the blood

other PBGM did not consistently underestimate or overestimate concentrations. For mid-glycemic samples, mean deviation from reference method values ranged from −0.6 mmol/L (DEX) to −1.2 mmol/L (Elite); most values obtained with the PBGM were less than the reference method value. The Elite, SureStep, and Accu-Chek meters had very few measurements that were greater than the reference method value, and the DEX and QID meters had several. For hyperglycemic samples, the DEX yielded measurements that were higher or lower than the reference method value, most values obtained with the Elite meter were lower than the reference method value, and the DEX and Accu-Chek meters were less than the reference method value; for samples with reference concentrations that were higher or lower than the reference method values, almost all values obtained with the QID meter were lower than the reference method values, with the largest differences (maximum, −7.5 mmol/L; mean, −2.5 mmol/L) for samples with high glucose concentrations. Overall, the Elite and Accu-Chek meters yielded the most reliable results. For all 5 PBGM, all measurements were within the clinically acceptable zones A and B (Table 4).
drop is not an issue, because blood samples are almost always applied with a syringe and small hypodermic needle, and the size of a drop from a 22- or 24-g needle is between 10 and 15 µL. However, capillary blood samples from dehydrated or hypoperfused patients may be too small for adequate measurement.

When these meters are used, blood glucose concentration may be overestimated in anemic patients. A possible reason for this is an increased diffusion rate of plasma to the reagent pad when the number of RBC is low. Because of a lack of anemic dogs with hyperglycemia in the study reported here, we were unable to examine the effect of low Hct on blood glucose measurements in hyperglycemic dogs. However, in hyperglycemic human patients, an inverse relationship was observed between glucose measurements and Hct when PBGM were used; this relationship was less pronounced in euglycemic patients. Therefore, it is possible that in hyperglycemic anemic dogs, use of PBGM would result in overestimation of blood glucose concentration even more pronounced than that seen with euglycemic anemic dogs. Thus, depending on which PBGM is used, the measured glucose concentration for an anemic dog may be closer to the reference method value (using a PBGM that normally underestimates the glucose concentration in dogs that are not anemic) or may be even higher than expected (using a PBGM that normally overestimates the glucose concentration in dogs that are not anemic). Clinicians should use caution when interpreting results from PBGM for dogs with anemia.

The high correlation between results of PBGM and results of the reference method (correlation coefficients were all > 0.98) was in agreement with results of a previous study. However, the correlation coefficient may not accurately describe the relationship between results of PBGM and those of the reference method. Perfect agreement between results of 2 measurement methods occurs when all data points are situated on the line of equality, whereas perfect correlation occurs whenever the data points form any straight line. Furthermore, the correlation coefficient increases as the range of values measured increases. This was apparent in the present study, in that correlation coefficients were high when all samples were included in the analysis but much lower when samples only within a particular range (eg, samples with glucose concentrations in the low glycemic range) were analyzed. Bland-Altman plots allow for a more straightforward interpretation of the difference between results of 2 methods and may reveal differences that correlation coefficients and calculations of mean differences will not show. For example, mean difference between results obtained with the DEX meter and results of the reference method was only 0.05 mmol/L; however, examination of the Bland-Altman plots indicated that this was associated with relatively large over- and underestimations of the glucose concentration for individual samples.

For all PBGM, deviations from values obtained with the reference method were small for samples with low glucose concentrations and samples with glucose concentrations in the reference range but somewhat higher for samples with high glucose concentrations. The DEX meter was as likely to overestimate glucose concentration as it was to underestimate it; the other 4 PBGM generally underestimated glucose concentration. Thus, compared with results obtained with the other 4 PBGM, results of the DEX meter may possibly be more difficult to interpret in a clinical situation. Consistent underestimation of blood glucose concentrations by 4 of the PBGM can be explained, in part, by the fact that whole blood glucose concentration may be 10 to 15% lower than plasma or serum glucose concentration. Thus, values obtained with the reference method, for which plasma or serum was used, can be expected to be 10 to 15% higher than values obtained with the PBGM, for which whole blood was used. In a previous study involving dogs, measurements obtained with PBGM were multiplied by 1.12 prior to comparison with values obtained using serum. Because clinicians tend to compare PBGM readings directly to laboratory values, we chose not to use a conversion in our study. If we had done so, however, results of the PBGM would have been more favorable.

Error grid analysis is widely used in human medicine and appears to be the most useful method for clinically evaluating accuracy of PBGM. Although it does not provide any information about analytical accuracy of an instrument, it categorizes individual measurements on the basis of therapeutic consequences. This analysis was developed for use in human medicine and is based on the assumption that the clinical goal is to maintain blood glucose concentration between 3.9 and 10.0 mmol/L. This range is narrower than the range typically achieved in the clinical management of diabetic dogs and cats. Even so, all readings from the PBGM were within the clinically acceptable zones (ie, zones A and B).

Overall accuracy of PBGM depends not only on the analytical performance of the instrument (potential analytical error) but also on the proficiency of the operator (potential user error). Manufacturers have tried with the newer generation of PBGM to avoid the possibility of user errors and to make handling of these devices easy: Instruments do not have buttons (Elite meter) or have only 1 or 2 buttons for calibration or memory function. Three of these PBGM turn on automatically when a test strip is inserted (Elite, QID, and DEX meters), and 1 of these meters (DEX) allows users to perform 10 tests in a row through a unique self-calibrating 10-test cartridge. Four of the PBGM used in this study have to be calibrated every time a new box of test strips is opened, but with the DEX meter, calibration is performed automatically. Application of a blood drop to the test strip is easy with all devices. The Elite and DEX meters use a test strip that employs capillary action to suck blood from the front of the test strip into the reaction chamber to start the measurement, whereas the blood has to be applied to a test field located on the test strip for the remaining devices. A special feature of the Accu-Chek and SureStep meters is a visual control field on the backside of the test strip that shows whether sufficient blood was applied and shows the approximate range in which the digitally displayed glucose concentration should fall. The test requires between 20 and 30 seconds for all 5 PBGM.
Glucometer Elite portable blood glucose monitor, Bayer Diagnostics Inc, Tarrytown, NY.
Glucometer DEX portable blood glucose monitor, Bayer Diagnostics Inc, Tarrytown, NY.
SureStep (marketed under the name Gluco Touch in Europe) portable blood glucose monitor, LifeScan Inc, Milpitas, Calif.
Precision QID portable blood glucose monitor, MediSense Inc, Bedford, Mass.
Accu-Chek Simplicity (marketed under the name Glucotrend in Europe) portable blood glucose monitor, Roche Diagnostics Inc, Indianapolis, Ind.
Cobas Integra analyzer, Roche, Basel, Switzerland.
Glucocard Memory 2 and Accutrend sensor blood glucose meters.


References