On-farm use of point-of-care chemistry analyzers in bovine practice

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Abstract

Appropriate identification of acid-base and electrolyte disorders can improve patient care for many medical conditions of bovines. The increased portability of handheld blood gas and electrolyte chemistry point-of-care analyzers and relative affordability now allows practitioners ready access to the identification of these conditions animal-side. Increased use of this technology will enable practitioners to provide more individualized animal care on-farm with the goal of improving treatment outcomes.

Key words: blood gas; electrolyte; point-of-care testing

Introduction

The technology and portability of blood gas and electrolyte chemistry analyzers has increased dramatically over recent years, making this key tool available in a hand-held format for ambulatory practitioners to improve treatment decisions as a point-of-care (POC) tool for patient-side use on-farm. As with any diagnostic test, the goal of performing the test is to improve either individual case management or management of the herd. In bovine practice, the use of this tool is most effective as an adjunct to the physical examination for detection and rapid treatment of acid-base and electrolyte disorders. Many, but not all, of these disorders share a common feature in that appropriate treatment often involves the IV administration of fluids or solutions targeted to alter the acid-base or electrolyte status of the animal. However, the identification and treatment of several other clinical disease entities can be readily improved with this tool, making it a valuable addition to the toolkit of any ambulatory clinician who frequently evaluates individual animals.

Several handheld blood gas and electrolyte chemistry analyzers are currently available on the veterinary market in the U.S. today [a,b]. These machines have the ability to directly utilize whole blood samples either directly from a blood draw syringe or following collection into a heparin-containing blood tube. Table 1 demonstrates the commonly available parameters applicable to bovine medicine that can be obtained using these testing modalities; not all parameters listed are available on all test units or test cartridges. Small volume (<100µl) blood samples are typically added directly to a testing card which is then inserted into the testing machine with results reported directly on the unit within a few minutes of initiating the testing. Several recent studies have validated the accuracy of POC testing in bovines with at least one of the available test units[a] in regards to electrolyte (sodium, potassium, chloride, ionized calcium)[18,19], blood gas[2], and chemistry values (lactate, cardiac troponin, glucose)[7,11]. Because instrument-specific reference intervals are not currently available for bovines (both available units currently only offer canine, feline and equine) some minor bias has been shown to exist for certain variables when compared to laboratory analyzers, but not of a significant enough magnitude to interfere with the clinical usefulness of the results[2,14].

The on-farm use of a POC blood gas and electrolyte chemistry analyzer provides several key advantages to the ambulatory practitioner over in-house or mail-out testing. Alterations in acid-base status are frequently encountered in bovine practice, yet often go undiagnosed or untreated due to a lack of appropriate tools to accurately identify the condition. For many large animal practices, even if in-house chemistry testing is available, blood gas analysis may not be readily available due to the additional equipment necessary. Using POC testing, following blood draw or catheter placement, results are available within minutes to develop a therapy specifically targeted to the unique clinical condition of the animal being examined. Identification on-farm eliminates the need to return to the clinic to perform testing via in-house analyzers and thus decreases the amount of return trips needed to provide appropriate initial therapy when test results do not match the initial clinical assessment and treatment. By specifically targeting treatment to the animal being examined, a decrease in treatment failure and repeat visits is also anticipated as opposed to blanket therapy. For general large animal practices, many uses exist for examination of conditions in small ruminants and equine patients; for mixed animal practitioners, additional uses in small animal practice in anesthesia monitoring as well as emergency triage of medical cases also make the investment in this technology one that can be spread across all segments of the practice.

Applications for Detection of Neonatal Disorders

Table 2 lists the most common disorders encountered in clinical bovine practice (based on primary practice area) whose identification or treatment can be enhanced through the use of currently available POC analyzers. In bovine neo-

Table 1. List of common parameters available via hand-held point-of-care chemistry analyzers[a,b] for evaluation of venous samples and their normal ranges in the bovine[4,7,9,16]; not all parameters are available on all units or on the same test cartridge.

Category	Available Test Parameters	Measured or Calculated	Normal range
Electrolyte	Sodium	Measured	132-152 mEq/L [4]
	Potassium	Measured	3.9-5.8 mEq/L [4]
	Chloride	Measured	97-111 mEq/L [4]
	Ionized Calcium	Measured	>1.17 mmol/L [9]
Blood gas	pH	Measured	7.31-7.53 [4]
	pCO2	Measured	35-44 mm Hg [4]
	Bicarbonate	Calculated	17-29 mEq/L [4]
	Base Excess	Calculated	0 (+/- 2) mEq/L [4]
	Anion Gap	Calculated	14-20 mEq/L [4]
	Lactate	Measured	<2.2 mmol/L[4]
Chemistry	BUN	Measured	20-30 mg/dL[4]
	Creatinine	Measured	1.0-2.0 mg/dL[4]
	Glucose	Measured	45-75 mg/dL (adult) [4] 80-120 mg/dL (neonate)[16]
Red cell parameters	Hct	Measured	22-33 %[4]
	Hgb	Calculated	8.5-12.2 g/dL [4]
Other	Cardiac troponin	Measured	0.0–0.036 ng/mL[7]

Table 2. List of commonly encountered conditions in bovine medicine for which diagnosis and/or treatment can benefit from point-of-care blood gas and electrolyte testing on-farm.

	Neonatal (dairy or beef)	**Dairy**	**Beef cow-calf**	**Beef feedlot**
Acid-base disorders	Neonatal diarrhea D-lactic acidosis	Vagal indigestion Hardware disease RDA/LDA Grain overload	Vagal indigestion Hardware disease Grain overload	Grain overload
Electrolyte disorders	Neonatal diarrhea Hypernatremia	Hypocalcemia Hypokalemia	Hypocalcemia Hypokalemia	Urinary obstruction
Other conditions	Hypoglycemia Azotemia (pre-renal, renal, post-renal)	Hypoglycemia Azotemia (pre-renal, renal, post-renal)	Azotemia (pre-renal, renal, post-renal)	Azotemia (pre-renal, renal, post-renal)

nates, by far the most common condition associated with altered acid-base and electrolyte status is metabolic acidosis due to either diarrhea and/or d-lactic acidosis. While much work has been devoted to identification of acid-base status of calves with diarrhea via physical examination and age at examination, the accuracy of these methods on an individual basis is less than when individual blood gas and electrolyte testing is utilized due to the varied nature of the disease[1,15]. In addition, veterinarians are frequently called to examine animals that have been treated previously by producers with varying oral electrolyte products which are designed to alter the acid-base or electrolyte status of the animal. Thus, the clinical picture presented to the veterinarian called to examine a down calf with diarrhea can vary dramatically in regards to acid-base and electrolyte status. In particular, academia with a blood pH of <6.85 has been associated with poorer treatment outcomes in calves with diarrhea, and although this factor alone cannot fully be used to predict prognosis, identification and appropriate treatment of the acid-base status of calves with diarrhea can be critical to survival of these animals[17].

Table 3 represents an example of POC testing results from three different calves all presenting with similar history (beef calves of 2-3 weeks of age with several days duration of diarrhea and previous oral electrolyte therapy) and clinical signs (depressed and unable to stand with moderate clinical dehydration). The wide variation in the blood gas and electrolyte parameters of these calves makes successful treatment via a blanket approach challenging; however, by utilizing POC testing, an individualized treatment plan with increased chance of success can be developed. One of the additional benefits of the results obtained from POC testing of neonates with diarrhea is calculation and provision of base excess, which can then be used directly for calculation of IV bicarbonate replacement via the following formula[13]:

Base excess (deficit) X body weight (kg) X 0.6 (total body water factor) = mEq of bicarbonate

Isotonic bicarbonate (1.3% - prepared with 13gm of baking soda per L sterile or deionized water) will provide approximately 154 mEq/L of bicarbonate, while commercially available hypertonic bicarbonate (8.4%) will provide 1 mEq/mL of bicarbonate. In the examples given in Table 3, assuming a body weight of 110 lb (50kg) for all calves, calf #1 would best be treated using isotonic bicarbonate; further analysis also reveals an increased anion gap in this calf, suggestive of a d-lactic acidosis (note: d-lactate cannot be measured with any currently available clinical chemistry analysis, POC or otherwise). For calf #2, the addition of hypertonic bicarbonate to fluids containing increased sodium and chloride concentrations such as 0.9% NaCl would aim to treat the metabolic acidosis, dehydration, hyponatremia, hypochloremia, and hyperkalemia simultaneously in this animal (an alternative approach would be the additional of hypertonic saline to isotonic bicarbonate to achieve the same goal). It is also important to note that POC testing identified significant hyperkalemia in this calf, which can lead to life-threatening cardiac arrhythmias. Treatment of calf #3 is the most challenging depending on the duration of hypernatremia as chronic hypernatremia requires slow restoration to normal sodium levels over an extended period of time using solutions calculated to match the current sodium level and replace the total body water deficit over time. Further inves-

Table 3. Example of three cases of neonatal diarrhea presenting with similar clinical signs yet substantially different acid/base and electrolyte status for which treatment benefited from point-of-care blood gas/electrolyte testing[a,c].

Test	Units	Calf #1	Calf #2	Calf #3
Sodium	mEq/L	138	115	>180
Potassium	mEq/L	3.1	8.4	6.8
Chloride	mEq/L	107	88	>175
Bicarbonate	mEq/L	10.2	21.4	29.4
Glucose	mg/dL	112	131	157
pH		7.193	7.221	7.551
pCO2	mm Hg	26.4	48.3	29.4
BUN	mg/dL	15	84	50
Base Excess	mEq/L	-18	-8	3.0
Anion Gap	mEq/L	24	14	-- (unable to read)
DIAGNOSIS		Metabolic acidosis (540 mEq deficit) with dehydration	Metabolic acidosis (240 mEq deficit) with dehydration, hyponatremia, hypochloremia, hyperkalemia and azotemia	Mixed metabolic status with hypernatremia, hyperchloremia, dehydration and azotemia
INITIAL TREATMENT		4L Isotonic bicarbonate (1.3%) IV	4L 0.9% NaCl supplemented with 240mL 8.4% bicarbonate	CHALLENGING! Hypertonic saline of decreasing concentration over time
FOLLOW-UP TREATMENT		Oral electrolytes	Additional IV fluid therapy, recheck bloodwork	Intensive management for several days

tigation revealed that this particular calf had likely been fed incorrectly mixed milk replacer along with oral electrolytes for some time prior to presentation, leading to the hypernatremia. POC testing also identified that all of these calves were normoglycemic on examination and thus did not require initial dextrose supplementation. A wide variety in glucose levels is typically identified in calves presenting with these clinical signs, thus a more tailored approach to dextrose supplementation can be performed if this information is available as over supplementation of dextrose can exacerbate fluid and electrolyte loss through osmotic diuresis when the renal glucose threshold is exceeded. Recent research has also identified that severe hypoglycemia of <36 mg/dL is associated with significantly increased mortality in calves, and could not be easily diagnosed via clinical signs alone[16]. Hypoglycemia can also be observed in cases of septicemia, and thus identification of this condition in combination with other clinical signs may also assist the clinician in determining if antibiotic therapy is warranted.

Applications for Detection of Disorders of Adult or Juvenile Cattle

While targeted therapy of neonatal diarrhea is the most commonly encountered condition in bovine practice for which POC blood gas/electrolyte testing is immediately beneficial, bovine practitioners are often presented with adult cattle demonstrating signs of gastrointestinal disorders that can also benefit from POC testing. While a thorough physical exam can often pinpoint the likely cause of the disorder, in many cases the addition of POC blood gas/electrolyte testing can add valuable information in regards to specific treatment options and prognosis. Table 4 demonstrates the results of POC testing obtained from four adult animals presenting with anorexia, abdominal distension, and signs referable to the gastrointestinal tract. In juvenile or adult cattle, grain overload is the most commonly observed cause for metabolic acidosis. In cases where a known incidence of access to grain occurred, POC testing can be beneficial to determine the systemic metabolic status of the animal. While systemic metabolic acidosis is frequently observed in the immediate (1-2 day) period following ingestion of excessive carbohydrate sources, examination further into the disease process (>2 days) may actually reveal metabolic alkalosis due to gastrointestinal stasis. In cases where no known carbohydrate ingestion was reported but is suspected by the clinician, demonstration of clinical metabolic acidosis can be diagnostic for the condition in combination with other clinical signs and may allow for recommendation and provision of appropriate care including intravenous fluid therapy

Table 4. Example of four cases of adult gastrointestinal disease presenting with similar clinical signs yet substantially different acid/base and electrolyte status for which treatment benefited from point-of-care blood gas/electrolyte testing[a,c].

Test	Units	Cow #1	Cow #2	Cow #3	Cow #4
Sodium	mEq/L	128	138	134	136
Potassium	mEq/L	2.0	3.7	3.0	3.1
Chloride	mEq/L	69	95	101	53
Bicarbonate	mEq/L	46.3	33.0	9.5	45.0
Glucose	mg/dL	177	82	103	407
pH		7.687	7.579	7.182	7.630
pCO2	mm Hg	38.6	35.3	25.4	38.0
BUN	mg/dL	27	9	14	77
Base Excess	mEq/L	26	11	-17	23
Anion Gap	mEq/L	15	14	26	41
DIAGNOSIS		Severe metabolic alkalosis due to RDA with torsion	Mild metabolic alkalosis due to mild vagal indigestion	Metabolic acidosis due to lactic acidosis (grain overload)	Mixed metabolic status due to severe vagal indigestion with traumatic reticuloperitonitis
INITIAL TREATMENT		Surgical correction, 2-3L hypertonic saline IV with 10-20 gal oral fluids and electrolytes	Magnet, rumen decompression, antibiotics, NSAIDS	Rumenotomy with 20L isotonic bicarbonate IV fluids	Owner elected humane euthanasia
FOLLOW-UP TREATMENT		Oral fluids and electrolytes	None – resolved after initial treatment	Rumen transfaunation, antibiotics, NSAIDS	--

with isotonic bicarbonate solutions and/or rumenotomy to remove the carbohydrate source as demonstrated for cow #3 in Table 4. Similar to neonates, base excess can be used in the following equation to calculate intravenous fluid therapy using isotonic bicarbonate for treatment of cases of severe systemic metabolic acidosis (note that the total body water factor used in this calculation is different between neonates and adult animals)[4]:

Base excess (deficit) X body weight (kg) X 0.3 (total body water factor)= mEq of bicarbonate

In functional ruminant animals, however, by far the most commonly encountered acid-base disorder related to gastrointestinal conditions is actually metabolic alkalosis. Metabolic alkalosis can be caused by any condition that contributes to gastrointestinal stasis or failure of abomasal outflow, both of which lead to decreased systemic chloride availability. Conditions such as vagal indigestion and/or hardware disease and abomasal displacements with or without volvulus or torsion can all lead to significant metabolic alkalosis with electrolyte derangements that can be clearly identified via POC testing as demonstrated in Table 4. The addition of POC testing can assist in identification of these conditions and aid in both treatment and prognosis determination. For example, the severity of the acid-base abnormalities combined with azotemia was used in conjunction with physical exam and ultrasound findings to provide a poor prognosis for cow #4 and assisted the owner in choosing humane euthanasia; on necropsy, severe peritonitis due to the presence of several wires found free in the abdomen confirmed the poor likelihood of treatment success in this case. Use of either another test cartridge measuring lactate, or a separate handheld lactate meter also can be beneficial for these cases as lactate concentration has also been shown to be an indicator of prognosis gastrointestinal diseases such as right-displaced abomasal disorders[5,6].

The downer cow is a frequent and frustrating presentation to the bovine practitioner and often may present a diagnostic challenge if not a classic presentation of disease such as a recently fresh multiparous dairy cow with uncomplicated hypocalcemia. Completion of a thorough examination can also be challenging on down animals depending on the location and disposition of the animal, therefore POC blood gas/electrolyte testing can be a useful adjunct to extend any physical examination to evaluate the metabolic status of the animal. As described above, severe manifestations of gastrointestinal disorders such as grain overload and vagal indigestion can be readily identified via POC testing as the proximate cause of recumbency. Hypocalcemia and hypokalemia can also be rapidly identified cow-side using the currently available POC testing modalities[3,9]. While the majority of fresh-cow hypocalcemia cases are straightforward and do not require additional testing for accurate diagnosis, the evaluation and diagnosis of recurrent recumbency following treatment or non-typical presentations such as mid-lactation hypocalcemia benefit greatly from rapid electrolyte evaluation cow-side. One drawback to the currently available POC testing, however, is that while excellent for diagnosis of hypocalcemia and hypokalemia, current testing modalities do not have the option for evaluation of hypophosphatemia or hypomagnesemia, and therefore cannot be utilized to confirm these diagnoses.

The diagnosis of several additional medical conditions of juvenile and adult ruminants can also be assisted via POC blood gas/electrolyte testing in combination with physical examination, including uroabdomen following urethral obstruction (hyponatremia, hypochloremia, and hyperkalemia with azotemia) and renal azotemia if increased BUN and/or creatinine are present in the absence of dehydration or obstruction. Separate POC cartridges are also available for evaluation of cardiac troponins and have been validated for use in bovines[7,14]. Cardiac troponin has been shown to be elevated in cases of ionophore toxicity and other clinical conditions of the bovine thorax as well as in downer cows less likely to survive, however, the practicality of its use on a regular basis in clinical practice is currently unknown[8,10].

Potential for production animal uses

To this point, the discussion has primarily focused on the uses of POC blood gas/chemistry analyzers in the treatment of individual animals. However, as demonstrated by the adoption of handheld BHBA testing units for diagnosis and management of ketosis at the herd level on dairy operations, targeted tested of certain herd members for specific conditions via POC testing can be a valuable tool in production animal medicine. The currently available POC analyzers have the ability to test several analytes that may provide valuable information at the herd level as well as the individual level. Overfeeding of protein has been shown to have detrimental effects on reproduction, and blood BUN levels can be used to monitor protein status similar to milk MUN[12]. Monitoring of calcium levels in recently fresh cows prior to and following herd level standardized treatments such as oral calcium boluses may be beneficial in determining if either pre-fresh dietary changes need to be made, or if additional therapies should be instituted on post-fresh animals to prevent clinical hypocalcemia from occurring[3]. Herd level monitoring of calves with diarrhea pre- and post-treatment with oral electrolytes might assist the practitioner in evaluating the effectiveness of the treatment protocols on calf ranches and large dairies, or be utilized to evaluate causes for failure of treatment response, and recommend more appropriate therapies targeted to the common patterns seen on each individual operation. In beef operations, evaluation of acid-base status in herd outbreak situations with diarrhea may also be valuable in targeting appropriate therapies.

Conclusion

The portability and ease of use of hand-held POC blood gas and electrolyte chemistry analyzers have now made the ability to rapidly diagnosis acid-base and electrolyte abnormalities patient-side on-farm a reality. Appropriate identification of acid-base and electrolyte disorders can improve patient care for many medical conditions of bovines, thus, bovine practitioners should consider if the addition of this tool could benefit their current practice.

Endnotes

[a] i-STAT 1, Abbott, Union City, CA
[b] Element POC (EPOC), Heska, Loveland, CO
[c] i-STAT EC8+ test cartridge, Abbott, Union City, CA

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