The Veterinary Journal 238 (2018) 10–14

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Original Article

Evaluation of a portable ion-selective electrode meter for measuring potassium concentrations in whole blood and plasma of calves

F.M. Trefz[a,*], I. Lorenz[b], P.D. Constable[c]

[a] Clinic for Ruminants with Ambulatory and Herd Health Services at the Centre for Clinical Veterinary Medicine, LMU Munich, Sonnenstraße 16, 85764 Oberschleißheim, Germany
[b] Bavarian Animal Health Service (Tiergesundheitsdienst Bayern e.V.), Senator-Gerauer-Str. 23, 85586 Poing, Germany
[c] Department of Veterinary Clinical Medicine, College of Veterinary Medicine, University of Illinois, Urbana-Champaign, IL, USA

ARTICLE INFO

Article history:
Accepted 5 June 2018

Keywords:
Calf-side test
Calves
Hyperkalaemia
Hypokalaemia
Point-of-care

ABSTRACT

An ion-selective electrode (ISE) handheld meter (LAQUAtwin B-731; Horiba) has recently become available for the measurement of potassium concentrations [K^+] in biological fluids. The ISE meter has the potential to facilitate the diagnosis and treatment of potassium balance disorders of critically ill cattle. The objective of this study was to characterise the analytical performance of the ISE meter in a study sample of hospitalised calves with a broad range of plasma [K^+]. For the purpose of the study, whole blood and plasma samples from 125 calves (age $\leq$ 3 months) were used for analysis. The accuracy of the meter against the reference method (indirect ISE, Cobas c 311, Roche) was assessed using Passing–Bablok regression and Bland–Altman plots.

The [K^+] in whole blood as measured by the ISE meter in direct mode ranged from 2.4 to 9.9 mmol/L. The meter measured whole blood [K^+] as 3.8% higher than plasma [K^+]. Passing–Bablok regression for whole blood [K^+] measured by the meter against plasma [K^+] determined by indirect potentiometry revealed a linear relationship that was almost identical to the line of identity. However, the Bland–Altman plot indicated that the meter measured plasma [K^+] 5.1% lower than the reference method. This result was consistent with analytical differences of direct and indirect ISE methods in respect to variation in the plasma protein concentration. In conclusion, the LAQUAtwin B-731 meter provides an accurate, rapid and low-cost tool for the diagnosis of potassium derangements in critically ill calves, particularly when whole blood samples are analysed.

Introduction

Potassium balance disorders (both hypo- and hyperkalaemia) are common electrolyte imbalances in critically ill cattle (Constable et al., 2013; Trefz et al., 2013a, 2015; Schneider et al., 2016). Ion-selective electrode (ISE) handheld meters (CARDY C-131 and LAQUAtwin B-731; Horiba) have recently become available for the measurement of potassium concentrations [K^+] in biological fluids. These meters have the potential to facilitate the on-farm diagnosis and treatment of potassium balance disorders of critically ill cattle. A recent validation study indicated that the two meters provided practical, rapid and accurate point-of-care instruments that were suitable for measuring potassium concentrations in whole blood, plasma, milk, and abomasal fluid of dairy cattle (Megahed et al., 2016). However, in that study, blood samples from hypo- and normokalaemic adult dairy cows were used for analysis and consequently, the accuracy of the meters was not assessed in hyperkalaemic cattle. This is of relevance because hyperkalaemic diarrhoeic calves can have lower plasma protein concentrations than critically ill adult cattle which may affect the analytical performance of the meter (Megahed et al., 2016). Therefore, the aim of the present study was to assess the analytical performance of the LAQUAtwin B-731 ISE meter in a study sample of hospitalised calves with a broad range of plasma potassium concentrations.

Materials and methods

Study population

The study used a convenience sample of 125 calves up to an age of 3 months admitted to the Clinic for Ruminants with Ambulatory and Herd Health Services, Ludwig-Maximilians-Universität (LMU) Munich, between 12 November 2016 and 31 May 2017. Most of the calves (89.6%; n = 112) belonged to the Simmental breed (German Fleckvieh) and the median (interquartile range) age of

* Corresponding author.
E-mail address: florian.trefz@campus.lmu.de (F.M. Trefz).

https://doi.org/10.1016/j.tvjl.2018.06.004
1090-0233/

calves of the study population was 9 (6–15) days. Calves were admitted to the hospital for a variety of medical conditions, and the majority of calves (80%, $n = 100$) were hospitalised for reasons of diarrhea. The study used blood samples that were routinely taken for diagnostic purposes (blood gas and electrolyte analysis, clinical biochemistry analysis) on admission to the hospital. Therefore, an institutional animal care and use committee approval was not required for this study.

Laboratory analyses

Blood sampling included collection of a lithium-heparinised blood sample that was anaerobically taken from the jugular vein and immediately transported to an adjacent climate-controlled laboratory area and analysed within 15 min after collection using a blood pH, gas, and electrolyte analyser with ion-selective electrodes (Rapidpoint 405, Siemens Healthcare Diagnostics). This measured blood [K^+] by means of direct potentiometry. Immediately thereafter whole blood [K^+] was measured using the LAQUAtwin B-731 meter according to the manufacturers' recommendations and as previously described (Megahed et al., 2016). Briefly, the two visible sensors on the sensor pad were covered with two to three drops of heparinised whole blood. The measured [K^+] was recorded within 45 s when the reading on the display screen became stable. Measured values for [K^+] were displayed by the meter in parts per million and were multiplied by 0.026 (the reciprocal of the molecular weight of potassium which is 39.1 g/mol) to convert the units to mmol/L. As previously described (Megahed et al., 2016), the LAQUAtwin meter was calibrated at least once daily using a 2-point calibration method by means of standard potassium solutions (150 ppm = 3.9 mmol/L; 2000 ppm = 52 mmol/L) provided by the manufacturer.

After determination of whole blood [K^+], the remainder of the heparinised blood sample was centrifuged at 1500 *g* for 5 min and stored at room temperature. Harvested plasma samples were then analysed using the LAQUAtwin B-731 meter in the same manner as for analysis of whole blood. The remainder of the plasma sample was transferred to a polypropylene vial and submitted to an in-house laboratory where plasma [K^+] was measured using an automatic analysing system with ion-selective electrodes (Cobas c 311, Roche Diagnostics). This analysis was based on indirect potentiometry after diluting the sample 1:31. The Cobas c 311 analyser (biuret method) was also used to determine the plasma total protein concentration.

Statistical analyses

Statistical analysis was conducted using MedCalc Statistical Software version 17.9.7 (MedCalc Software bvba) and GraphPad Prism (version7.01, GraphPad software). Normal distribution of data was assessed by the Shapiro–Wilk test and visual inspection of QQ plots. The majority of variables were not normally distributed and consequently data was reported as median and interquartile ranges (Q_1–Q_3).

The within-day repeatability of the LAQUAtwin B-731 meter and respective reference methods was assessed by determining the coefficient of variation (CV) for 20 consecutive measurements for a purposively selected sample with a low, mid, and high [K^+].

Passing–Bablok regression was used to assess the relationship between whole blood and plasma [K^+] measured by the LAQUAtwin B-731 meter and the reference methods. These analyses included the determination of slope and intercept values for respective regression lines and associated 95% confidence intervals (CI). Agreement between the test and reference methods were also examined using Bland–Altman difference plots (Bland and Altman, 1986) by displaying the percentage difference of the measurements against the mean of the two measurements. This approach is required whenever the magnitude of the variability increases directly with the mean value. The upper and lower limits of agreement were calculated from the bias $\pm$ 1.96 $\times$ SD. The association between the observed differences between the test and reference methods for measured [K^+] and the plasma total protein concentrations was evaluated using Spearman's rho (van den Ancker et al., 2015).

Results

General conditions

Descriptive statistics for measured [K^+] using the applied test methods are provided in Table 1. The median (interquartile range) value for plasma protein concentration was 63.2 (56.4–71.0) g/L.

Repeatability

The within-day CV of three whole blood samples with a [K^+] of 2.9, 4.9, and 9.6 mmol/L as determined by the LAQUAtwin B-731 meter were 4.0, 4.7, and 5.3%, respectively. Within-day CV for whole blood samples with [K^+] values of 2.2, 4.8, and 7.3 mmol/L as determined by the Rapidpoint 405 blood gas analyser were 1.0, 0.9, and 1.1%, respectively. The within-day CV for plasma samples with [K^+] values of 2.6, 5.4, and 9.1 mmol/L as determined by the LAQUAtwin B-731 meter were 4.4, 3.7, and 3.0%, respectively. Within-day CV for plasma samples with [K^+] values of 3.1, 5.3, and 9.0 mmol/L as determined by the Cobas c 311 analyser were 0.2, 0.3, and 0.2%, respectively.

Comparison between whole blood and plasma [K^+]

The relationship between whole blood and plasma [K^+] determined by the LAQUAtwin B-731 meter is shown in Fig. 1A. Passing–Bablok regression revealed no proportional bias (1.00; 95% CI, 1.00–1.00) but a constant bias of 0.26 mmol/L (95% CI, 0.26–0.26). The Bland–Altman plot indicated a mean positive bias of 3.8%, which was different from zero ($P < 0.001$) (Fig. 1B). The 95% limits of agreement were −6.7 to 14.3%.

Method comparison for whole blood [K^+]

Passing–Bablok regression analysis for the agreement between whole blood [K^+] measured in direct mode by the LAQUAtwin B-731 and the Rapidpoint 405 blood gas analyser indicated a proportional bias of 1.11 (95% CI, 1.06–1.16) and a constant bias of −0.37 mmol/L (95% CI, −0.60 to −0.13) (Fig. 2A). Bland–Altman analysis (Fig. 2B) revealed a mean positive bias of 3.6% that was different ($P < 0.001$) from zero. The 95% limits of agreement were −8.4% to 15.5%. The observed concentration differences were positively associated ($r_s = 0.40$, $P < 0.001$) with respective mean values of whole blood [K^+] as measured by those two methods.

Passing–Bablok regression for whole blood [K^+] measured by the LAQUAtwin B-731 meter against plasma [K^+] determined by the Cobas c 311 analyser (indirect potentiometry) revealed a linear relationship (Fig. 3A) that was equivalent to the line of identity with a slope of 1.00 (95% CI, 0.96–1.04) and an intercept value of −0.06 (95% CI, −0.30 to 0.13). However, the Bland–Altman plot (Fig. 3B) revealed a bias of −1.4% that was different from 0 ($P = 0.014$) and 95% limits of agreement from −13.3 to 10.6%.

Table 1
Descriptive summary statistics for whole blood and plasma potassium concentrations [K^+] measured by three test methods on whole blood or plasma in 125 calves admitted to a veterinary hospital.

	Whole blood [K^+] mmol/L		Plasma [K^+] mmol/L	
	LAQUAtwin B-731	Rapidpoint 405	LAQUAtwin B-731	Cobas c 311
Median	4.94	4.77	4.68	4.98
Q_1	4.16	4.21	4.16	4.37
Q_3	5.72	5.45	5.46	5.71
Minimum	2.42	2.45	2.39	2.53
Maximum	9.88	9.06	9.62	10.13

Q_1, first quartile; Q_3, third quartile.