Evaluation of Precision Xceed® meter for on-site monitoring of blood β-hydroxybutyric acid and glucose concentrations in dairy sheep

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A R T I C L E   I N F O

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A B S T R A C T

The accuracy of the Precision Xceed® hand-held meter as an on-site method for measuring blood β-hydroxybutyric acid (BHBA) and glucose concentrations, for the diagnosis of pregnancy toxemia and ketosis in dry and lactating dairy sheep, was assessed. Five to eight hours after the start of the morning feed, blood was collected once from 193 clinically healthy sheep (143 dry and 50 lactating). BHBA and glucose analyses were performed with serum in the laboratory, and with whole blood with the Precision Xceed®. Overall, BHBA and glucose determinations by the two methods were not statistically different (P > 0.05). Strongly significant positive correlations were found for glucose and BHBA concentrations between the Precision Xceed® and laboratory results (r = 0.76, n = 150, P < 0.01 and r = 0.99, n = 193, P < 0.01, respectively). The Precision Xceed® was highly sensitive (98.6%) and specific (98.2%), and had excellent test agreement for the detection of pregnancy toxemia and ketosis.

1. Introduction

Early and accurate diagnosis of subclinical metabolic disorders, like pregnancy toxemia and ketosis, is important for the dairy sheep industry. An immediate and accurate diagnosis usually increases the possibility for their successive treatment and prevention (Brozos et al., 2011).

It is accepted that measurement of blood β-hydroxybutyric acid (BHBA) concentration in the laboratory is the gold standard for the diagnosis of ketosis (Oetzel, 2007). Alternatively, the diagnosis can be made by monitoring blood BHBA or urine acetoacetate on-site; however, as it has been proved in cows, their sensitivity and specificity can differ to actual blood concentrations (Oetzel, 2004). Since laboratory measurement of BHBA is costly and time consuming, a reliable on-site test for measurement of blood BHBA and glucose concentrations for diagnosis of pregnancy toxemia or ketosis will be useful in clinical practice or data collection during research.

Abbott Laboratories have developed a small hand-held meter (trade name in Greece: Precision Xceed® and elsewhere: Precision Xtra®) for use in people, which measures whole blood BHBA or glucose concentrations, using appropriate strips. In cows, the meter has been found to be accurate for measurement of blood BHBA concentration (Voyvoda and Erdogan, 2010). There are no reports on the accuracy of this meter in measuring blood BHBA or glucose concentrations in sheep.

Objective of this study was to determine the accuracy of Precision Xceed® hand-held meter for rapid measurement of blood BHBA and glucose concentrations in sheep.

2. Materials and methods

2.1. Animals, samples and techniques used

One hundred and ninety-three (193) clinically healthy, intensively-managed Chios and Chios crossbred dairy sheep (1–5 years old) were selected and blood-sampled. The animals were divided into two groups: dry sheep (10–30 days pre-lambing; n = 143) and lactating sheep (5–40 days post-lambing; n = 50).

BHBA analyses were performed for all the 193 ewes, whereas glucose was measured for 150 sheep (100 lactating and 50 dry). Two blood samples were collected from the jugular vein of each animal, 5–8 h after start of the morning feeding; one sample was collected into a 3 ml glass tube with K₃-EDTA as anticoagulant (Vacutette®) for hematocrit (HCT) measurement and another into a 10 ml plain glass tube (BD Vacutainer®) without anticoagulant for serum BHBA and glucose measurement. Whole blood BHBA and glucose were measured on-site by means of the Precision Xceed® (Abbott, Abbott Diabetes Care Ltd., Oxon, UK) hand-held meter. Measurement was carried out within 15 min of sampling.
following the manufacturers' instructions and at room temperature between 21 and 23 °C.

Hematocrit was measured by means of the Wintrobe method. BHBA and glucose serum concentrations were also measured in the laboratory, by a spectrophotometric kinetic method (Gau, 1987) or a colorimetric spectrophotometric method (Barham and Trinder, 1972), respectively.

2.2. Data management and analysis

Serum BHBA concentrations measured in the laboratory were regarded as the gold standard. Sheep with serum BHBA concentrations ≥ 0.8 mMol/L were considered at risk for developing pregnancy toxemia (Russel, 1984; Rook, 2000; Sargison, 2007). A similar threshold for ketosis in lactating sheep is not available in the literature, the value of > 0.8 mMol/L was used also for that; in that case, sheep with BHBA concentrations <0.8 mMol/L were considered to be healthy.

For statistical analysis, data were entered onto a computerized database and analyzed with the Statistical Program of Social Sciences (SPSS) software for Windows, Version 17.0. Correlation coefficients (Pearson’s Product Moment Correlation Coefficient) were calculated between BHBA serum concentrations measured in the laboratory and those obtained with Precision Xceed® for whole blood. Descriptive statistics were carried out for the variables under study. Sensitivity, specificity, positive and negative predicted values and their binomial 95% confidence interval (Clo) for the hand-held meter at the cut-off point (BHBA concentration ≥ 0.8 mMol/L) and k-statistics (test agreement between the gold standard and the Precision Xceed® hand-held meter) were also calculated. Sensitivity was calculated as the proportion of sheep with serum BHBA concentrations ≥ 0.8 mMol/L correctly diagnosed by the Precision Xceed® meter. Specificity was calculated as the proportion of sheep with serum BHBA concentrations <0.8 mMol/L correctly diagnosed by the Precision Xceed® meter. The positive predicted value was calculated as the proportion of animals with positive (i.e., ≥0.8 mMol/L) Precision Xceed® meter value that were at risk for developing pregnancy toxemia or with subclinical ketosis (as defined by the gold standard). The negative predicted value was calculated as the proportion of animals with positive (i.e., >0.8 mMol/L) Precision Xceed® meter value that were not at risk for developing pregnancy toxemia or with subclinical ketosis.

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3. Results

Means, standard deviations, minimum and maximum values of measured BHBA and glucose concentrations using the two different methods are shown in Tables 1 and 2, respectively.

BHBA overall concentrations varied from 0.1 to 5.4 mMol/L. Ranges of serum BHBA concentrations obtained by the laboratory method was 0.3–5.1 mMol/L for dry sheep and 0.3–2.2 mMol/L for lactating sheep. Ranges of BHBA blood concentrations obtained with the Precision Xceed® were 0.1–5.4 mMol/L for dry sheep and 0.2–2.5 mMol/L for lactating sheep. Overall, mean blood BHBA concentrations obtained with any of the two tests (laboratory or rapid test) were not statistically different between, even when data were stratified according to production status (dry or lactating animal) (P > 0.05). BHBA concentrations were significantly higher (P < 0.05) in dry than in lactating sheep, and this was consistent to using either test (Table 1). However, when data were stratified according to the BHBA threshold value (≥0.8 mMol/L/0.8 mMol/L), results obtained between the two tests were significantly different (P < 0.05) for BHBA concentrations <0.8 mMol/L.

Glucose concentrations varied from 34 to 84 mg/dL with the laboratory method and from 29 to 95 mg/dL with the Precision Xceed®. Overall, mean glucose concentrations were not statistically different (P > 0.05) between the two methods, even when data were stratified according to their production status and BHBA concentrations. The negative predicted value was calculated as the proportion of animals with negative (i.e., <0.8 mMol/L) Precision Xceed® meter value that were at risk for developing pregnancy toxemia or with subclinical ketosis.

Analysis of pooled data revealed strongly significant positive correlations (Figs. 1 and 2) for BHBA and glucose concentrations between the test methods and Precision Xceed®; correlation for BHBA was higher than that for glucose (r = 0.99, n = 193, P < 0.01 and r = 0.76, n = 150, P < 0.01, respectively). Also, a statistically significant (n = 150, P < 0.01) negative correlation (r = −0.53) between BHBA and glucose measured with laboratory reference methods was evident, whereas correlation coefficient between BHBA and glucose measured with the hand-held meter was −0.54 (n = 150, P < 0.001). Overall, test performance of Precision Xceed® hand-held meter at ≥0.8 mMol/L was highly sensitive and highly specific relative to serum BHBA (Table 3). From sensitivity of 98.6% and specificity of 98.2%, Precision Xceed® provided <1% and <0.5% false negatives and false positives, respectively, for BHBA testing.

The HCT values of sheep in the study ranged from 26.2 to 42.4% (26.2 to 36.5% in dry sheep, 28.4 to 42.4% in lactating sheep).

### Table 1
**Descriptive statistics of β-hydroxybutyric acid (BHBA) concentrations in dry or lactating dairy ewes.**

<table>
<thead>
<tr>
<th>BHBA (mMol/L)</th>
<th>Method used</th>
<th>Laboratory</th>
<th>Precision Xceed®</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>All sheep</td>
<td>193</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Dry sheep</td>
<td>143</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Lactating sheep</td>
<td>50</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Animals with BHBA concentration &lt;0.8 mMol/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry sheep</td>
<td>97</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Lactating sheep</td>
<td>41</td>
<td>0.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

### Table 2
**Descriptive statistics of glucose concentrations in dry or lactating dairy ewes.**

<table>
<thead>
<tr>
<th>Glucose (mg/dL)</th>
<th>Method used</th>
<th>Laboratory</th>
<th>Precision Xceed®</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>All sheep</td>
<td>150</td>
<td>64.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Dry sheep</td>
<td>100</td>
<td>63.3</td>
<td>8.3</td>
</tr>
<tr>
<td>Lactating sheep</td>
<td>50</td>
<td>66.4</td>
<td>8.1</td>
</tr>
<tr>
<td>At BHBA concentration &lt;0.8 mMol/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry sheep</td>
<td>92</td>
<td>64.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Lactating sheep</td>
<td>41</td>
<td>68.0</td>
<td>7.3</td>
</tr>
<tr>
<td>At BHBA concentration ≥0.8 mMol/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry sheep</td>
<td>8</td>
<td>52.9</td>
<td>13.1</td>
</tr>
<tr>
<td>Lactating sheep</td>
<td>9</td>
<td>59.2</td>
<td>8.2</td>
</tr>
</tbody>
</table>

Mean difference of rows and columns with same letter is statistically significant (P < 0.05).
4. Discussion

Mean BHBA concentrations obtained with the Precision Xceed® were similar to those obtained with the laboratory method. To the authors’ knowledge, this is the first time that such a comparison for BHBA values in sheep is being presented.

A high positive correlation between BHBA measurement with the hand-held meter and laboratory was reported in lactating dairy
cows (Jeppesen et al., 2006; Kupczynski and Cupok, 2007; Oetzel and McGuirk, 2007; Iwersen et al., 2009; Voyvoda and Erdogan, 2010), dogs and cats (Hoenig et al., 2008) and humans (Byrne et al., 2000; Chiu et al., 2002; Noyes et al., 2007; Ronald, 2008). Our results confirm that the strong ($r = 0.99$) significant positive correlation, the excellent sensitivity and specificity and the perfect test agreement of results by the Precision Xceed$^\text{a}$ to those by laboratory measurements in ewes. Consequently, the Precision Xceed$^\text{a}$ can be useful for on-site monitoring of sheep and decision-making to start treatment in cases of pregnancy toxemia or ketosis in ewes.

In dairy cows, a diurnal variation of BHBA concentrations related to time after feeding (Eicher et al., 1998; Duffield, 2000), has been recorded. In order to record peak BHBA concentrations, all blood samples in the present research were collected between five and eight hours after start of the morning feeding. This period would make the detection of animals with BHBA concentrations easier. The time required for each BHBA measurement is only 10 s, after a small drop of whole blood contacts the receptor at the end of the strips. Less than 1.5 μL of whole blood is required and an important practical issue is that additional calibration or adjustment is not necessary to obtain results. Respective blood volume and time for glucose measurement is less than 0.6 μL and 5 s, respectively. Furthermore, the cost of the apparatus (approximately 60 €) and the strips (approximately 1.2 € per strip for BHBA and 0.15 € per strip for glucose) [Note: above prices as in Greece] is affordable and cheaper than carrying out a laboratory test. Moreover, sending a blood sample to a laboratory for BHBA analysis requires some processing and is time-consuming.

In clinical practice, on-site reliable tests conveniently allow the rapid diagnosis and monitoring of diseases are awarding. The low percentage of false positive (<0.5%) and false negative (<1%) for BHBA testing indicates that the Precision Xceed$^\text{a}$ is an accurate test and that its results are highly reliable under field conditions.

The most rewarding use of on-site blood BHBA testing can be for diagnosing pregnancy toxemia at flock level. The on-site BHBA test with the hand-held meter can replace sending samples to a laboratory, at a smaller cost. Moreover, the results are given immediately. Nevertheless, the test can also be used for individual sheep to diagnose pregnancy toxemia or ketosis, for applying immediate treatment, which is important for a successful outcome (Brozos et al., 2011).

Although it is not necessary to confirm hypoglycemia in an animal before starting treatment with an oral glucose precursor or intravenous glucose administration, there are situations involving individual sick animals where the glucose status is uncertain. In these circumstances, knowledge of the animal's glucose status would be useful prior to treatment and the Precision Xceed$^\text{a}$ offers a rapid and reliable result.

5. Conclusions

Precision Xceed$^\text{a}$ has been found a very useful tool for practicing veterinarians. Significant positive correlations were found for BHBA and glucose concentrations recorded by the Precision Xceed$^\text{a}$ and laboratory tests. The Precision Xceed$^\text{a}$ was highly sensitive and specific (and had excellent test agreement for detection of animals with blood BHBA concentrations $\geq 0.8$ mMol/L).

### Table 3

<table>
<thead>
<tr>
<th>Precision Xceed$^\text{a}$ BHBA</th>
<th>BHBA threshold value (nMol/L)</th>
<th>Sensitivity (CI 95)</th>
<th>Specificity (CI 95)</th>
<th>PPV (CI 95)</th>
<th>NPV (CI 95)</th>
<th>k-Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Sheep ($n = 193$)</td>
<td>$\geq 0.8$</td>
<td>$98.6%$</td>
<td>$98.2%$</td>
<td>$99.3%$</td>
<td>$96.4%$</td>
<td>$0.96$</td>
</tr>
<tr>
<td></td>
<td>($94.3–99.7%$)</td>
<td>($89.0–99.9%$)</td>
<td>($95.4–99.9%$)</td>
<td>($86.6–99.4%$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry sheep ($n = 143$)</td>
<td>$\geq 0.8$</td>
<td>$97.9%$</td>
<td>$97.3%$</td>
<td>$99.0%$</td>
<td>$95.8%$</td>
<td>$0.95$</td>
</tr>
<tr>
<td></td>
<td>($92.0–99.6%$)</td>
<td>($87.0–99.9%$)</td>
<td>($93.5–99.9%$)</td>
<td>($84.3–99.3%$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactating sheep ($n = 50$)</td>
<td>$\geq 0.8$</td>
<td>$100%$</td>
<td>$100%$</td>
<td>$100%$</td>
<td>$100%$</td>
<td>$1.00$</td>
</tr>
</tbody>
</table>

PPV: Positive predicted value.  
NPV: Negative predicted value.

References


