Measurement of blood glucose concentration is a basic test commonly used for clinical evaluation of patients in veterinary medicine. Veterinarians ultimately make clinical decisions on the basis of blood glucose concentrations, so it is imperative that methods used for this measurement be validated to ensure their accuracy and comparability across veterinary species.1 Practical considerations when measuring blood glucose concentrations include assessment of serial samples coupled with rapid reporting of results, which are frequently desired for the treatment and monitoring of patients with conditions associated with hypoglycemia or hyperglycemia. For these cases, devices that require a minimal amount of blood would be ideal.1 The use of devices with small blood volume requirements is also important when the size of a patient limits the amount of blood that can be collected.

In recent years, the introduction of reliable, inexpensive, and accurate handheld POC blood glucose meters has greatly facilitated the diagnosis, treatment, and monitoring of humans,2 cats,3 and dogs4 with blood glucose concentration abnormalities as a component of their illness. Routine use of such devices in veterinary medicine is possible because of studies1,3–11 in which the accuracy of specific devices was determined in the species of interest. Unfortunately, these devices have not been validated for use in numerous species, including prairie dogs.

Black-tailed prairie dogs (Cynomys ludovicianus) belong to the order Rodentia and the family Sciuridae.12,13 Prairie dogs are a keystone species in prairie

**OBJECTIVE**

To compare blood glucose concentrations of black-tailed prairie dogs (Cynomys ludovicianus) measured by use of a variety of portable analyzers with results from a laboratory biochemistry analyzer.

**SAMPLE**

Venous blood samples (3 mL) obtained from each of 16 healthy black-tailed prairie dogs.

**PROCEDURES**

A portion of each blood sample was used to measure glucose concentrations by use of an amperometric human point-of-care glucometer and a colorimetric species-specific portable blood glucose meter designed for veterinary use with both canine (code 5) and feline (code 7) settings. The remainder of each blood sample was placed into 2 tubes (one contained lithium heparin and the other contained no anticoagulant). A portable veterinary chemistry analyzer (PVCA) and a handheld analyzer were used to measure glucose concentration in heparinized blood. Serum glucose concentration was measured in the remaining portion by use of a biochemistry analyzer. A general linear mixed models approach was used to compare glucose concentrations and measurement bias obtained with the various measurement methods.

**RESULTS**

Measurement bias and differences in mean glucose concentrations were apparent with all measurement methods. In particular, the veterinary glucometer, whether used on the canine or feline setting, overestimated mean glucose concentrations, whereas the human glucometer, PVCA, and handheld analyzer underestimated mean glucose concentrations relative to the concentration obtained with the biochemistry analyzer.

**CONCLUSIONS AND CLINICAL RELEVANCE**

Results indicated that none of the measurement methods provided consistently accurate blood glucose concentrations of black-tailed prairie dogs, compared with values determined with a biochemistry analyzer. (Am J Vet Res 2015;76:532–539)
ecology, which makes them an important species to biologists and wildlife veterinarians. Black-tailed prairie dogs are also frequently used in research, maintained in zoological collections, and kept as pets. Prairie dogs can require veterinary attention for a variety of reasons, but the most common reason is non-specific clinical signs of generalized malnutrition or weakness. Measurement of blood glucose concentration is an important part of an overall metabolic evaluation, especially because blood glucose concentrations are frequently altered secondary to other disease processes. Additionally, some rodents (including Chinese hamsters, gerbils, rats, mice, guinea pigs, chinchillas, and degus) can have primary health conditions that cause issues with glucose homeostasis, most commonly in the form of diabetes mellitus. Venous access in these animals can be difficult to obtain, and as such, the amount of blood that can be collected at any given time is limited.

The objective of the study reported here was to compare blood glucose concentrations of black-tailed prairie dogs measured in whole blood analyzed with a variety of portable analyzers with the blood glucose concentration measured in serum samples analyzed with a laboratory biochemistry analyzer, which was used as the reference test. Ultimately, we wanted to assess whether blood glucose concentration of black-tailed prairie dogs can be measured accurately by rapid output methods that use small amounts of blood, relative to concentrations measured by use of a biochemistry analyzer in a laboratory setting. On the basis of results of previous studies, it was hypothesized that there would be some level of disagreement between results for the biochemistry analyzer and the other measurement methods.

Materials and Methods

Animals

Seventeen black-tailed prairie dogs from 2 zoological collections in Kansas were admitted over a 5-month period for health examinations performed by members of the Kansas State University College of Veterinary Medicine Zoological Medicine Service. Each animal underwent a complete clinical evaluation that included physical examination, a CBC, serum biochemical analysis, and whole body radiography. All animals were fed a standard diet of rodent chow.

All animal care procedures conformed to guidelines established by the Institutional Animal Care and Use Committee at Kansas State University.

Prairie dogs were anesthetized for the health examination. Food was withheld for 4 to 5 hours prior to anesthesia. Anesthesia was induced by placing each prairie dog into a chamber and administering 5% isoflurane gas in oxygen (2 L/min). After anesthetic induction, anesthesia was maintained by use of a small face mask and nonrebreathing circuit to deliver 2.5% isoflurane in oxygen (1.5 L/min). Vital signs were monitored with a stethoscope, a Doppler ultrasonography unit placed on the plantar surface of a foot to monitor heart rate, and a pulse oximeter.

Anesthesia was induced by placing each prairie dog into a chamber and administering 5% isoflurane gas in oxygen (2 L/min). After anesthetic induction, anesthesia was maintained by use of a small face mask and nonrebreathing circuit to deliver 2.5% isoflurane in oxygen (1.5 L/min). Vital signs were monitored with a stethoscope, a Doppler ultrasonography unit placed on the plantar surface of a foot to monitor heart rate, and a pulse oximeter. Once anesthetized, each prairie dog underwent the health examination. Mean ± SD anesthetic procedure time was 89 ± 16 minutes (range, 60 to 111 minutes).

Of the 17 animals examined, 16 were selected for inclusion in the study because they were deemed healthy on the basis of results of the health examination. One animal was not included because it had overwhelming systemic disease.

Sample collection

Blood samples were obtained from animals during anesthesia. A 22-gauge needle and 3-mL syringe were used to collect approximately 3 mL of blood from a jugular vein. A portion of each blood sample was used for immediate measurement of glucose concentration with an amperometric human POC glucometer and a species-specific colorimetric portable blood glucose meter designed for veterinary use with both canine (code 5) and feline (code 7) settings. The remainder of each blood sample was then divided into 2 portions and placed into microtubes (one that contained lithium heparin and the other that contained no anticoagulant). Blood glucose concentration for the heparinized sample was then measured with a POC glucometer and handheld analyzer. The final portion of the samples was submitted to the clinical pathology laboratory at the Kansas State University Veterinary Health Center for measurement of glucose concentration with a laboratory biochemistry analyzer.

Amperometric POC glucose meter

The human glucometer used in the present study was an amperometric device. Amperometric devices use a reaction between glucose in the blood sample and glucose oxidase or glucose-6-dehydrogenase to produce an anodic current. The device then measured the resulting current and converted it into a glucose concentration that was shown on the unit’s liquid crystal display. The reaction took place within the hollow portion of a test strip, which automatically drew in the correct volume of the blood sample.

Colorimetric POC glucose meter

The veterinary glucometer used in the present study was a colorimetric portable blood glucose meter designed for veterinary use. Similar to the human glucometer, this colorimetric device was used to evaluate blood glucose concentration and automatically drew the correct volume of the blood sample into the hollow portion of a strip. The glucose concentration was measured when glucose in the blood was oxidized, which resulted in a concentration-dependent color change that was analyzed by use of reflectance photometry. This information was then converted into a blood glucose concentration shown on the unit’s liquid crystal display. The veterinary glucometer used in the present study included differential settings for
canine (code 5) or feline (code 7) sample analysis, and each blood sample was tested by use of both settings.

**PVCA and handheld analyzer**

The PVCA and handheld analyzer used in the present study both involved use of a modified version of the hexokinase method\(^\text{23}\) to measure glucose concentration. These reactions took place in a diagnostic rotor\(^a\) specific for mammalian biochemical analyses (for the PVCA) or in a cartridge\(^b\) specific for measurement of mammalian glucose concentration (for the handheld analyzer).

**Laboratory biochemistry analyzer**

The biochemical analyzer used in the present study measured plasma glucose concentrations via an enzymatic hexokinase oxidase reaction. Results of the reaction were detected photometrically. According to the manufacturer, lipemia, hemolysis, or icterus does not interfere with measurement of glucose concentrations.

**Quality control**

All portable devices used to measure blood and serum glucose concentrations were calibrated before each use in accordance with manufacturer recommendations by use of a new calibration solution and new box of test strips. Only one of each type of device was used to avoid potential differences among devices. The same lots of glucose strips, rotors, or cartridges were used for all tests, and the strips, rotors, and cartridges were stored and maintained in accordance with manufacturer recommendations. The PVCA and handheld analyzer performed an automatic quality assurance test when turned on, and there were no error reports for the glucose concentration measurements by any of the machines. All calibrations and sample analyses for the portable devices were performed by the same clinician (DE). The biochemical analyzer was calibrated daily at the Kansas State University Veterinary Teaching Hospital clinical pathology laboratory by use of commercial quality-control standards.

**Measurement of glucose concentrations**

Immediately after blood samples were collected, glucose concentration was assessed with the human glucometer and veterinary glucometer by use of both the canine and feline settings. Randomization was achieved by having a person arbitrarily select the order in which testing with the human glucometer and veterinary glucometer was performed, and the order of samples was randomized such that the canine and feline settings were not used in any particular order. Then heparinized blood (0.1 mL) was tested by use of the PVCA with a comprehensive diagnostic rotor designed for mammals and the handheld analyzer with a specific glucose test cartridge. Randomization was achieved by having a person arbitrarily select the order for testing with the PVCA and handheld analyzer.

After blood samples in tubes that contained no anticoagulant arrived at the laboratory, they were immediately centrifuged for 5 minutes. Supernatant was harvested and centrifuged for an additional 5 minutes; serum was harvested for measurement of glucose concentrations determined by use of the biochemical analyzer. Serum testing was completed within 2 hours after blood sample collection.

**Statistical analysis**

Response variables of interest included glucose concentration as well as glucose concentration measurement bias. Bias was defined for each sample as the difference in glucose concentration between the value for a given method and the value obtained with the biochemical analyzer for that same blood sample. A general linear mixed model that included the fixed effect of measurement method was fitted to each of these responses. The model fitted to measurement bias also included glucose concentration measured with the biochemical analyzer as an explanatory covariate and the cross product of biochemical-based glucose values with measurement method, which resulted in heterogeneous slopes across methods. Other explanatory variables considered were age and body weight. Neither of these variables helped explain the response; thus, they were removed from the corresponding final models. Additionally, preliminary analysis of data indicated that there were no appreciable differences in results between male and female prairie dogs; thus, data were pooled across sexes. Random effects in the model included subgroup (each zoological collection was considered a subgroup) as a blocking factor and animal nested within subgroup to identify repeated measures within each animal as well as animal crossed with measurement method to recognize subsampling or technical replication at the residual level. The effect of animal nested within subgroup served as a blocking factor that made it possible to remove animal-to-animal variability and to then compare glucose concentration measurements made with various methods. Model assumptions were evaluated on the basis of externally Studentized residuals and were considered to be appropriately met. A glucose concentration measured with the PVCA method was identified as an outlier on the basis of results for a Bonferroni-adjusted t test on Studentized residuals and was excluded from analyses.

To further compare methods for measurement of glucose concentrations, we adhered to current standards in human medicine\(^\text{24,25}\) and defined a binary measure of discrepancy relative to the biochemical analyzer. More specifically, for each glucose concentration measurement, we examined whether the glucose concentration differed by > 15% from that obtained with the biochemical analyzer for the same sample. A generalized linear mixed model was fitted to the binary response defined as discrepancy ≥ 15% between results for each candidate method and those
for the biochemistry analyzer. The logit link was used to connect the probability of discrepancy with the linear predictor, which was similar to the general linear mixed models approach. Random effects for the linear predictor included subgroup and animal nested within subgroup as blocking factors. Overdispersion was evaluated by use of the maximum likelihood–based fit statistic Pearson χ² and degrees of freedom; no evidence of overdispersion was detected.

Variance components were estimates on the basis of residual pseudolikelihood. The Kenward-Roger procedure was used to estimate degrees of freedom and make corresponding adjustments in estimated SE. All models were fitted in a commercial statistical analysis software program developed specifically for generalized linear mixed models, which was implemented by means of the Newton-Raphson method with ridging as the optimization technique. Estimated least squares means and corresponding 95% CIs were reported. Pairwise comparisons of the glucose concentration obtained for each measurement method against the glucose concentration obtained for the biochemistry analyzer were conducted by means of Dunnett adjustment to prevent inflation of the type I error rate attributable to multiple comparisons.

Results

The 16 prairie dogs comprised 10 males and 6 females. Mean age was 22.5 months (range, 6 to 54 months), and mean body weight was 0.85 kg (range, 0.62 to 1.10 kg). Median PCV of the samples was 44% (range, 31% to 51%), which was considered to be within the reference range for this species. Mean glucose concentration determined by use of the laboratory biochemistry analyzer was 192.6 mg/dL (range, 133 to 297 mg/dL). Previous studies regarding measurement of blood glucose concentrations in healthy black-tailed prairie dogs have yielded ranges of 138 to 510 mg/dL (mean, 317.7 mg/dL) and 133 to 273 mg/dL (mean, 214 mg/dL). On the basis of the ranges reported in those studies, we considered the blood glucose concentrations of the prairie dogs in the present study to be clinically normal. Mean glucose concentration differed significantly (P < 0.001) for each of the measurement methods, relative to that for the biochemistry analyzer (Figure 1). Specifically, the veterinary glucometer by use of both the canine and feline settings significantly overestimated mean glucose concentrations, whereas the human glucometer, handheld analyzer, and PVCA significantly underestimated mean glucose concentrations, relative to results for the biochemistry analyzer.

Differences in glucose concentration among methods were further explored by evaluation of measurement bias relative to the biochemistry analyzer. Magnitude of the measurement bias also differed significantly (P < 0.001) among methods in that the mean bias in glucose concentration measured with the veterinary glucometer by use of both the canine and feline settings, handheld analyzer, human glucometer, and PVCA depended on the glucose concentration as determined by use of the biochemistry analyzer. Estimated bias in glucose concentration was plotted separately for each measurement method as a function of blood glucose concentration determined with the biochemistry analyzer (Figure 2).

When measured glucose concentration determined with the biochemical analyzer was between 150 and 200 mg/dL, the veterinary glucometer for both the canine and feline settings significantly overestimated glucose concentration, whereas the human glucometer significantly underestimated glucose concentrations, as indicated by positive and negative biases, respectively. The corresponding 95% CIs for bias of each of these methods (relative to results for the biochemical analyzer) at low blood glucose concentrations did not overlap with the null value of 0 (ie, null bias; Table 1). Overall, the human glucometer significantly underestimated glucose concentrations across the entire range of glucose concentrations determined with the biochemistry analyzer in this study, although the magnitude of the bias increased considerably with higher glucose concentrations quantified by use of the biochemistry analyzer (Figure 2).

Glucose concentration obtained with the PVCA and handheld analyzer had no evidence for bias at glucose concentrations of 150 mg/dL measured with the biochemistry analyzer (Table 1). However, as glucose concentration increased to ≥ 200 mg/dL, the PVCA

Figure 1—Estimated blood glucose concentrations (least squares mean estimate and 95% CI) in 16 black-tailed prairie dogs (Cynomys ludovicianus) measured with a laboratory biochemistry analyzer (LBA) and an amperometric human POC glucometer (HG), a species-specific colorimetric portable blood glucose meter designed for veterinary use with both canine (code 5; VG5) and feline (code 7; VG7) settings, a PVCA, and a handheld analyzer marketed for veterinary use (HH). *Value differs significantly (P < 0.001) from the value for the biochemistry analyzer.
and handheld analyzer consistently underestimated glucose concentrations, as indicated by the negative value of the upper boundaries of their 95% CIs (Figure 2).

When the glucose concentration was approximately 250 mg/dL, the veterinary glucometer for both canine and feline settings had no evidence for bias in that the corresponding 95% CIs overlapped with 0 (Figure 2; Table 1). This was also the case for the veterinary glucometer for the canine setting at blood glucose concentrations of approximately 300 mg/dL measured by use of the biochemistry analyzer. However, all other measurement methods significantly underestimated glucose concentrations when the glucose concentration measured by use of the biochemistry analyzer was within the maximum range observed in this study (approx 300 mg/dL), as indicated by negative bias estimates with 95% CIs that did not overlap with 0.

To further characterize comparisons between measurement methods, the probability of a discrepancy of at least 15% in glucose concentrations,24,25 relative to concentrations measured with the biochemical analyzer, was evaluated. All measurement methods had considerable estimates of discrepancy (approx ≥ 40%). Furthermore, significant (P = 0.007) differences in discrepancy between the measurement methods were apparent (Figure 3), with the human glucometer having the highest probability of discrepancy relative to results for the biochemical analyzer and the PVCA and handheld analyzer having the smallest probability of such discrepancies. The veterinary glucometer for both canine and feline settings had intermediate estimates of probability of discrepancies and did not differ significantly from any of the remaining measurement methods.

Estimates of variance components indicated that variation among animals accounted for approximately 30% of the dispersion (total variance) in measured glucose concentrations. In turn, variation among methods within a given animal accounted for approximately half of that (approx 16% of the variability in measured glucose concentrations). The largest source of variability in the data was attributed to subgroups (approx 52% of total variance). Technical variability within each measuring device was relatively minor and accounted for approximately 2% of total variance, which indicated that each device yielded fairly consistent values for glucose concentration, although they differed relative to results for the biochemical analyzer.

**Discussion**

In the present study of black-tailed prairie dogs, mean blood glucose concentrations obtained with 3 POC meters and a PVCA were compared with values obtained by use of a laboratory biochemistry analyzer. On the aggregate, the veterinary glucometer with both the canine and feline settings overestimated mean glucose concentrations, whereas the human

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**Figure 2**—Estimated measurement bias (and corresponding 95% CI) in blood glucose concentration for 16 black-tailed prairie dogs determined by use of a human glucometer, a veterinary glucometer with both canine and feline settings, a PVCA, and a handheld analyzer across the range of glucose concentrations determined by use of a laboratory biochemistry analyzer. See Figure 1 for remainder of key.

**Table 1**—Estimated bias in blood glucose concentration of 16 black-tailed prairie dogs (Cynomys ludovicianus) measured with an amperometric human POC glucometer, a species-specific colorimetric portable blood glucose meter designed for veterinary use with both canine (code 5) and feline (code 7) settings, a PVCA, a handheld analyzer marketed for veterinary use, and a laboratory biochemistry analyzer (criterion-referenced standard).

<table>
<thead>
<tr>
<th>Blood glucose concentration (mg/dL)</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Veterinary glucometer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canine setting</td>
<td>66.2 (51.2 to 81.2)*</td>
<td>40.9 (30.7 to 51)*</td>
<td>15.5 (−1.9 to 32.9)</td>
<td>−9.8 (−38.5 to 19.0)</td>
</tr>
<tr>
<td>Feline setting</td>
<td>42.9 (27.9 to 57.9)*</td>
<td>14.5 (4.3 to 24.6)*</td>
<td>−14 (−31.4 to 3.4)</td>
<td>−42.5 (−71.2 to −13.7)*</td>
</tr>
<tr>
<td>PVCA</td>
<td>−2.9 (−18.0 to 12.2)</td>
<td>−36.56 (−46.8 to −26.4)*</td>
<td>−70.3 (−87.8 to −52.9)*</td>
<td>−104.1 (−132.8 to −75.3)*</td>
</tr>
<tr>
<td>Handheld analyzer</td>
<td>−13 (−28.1 to 2.1)</td>
<td>−46.2 (−56.4 to −36)*</td>
<td>−79.4 (−96.8 to −62.0)*</td>
<td>−112.6 (−141.4 to −83.8)*</td>
</tr>
<tr>
<td>Human glucometer</td>
<td>−30.5 (−45.5 to −15.5)*</td>
<td>−67.0 (0 to −56.9)*</td>
<td>−103.4 (−120.8 to −86.0)*</td>
<td>−139.9 (−168.7 to −111.1)*</td>
</tr>
</tbody>
</table>

*Values reported are estimated least squares mean (95% CI).
*Values are significantly (P < 0.05) biased, relative to the glucose concentration measured by use of the biochemistry analyzer.
glucometer, handheld analyzer, and PVCA underestimated mean glucose concentrations relative to the biochemistry analyzer; however, each of the measurement methods functioned differently across the range of blood glucose concentrations found in this study. In particular, there was no evidence of bias for the PVCA or handheld analyzer at low glucose concentrations (150 mg/dL) measured by use of the biochemistry analyzer. At high glucose concentrations (≥250 mg/dL), there was no evidence of bias for the veterinary glucometer, particularly with the canine setting; however, in the intermediate glucose range (200 to 250 mg/dL), all methods had evidence of biased measurement. Order in which the devices were used to measure blood glucose concentrations was randomized to minimize the potential for partiality.

The PVCA and handheld analyzer had the smallest probability of a discrepancy ≥15%, compared with the probability of discrepancy for the other POC methods; however, it is important to mention that the probability of discrepancy for all methods was estimated at approximately 40%. The only situation in which these methods could be recommended for use would be when glucose concentrations are low (ie, approx 150 mg/dL). The difficulty with this recommendation comes in the inability of knowing the glucose concentration that could be expected for a patient.

Other studies of nonhuman species have also revealed that POC glucose meters do not provide accurate measurements of blood glucose concentrations, compared with results for a biochemical analyzer; however, the PVCA and handheld analyzer have shown promise for use in a few mammalian species. In seabirds, POC glucose meters were found to underestimate blood glucose concentrations by approximately 33%, compared with the blood glucose concentration measured by use of a biochemical analyzer. Similar to the PVCA and handheld analyzer, the human glucometer used in the present study underestimated blood glucose concentration, compared with the blood glucose concentration measured by use of a laboratory analyzer. Another study of the same group of Hispaniolan Amazon parrots revealed poor agreement between results of veterinary and human POC glucose meters and those of a laboratory analyzer, thus leading the authors to discourage the use of both human and veterinary POC glucose meters for psittacine species.

A study of juvenile white-tailed deer revealed that results of 2 human POC glucose meters had poor agreement with those of a laboratory analyzer and with each other; however, agreement between results of the PVCA and laboratory analyzer was good. The POC glucose meters yielded glucose concentrations that were both higher and lower than those determined by use of the biochemical analyzer.

In ferrets, results for a veterinary POC glucose meter coded to test a canine blood sample had the greatest agreement with those of a laboratory analyzer, with a small bias of 1.9 mg/dL. The 2 human POC glucose meters used in that study and the veterinary POC glucose meter with a feline setting significantly underestimated blood glucose concentrations, and results of the human POC glucose meters had the least agreement with those of the laboratory analyzer. In contrast, a study of rabbits found that a veterinary POC glucose meter unacceptably overestimated glucose concentrations, compared with results for a laboratory analyzer. However, it was determined that the human POC glucose meter evaluated in that study was acceptable for testing blood glucose concentrations of rabbits.

In 1 study of dogs, all 5 human POC glucose meters provided results that were significantly different from results of a biochemistry analyzer; however, a handheld analyzer (the same one that was used in the present study) yielded more accurate results than did the other POC glucose meters. Another study of dogs revealed that accuracy of 5 human POC glucose meters differed on the basis of glucose concentration of a sample. The largest differences between results of the POC glucose meters and results of a biochemistry analyzer were for samples with high glucose concentrations, where 4 human POC glucose meters tended to underestimate and 1 tended to overestimate the glucose concentration obtained by use of the biochemistry analyzer. Results from the human POC glucose meters were also significantly higher for blood samples with a low Hct or small volume (<3 µL).

Overall, the human glucometer used in the present study underestimated blood glucose concentration, compared with the blood glucose concentration measured by use of the biochemistry analyzer.

**Figure 3**—Estimated probability (and corresponding 95% CI) of discrepancy ≥15% in glucose concentrations measured with various portable devices, relative to concentrations measured with a laboratory biochemistry analyzer, for 16 black-tailed prairie dogs. Values with different letters differ significantly (P < 0.05). See Figure 1 for remainder of key.
by use of a laboratory biochemical analyzer, of prairie dogs. That human glucometer also underestimates blood glucose concentration of ferrets\(^{10}\) and avian species,\(^{5,6}\) with mixed results for juvenile deer.\(^{3}\) In contrast, the human glucometer is the most accurate portable blood glucose meter when used for samples obtained from rabbits.\(^{21}\) On the canine setting, the veterinary glucometer overestimates blood glucose concentration measurements of prairie dogs, ferrets,\(^{10}\) and rabbits,\(^{21}\) whereas on the feline setting, it underestimates blood glucose concentrations of ferrets\(^{10}\) but overestimates blood glucose concentrations of prairie dogs and rabbits.\(^{21}\) The PVCA and handheld analyzer used in the present study have consistently yielded blood glucose concentrations that are the closest to those of biochemical analyzers.\(^{4,7,21}\)

This finding is not surprising, given that the PVCA and handheld analyzer determine blood glucose concentrations in a manner similar (ie, hexokinase method) to that of common biochemical analyzers. Many studies have confirmed previous findings of different degrees of accuracy and bias with differences in blood glucose concentration,\(^{4,21}\) Hct,\(^{4,6,9,21}\) and sample size.\(^{4}\) Attempts to compare results of those studies or to group them together are difficult, especially considering that statistical analyses performed in each of those studies differed. Standardization of a study design and statistical protocol would greatly facilitate comparison of results among species.\(^{21}\) The vast differences in results seen among species highlight the importance of assessing the performance of glucose meters in the target species.\(^{21}\)

Several factors could have adversely affected blood glucose concentrations measured by the devices used in the present study. To measure glucose concentration, the human glucometer and veterinary glucometer used whole blood, the handheld analyzer and PVCA used plasma, and the biochemistry analyzer used serum. Compared with whole blood, plasma and serum have higher water content and therefore a glucose concentration that is approximately 1% to 12% higher at an Hct of 45%.\(^{22}\) This incongruity is likely to be encountered in any comparison of portable blood glucose meters, regardless of species, when metabolite concentrations of whole blood are compared with those of plasma or serum.\(^{10}\) Many commercially available POC glucose meters have calibrations in place to correct this incongruity, assuming the patient has an Hct within a specified reference interval. The Hct was known for every prairie dog used in the present study and was considered to be within the reference range for both the species and the devices used.\(^{27,28}\) The presence of these calibrations could explain the reason that we did not see higher glucose concentrations associated with the devices that used plasma and serum to measure blood glucose concentration.

In humans, rabbits, and birds, it has been proposed that a high Hct may be related to negative bias in glucose concentrations measured with POC blood glucose meters,\(^{4,6,9,21,22}\) This was unlikely to be the case in the present study, considering that Hct values of the prairie dogs in the study were within the published specifications for each device. Another study\(^{4,21}\) of dogs revealed that POC glucose meters can yield inaccurate results at low blood glucose concentrations (<40 mg/dL). None of the samples in the present study had a measured glucose concentration <133 mg/dL, as determined by use of the biochemical analyzer.

Additionally, mammalian species have different ratios for glucose stored in plasma and RBCs. In rabbits,\(^{21}\) approximately 85% of the blood glucose is in plasma, whereas approximately 87.5% and 93% of the blood glucose is in the plasma of dogs and cats, respectively.\(^{30}\) In contrast, only an estimated 58% of blood glucose is stored in the plasma of humans.\(^{21}\) To the best of the authors’ knowledge, the glucose storage ratio for black-tailed prairie dogs is unknown; we suspect that it would likely bear more resemblance to that of other veterinary species because results typically are consistent across a range of species, whether the animals are herbivorous, omnivorous, or carnivorous. Thus, it is not surprising that glucose concentrations obtained with POC glucose meters designed for humans are more likely to result in inaccurate readings in samples obtained from nonhuman animals, as supported by results for the present study and those of other studies.\(^{1,5,7,9,10,31}\)

In the present study, measurements were determined by use of venous blood instead of capillary blood, which was recommended for use by the manufacturer of the human glucometer. As a result of tissue use of glucose, postprandial glucose concentrations in blood from capillaries are typically 1.1 to 3.9 mmol/L (20 to 70 mg/dL) higher than glucose concentrations in venous blood.\(^{30,32}\) When food is withheld from animals, this difference is reduced to 0.11 to 0.28 mmol/L (2 to 5 mg/dL).\(^{32}\) In the study reported here, food was withheld from all prairie dogs for 4 to 5 hours before blood samples were collected. Therefore, we considered it unlikely that use of venous blood instead of capillary blood would induce a major bias in the results.

One limitation of the study reported here was small sample size. Future studies to evaluate efficacy of portable blood glucose meters would ideally include a greater number of animals to validate these results. In particular, it would be beneficial to evaluate a more varied sample of prairie dogs that were under various management conditions for potential comparison.

Blood glucose concentration abnormalities can be expected in diseased rodents, including prairie dogs. As such, the availability and simplicity of POC glucometers seemed to be promising factors to facilitate diagnosis and monitoring of such abnormalities. Results of the present study, which are in agreement with previous evidence,\(^{1,5,7,9}\) suggested that both the human and veterinary POC glucometers as well as the PVCA evaluated did not yield reliable blood glucose concentrations when used in clinical settings. Use of these devices for rapid preliminary screening of abnormalities in blood glucose concentrations of prairie dogs should be considered with caution.
References

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Footnotes
b. Doppler system 811-B, Parks Medical Electronics Inc, Aloha, Ore.
c. Nellcor handheld pulse oximeter N20PA, Coviden, Dublin, Ireland.
d. ACCU-CHEK, Roche Diagnostics, Indianapolis, Ind.
f. Microtainer tubes, Becton Dickinson Co, Rutherford, NJ.
g. VetScan VS2 analyzer, Abaxis Inc, Union City, Calif.
h. VetScan i-STAT 1 handheld analyzer, Abaxis Inc, Union City, Calif.
i. Cobas 6000 series automated chemistry analyzer, Roche Diagnostics, Indianapolis, Ind.
j. VetScan VS2 comprehensive diagnostic profile rotor, Abaxis Inc, Union City, Calif.
k. VetScan i-STAT glucose (G) cartridge test, Abaxis Inc, Union City, Calif.