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Establishing blood gas ranges in healthy bovine neonates differentiated by age, sex, and breed type

Patrick Dillane,* Lea Krump,* Aideen Kennedy,† Ríona G. Sayers,† and Gearóid P. Sayers*[1]
*Department of Biological and Pharmaceutical Sciences, Institute of Technology Tralee, Tralee, Co. Kerry, Ireland, V92 CX88
†Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co. Cork, Ireland, P61 C996

ABSTRACT

Calf mortality and morbidity commonly occurs within the first month of life postpartum. Standard health ranges are invaluable aids in diagnostic veterinary medicine to confirm normal or the degree and nature of abnormal parameters in (sub)clinically ill animals. Extensive research has indicated significant differences between the physiologies of neonate and adult cattle, particularly for blood parameters such as pH, base excess, anion gap, and bicarbonate (HCO_3^-). The objective of this research was to determine the influence of age, sex, and breed type, in addition to environmental factors, on the normal blood gas profiles of neonatal calves, and thus develop a scientifically validated reference range accounting for any significant factors. The study was conducted on healthy neonatal calves (n = 288), and completed over a 2-yr period. Individual calf blood gas analysis was conducted for parameters of pH, base excess, Na^+, K^+, Ca^{2+}, Cl^-, glucose, total hemoglobin, HCO_3^-, pCO_2, anion gap, strong ion difference, and hematocrit levels. Regression procedures examined the combined effect of year, farm, age, breed type, sex, and hours postfeeding on each variable. Significant effects were observed for age, sex, and breed type on several of the blood gas variables. Furthermore, year, farm, and hours postfeeding appeared to have less of an influence on neonatal bovine blood gas profiles. Consequently, specific ranges based on the neonate's age, sex, and breed type will allow for more detailed and accurate diagnosis of health and ill health in neonatal calves.
Key words: reference range, healthy neonatal calf, blood gas analysis, calf health, prevention

INTRODUCTION

The majority of calf mortality and morbidity occurs within the first month of life, with blood gas abnormalities commonly accompanying various neonatal diseases (Boden, 2005; Bleul et al., 2007; Smith, 2014). The assessment of ill calves is still commonly based on clinical examination alone; however, the emergence of pen-side blood gas analyzers has facilitated a more accurate approach to assess the degree and nature of blood gas derangement (Russell and Roussel, 2007; Bleul, et al., 2007). Therefore, the development of ad hoc reference ranges for neonates would allow for a more accurate interpretation of health and ill health.

Standard blood gas reference ranges aid clinicians and researchers in identifying and differentiating normal from abnormal parameters, particularly for disease diagnoses purposes (Knowles et al., 2000; Cornell University College of Veterinary Medicine, 2014; AACC, 2015). The most appropriate reference range is one generated from a group of healthy animals with environmental and physiological characteristics as closely related to the target patient as possible (Meyer and Harvey, 2004; Roland et al., 2014). In this regard, Mohri et al. (2007) suggested that separate reference ranges or values are required from a particular age or breed type of a calf.

Various reference ranges for healthy adult cattle, including that for blood gas, have been established (Divers and Peek, 2007; Marshall and Bangert, 2008; Smith, 2009; Wood and Quiroz-Rocha, 2010). Although these have been used extensively and successfully in adult cattle, applying adult ranges to young calves can be misleading due to the blood gas changes that are associated with normal prepubertal physiological development (Rice, 1994; Herfen and Bostedt, 1999; Knowles et al., 2000; Detry et al., 2003). Several studies have indicated significant differences between the physiology of young and adult cattle, particularly for serum pH, bicarbonate (HCO_3^-), base excess (**BE**), anion gap (**AG**), and strong ion difference (**SID**; Adams and Polzin, 1989; Gustin et al., 1997; Lorenz et al., 2005; Koch and Kaske, 2008). Furthermore, genetic (breed type), age, and environmental factors influence hematological and biochemical values in healthy animals (Sayers et al., 2016).

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[1]Corresponding author: gearoid.sayers@staff.ittralee.ie

Table 1. Description of calf husbandry regimens on each study farm for neonatal calves

Farm	Breeds[1]	Housing	Milk feeding system	Ad libitum water available?	Creep feed available?	Shared airspace with adult cattle?
A	HF, JeX, AbA, LM, NR	Males and females housed separately. Individual calf pen followed by group pens (up to 20 animals) at 3 d of age. Deep straw bedding in all pens.	Automatic feeders with an allowance of 6 L of milk replacer per calf per day as a routine.	Yes	Yes, from 1 wk of age	No
B	HF, JeX, NR	Males and females housed separately. Individual calf pen followed by group pens (up to 25 animals) at 3 d of age. Deep straw bedding in all pens.	Manual multicalf feeding buckets with an allowance of 6 L of milk replacer or whole milk per calf per day.	Yes	Yes, from 1 wk of age	Females no, Males yes
C	HF, JeX, AbA	Males and females housed separately. Individual calf pen followed by group pens (up to 12 animals) at 3 d of age. Deep straw bedding in all pens.	Automatic feeders with an allowance of 6 L of milk replacer per calf per day as a routine.	Yes	Yes, from 1 wk of age	Yes
D	HF, JeX, BB	Individual calf pen followed by group pens (up to 15 animals) at 2 d of age. Deep straw bedding in all pens.	Manual multicalf feeding buckets with an allowance of 6 L of milk replacer or whole milk per calf per day.	Yes	Yes, from 1 wk of age	No

[1]HF = Holstein-Friesian; JeX = Jersey cross; NR = Norwegian Red; AbA = Aberdeen Angus; LM = Limousin; BB = Belgian Blue.

Several studies have attempted to develop standard values for biochemical and hematological variables for neonatal calves; however, difficulties relating to sample size, breed variations, and age differentiations constrained their use (Tennant et al., 1974; Dubreuil and Lapierre, 1997; Hugi and Blum, 1997; Egli and Blum, 1998). Therefore, the aim of our research was to evaluate age, sex, and breed type factors that influence blood gas ranges in neonatal calves and to develop tailored reference ranges for this cohort.

MATERIALS AND METHODS

Sample Population

A total of 288 samples (263 individual calves, 21 calves repeated twice, and 2 calves sampled 3 times, all at different age points) from healthy neonatal bovines aged 1 (>24 h) to 30 d, from 3 research farms (farm A: n = 71, farm B: n = 129, farm C: n = 42) and 1 commercial dairy farm (farm D: n = 46), were completed over a 2-yr period in 2016 (n = 185) and 2017 (n = 103). A description of husbandry regimens for neonatal calves on each of the study farms is presented in Table 1. Healthy calves on these farms were randomly selected to be enrolled in the study. The inclusion criteria were based on 3 factors: (1) each calf did not have any prior recorded illness; (2) the housing facility of each calf was free of any disease outbreak before analysis; and (3) at the point of analysis, a clinical assessment was undertaken on each calf, incorporating calf demeanor, ear position, mobility, interest in surroundings, suckle reflex, feed intake, and dehydration status. All calves were assessed and scored simultaneously by 2 research veterinarians, and calves that were regarded as clinically healthy were enrolled in the study. Temperature was not recorded.

In addition to farm and year, the sample population of calves were differentiated by age (1–30 d), sex (male n = 157, female n = 131), breed [Dairy: Holstein-Friesian (n = 178), Jersey cross (n = 88), Norwegian Red (n = 2); Beef: Aberdeen Angus (n = 12), Limousin (n = 7), and Belgian Blue (n = 1)], and hours postfeeding (<1, 1–2, 2–4, >4 h).

Blood Sampling

An individual calf was blood sampled by jugular venipuncture on at least 1 but not more than 3 occasions over the duration of the study. A total volume of between 1.5 to 2 mL of venous blood was taken into labeled heparinized 2.5-mL syringes (Cruinn Diag-