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Arterial and Venous Blood Gas, Electrolytes, Biochemical and Hematological Values in Healthy Korean Native Calves

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Abstract : The objective of this study was to investigate arterial and venous blood gas, electrolytes, biochemical, and hematological values in healthy Korean native calves (KNC). The healthy 62 KNC within 3 weeks-old were examined. The arterial blood was collected from caudal auricular artery and the venous blood from jugular vein. The blood samples were analyzed immediately using a portable blood gas analyzer. The pH, pO_2, pCO_2, $cHCO_3^-$, BE, cSO_2, Na^+, Ca^{2+}, Cl^-, anion gap potassium (AgapK), Hct, cHgb, glucose, lactate and creatinine were determined. The normal values for blood gas, electrolytes, biochemical, and hematological variables determined in this study agree with other published values for normal calves. The mean concentration of glucose and lactate within 3 weeks old of KNC is higher than those of adult cattle. The blood values according to weeks of age within 3 weeks-old of arterial and venous blood variables were not significantly different ($P > 0.05$). Glucose ($r = 0.927$) had the strongest correlations between arterial and venous values. The correlation between the values of the arterial and the venous blood was strong in creatinine ($r = 0.925$), lactate ($r = 0.815$), Ca^{2+} ($r = 0.806$), Hct ($r = 0.799$), Na^+ ($r = 0.790$), cHgb ($r = 0.786$), base excess ($r = 0.749$), pH ($r = 0.710$), HCO_3^- ($r = 0.710$), and $cTCO_2$ (0.663). Analysis of blood samples in a field condition, using hand-held analyzer is rapid and useful in bovine practice.

Key words **:** blood gas values, arterial, venous, Korean native calves.

Introduction

Blood gas evaluations of various animal species are used by clinicians, surgeons, and research workers, and may be required under field conditions as well as in veterinary clinics and laboratories (18). Blood gases are involved in breathing and metabolic processes of vertebrates. The dispersal of gases such as O_2 and CO_2 (and its derivatives) is essential for maintaining a steady pH, ion balance and acid-base balance. Blood electrolytes, biochemical, and hematological variables can also use as an indicators for the estimation of the health status (10).

Differences in analytical methods and differences between geographically distinct populations of animals mean that the reference ranges provided by a local analytical service, which are based upon their own measurements, generally provide more accurate standards, although reference ranges published in the literature can be provide a useful guide. Reference ranges for blood biochemical, hematological and blood gas variables of domestic animals have been reported by many authors (2,3,9,14,16,17). They usually apply only to adult animals and they can be misleading if applied to young animals because there are often large changes in the values of the variables associated with the normal process of growth.

The sample of arterial blood can be valuable, not only for assessing an animal's condition for routine clinical examinations but also during surgery. The acid-base status, partial oxygen tension and hemoglobin saturation of arterial blood are valuable measurements (12). However, in veterinary medicine venous samples are usually used owing to the practical difficulties in collecting arterial samples. Therefore, a detailed study of acid-base balance requires not only venous blood analysis but also an examination of arterial blood, particularly in the assessment of blood gases (8).

Until recently, accurate determination of health status could only be achieved in a hospital setting. However, the introduction of hand-held devices such as the point-of-care analyzer has allowed patient-side analysis of certain variables in a variety of animal species (3,16). Advantage of hand-held devices over laboratory analysis is that results are usually more quickly available to guide treatment. The availability of faster test results expedites diagnosis and initiation of treatment and has a positive impact on the care of critically ill patients. The analytical performance of the hand-held devices has been established in previous studies (3,16).

Several investigators have examined the normal values of blood gas in bovine, equine, ovine, and porcine (9,16,17). However, normal blood gas values of KNC were not available. The purpose of the study reported here was to obtain normal values and reference ranges of blood gas, electrolytes, biochemical, and hematological variables of healthy KNC using hand-held devices from birth to 3 weeks of age reared under farm conditions.

Materials and Methods

Animals

From March to June 2014, we examined sixty-two KNC

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within 3 weeks-old in 15 farms in Yeong-wol, Gangwon-do, Korea. All the calves were in good health, normal temperature, activity, and appetite.

Blood sampling

For collecting arterial blood, the hair of dorsal surface of the pinna of ear, from the base to the middle of the pinna, was removed with a disposable razor. A 26 G needle was placed in the medial intermediate auricular branch of the caudal auricular artery and 0.2 ml of blood was collected. The 0.5 ml of Jugular blood sample was also collected from external jugular vein with 23 G needle. There were no side effects associated with the puncture of the caudal auricular arteries or jugular veins of the calves.

Hand-held analyzer

The hand-held, portable, battery-powered point-of-care analyzer (EPOC® blood analysis, Woodly Equipment Company Ltd, Lancashire, UK) was used. It has an integrated thermometer, barometer, and memory for the last 2,000 measurements, which are displayed on a screen and can be uploaded to a printer. The analyzer consists of a hand-held machine and single-use cartridge that combine various miniaturized microsensors, a single-point calibration system, fluid channel, and waste chamber.

Determination of blood variables

The blood samples were analyzed immediately at fields. Approximately 60 µl of blood was placed in a preformed sample entry well in the cartridge, which was then inserted in the analyzer. The analyzer started automatically after insertion of the cartridge, ran a test program, underwent self-calibration, and then analyzed the blood sample. Test results were displayed on the screen 120 seconds later. We measured the pH, partial pressure of oxygen (pO_2), partial pressure of carbon dioxide (pCO_2), base excess (BE), concentration of bicarbonate ($cHCO_3^-$), concentration of oxygen saturation (cSO_2), sodium, potassium, calcium, chloride, anion gap potassium (AgapK), hematocrit (Hct), concentration of hemoglobin (cHgb), glucose, lactate, and creatinine.

Statistical analysis

Statistical analyses were carried out with SAS program (version 9.3, SAS Institute Inc, USA). The mean ± standard deviation (SD) was calculated. The values of arterial blood variables were compared with those of venous blood. Correlation between arterial and venous values was analyzed by Pearson's method. Reference range of each blood variable was established based on the distribution of the data. Normal distribution (gaussian): When data is normally distributed, the mean ± 2 standard deviation is used to establish the reference intervals. With this approach, confidence intervals on the upper and lower limit of the reference interval can be provided. Non-normal distribution (non-gaussian): If the data is significantly skewed, percentiles are used to establish reference intervals. The 2.5 and 97.5 percentiles are the upper and lower limits of the reference intervals and incorporate the middle 95% of the data. Differences were considered significant at $P \leq 0.05$.

Results

Means of blood variables

Mean (sd) values of arterial and venous blood variables in 62 healthy KNC were presented in Table 1. The arterial blood values were pH (7.44 ± 0.04), pO_2 (75.0 ± 13.0 mmHg), pCO_2 (38.3 ± 3.3 mmHg), $cHCO_3^-$ (26.4 ± 2.8 mmol/L), BE (2.3 ± 3.3 mmol/L), cSO_2 (94.4 ± 5.0 mmol/L), $cTCO_2$ (27.6 ± 2.9 mmol/

Table 1. Mean (sd) values and reference ranges of arterial and venous blood and correlation values (R value) between arterial and venous blood in 62 healthy Korean native calves

	Arterial		Venous		Correlation
	Mean ± SD	Reference range	Mean ± SD	Reference range	R value
pH	7.44 ± 0.04	7.36-7.53	7.41 ± 0.04	7.35-7.48	0.7098
pO_2 (mmHg)	75.0 ± 13.0	55.7-97.8	32.5 ± 12.9	19.2-42.9	0.1044
pCO_2 (mmHg)	38.3 ± 3.3	31.9-44.7	45.7 ± 4.5	36.9-54.6	0.3958
$cHCO_3^-$ (mmol/L)	26.4 ± 2.8	20.9-31.9	29.0 ± 2.5	24.0-33.9	0.7096
BE (mmol/L)	2.3 ± 3.3	–3.1-8.2	4.3 ± 2.9	–1.4-10	0.7486
cSO_2 (mmol/L)	94.4 ± 5.0	88.5-101.2	58.7 ± 14.5	30.2-87.1	0.1692
$cTCO_2$ (mmol/L)	27.6 ± 2.9	22.0-33.2	30.4 ± 2.6	25.3-35.4	0.6627
AgapK (mmol/L)	16.6 ± 2.3	12.2-21.0	15.5 ± 2.5	10.7-20.3	0.1967
Na^+ (mmol/L)	139.2 ± 1.5	136.4-142.1	139.4 ± 1.5	136.5-142.4	0.7903
K^+ (mmol/L)	4.8 ± 0.3	4.2-5.4	4.9 ± 0.4	4.1-5.6	0.2412
Ca^{2+} (mmol/L)	1.38 ± 0.07	1.19-1.48	1.33 ± 0.08	1.18-1.48	0.8062
Cl^- (mmol/L)	101.0 ± 2.5	96.1-106.0	99.9 ± 2.7	94.5-105.2	0.4637
Hct (%)	30.4 ± 3.6	23.4-37.4	30.5 ± 3.1	24.3-36.6	0.7993
cHgb (g/dL)	10.3 ± 1.2	7.9-12.7	10.4 ± 1.1	8.3-12.5	0.7859
Glucose (mg/dL)	135.5 ± 21.7	93.2-177.7	127.8 ± 20.1	95.1-161.0	0.9274
Lactate (mmol/L)	3.31 ± 2.17	–0.49-6.69	2.79 ± 1.59	–0.11-5.4	0.8147
Creatinine (µmol/L)	122.6 ± 30.3	63.3-181.9	115.4 ± 31.6	53.5-177.3	0.9246

L), anion gap (16.6 ± 2.3 mmol/L), Na^+ (139.2 ± 1.5 mmol/L), K^+ (4.8 ± 0.3 mmol/L), Ca^{2+} (1.38 ± 0.07 mmol/L), Cl^- (101.0 ± 2.5 mmol/L), Hct (30.4 ± 3.6%), cHgb (10.3 ± 1.2 g/dL), glucose (135.5 ± 21.7 mg/dL), lactate (3.31 ± 2.17 mmol/L), and creatinine (122.6 ± 30.3 μmol/L). The venous blood values were pH (7.41 ± 0.04), pO_2 (32.5 ± 12.9 mmHg), pCO_2 (45.7 ± 4.5 mmHg), $cHCO_3^-$ (29.0 ± 2.5 mmol/L), BE (4.3 ± 2.9 mmol/L), cSO_2 (58.7 ± 14.5 mmol/L), $cTCO_2$ (30.4 ± 2.6 mmol/L), anion gap (15.5 ± 2.5 mmol/L), Na^+ (139.4 ± 1.5 mmol/L), K^+ (4.9 ± 0.4 mmol/L), Ca^{2+} (1.33 ± 0.08 mmol/L), Cl^- (99.9 ± 2.7 mmol/L), Hct (30.5 ± 3.1%), cHgb (10.4 ± 1.1 g/dL), glucose (127.8 ± 20.1 mg/dL), lactate (2.79 ± 1.59 mmol/L), and creatinine (115.4 ± 31.6 μmol/L).

Values according to weeks of age [1 week-old (21 calves), 2 weeks-old (21 calves), and 3 weeks-old (20 calves)] of arterial and venous blood variables were not significantly different ($P > 0.05$).

Reference range of blood variables

Reference ranges of arterial and venous blood variables in 62 healthy KNC were presented in Table 1. The reference ranges of arterial blood were pH (7.36-7.53), pO_2 (55.7-97.8 mmHg), pCO_2 (31.9-44.7 mmHg), $cHCO_3^-$ (20.9-31.9 mmol/L), BE (−3.1-8.2 mmol/L), cSO_2 (88.5-101.2 mmol/L), $cTCO_2$ (22.0-33.2 mmol/L), anion gap (12.2-21.0 mmol/L), Na^+ (136.4-142.1 mmol/L), K^+ (4.2-5.4 mmol/L), Ca^{2+} (1.19-1.48 mmol/L), Cl^- (96.1-106.0 mmol/L), Hct (23.4-37.4%), cHgb (7.9-12.7 g/dL), glucose (93.2-177.7 mg/dL), lactate (−0.49-6.69 mmol/L), and creatinine (63.3-181.9 μmol/L). The reference range of venous blood of were pH (7.35-7.48), pO_2 (19.2-42.9 mmHg), pCO_2 (36.9-54.6 mmHg), $cHCO_3^-$ (24.0-33.9 mmol/L), BE (−1.4-10 mmol/L), cSO_2 (30.2-87.1 mmol/L), $cTCO_2$ (25.3-35.4 mmol/L), anion gap (10.7-20.3 mmol/L), Na^+ (136.5-142.4 mmol/L), K^+ (4.1-5.6 mmol/L), Ca^{2+} (1.18-1.48 mmol/L), Cl^- (94.5-105.2 mmol/L), Hct (24.3-36.6%), cHgb (8.3-12.5 g/dL), glucose (95.1-161.0 mg/dL), lactate (−0.11-5.4 mmol/L), and creatinine (53.5-177.3 μmol/L).

Correlation of blood values between arterial and venous blood

Correlation coefficients between arterial and venous variables in 62 healthy KNC were presented in Table 1. Glucose ($r = 0.927$) had the strongest correlations between arterial and venous values. The correlation between the values of the arterial and the venous blood was strong in creatinine ($r = 0.925$), lactate ($r = 0.815$), Ca^{2+} ($r = 0.806$), Hct ($r = 0.799$), Na^+ ($r = 0.790$), cHgb ($r = 0.786$), base excess ($r = 0.749$), pH ($r = 0.710$), HCO_3^- concentration ($r = 0.710$), and $cTCO_2$ (0.663). However, correlation coefficients for pO_2, cSO_2, anion gap, K^+, pCO_2, and Cl^- were calculated as $r = 0.104$, 0.169, 0.197, 0.241, 0.396, and 0.464, respectively.

Discussion

Transportation of food animal patient samples to a laboratory is time consuming and costly, and causes a delay in specific treatment. Point-of-care-testing is commonplace in veterinary clinics but however, more complicated in the field. There are several studies which investigated normal blood values and normal reference data of adult cattle (9,17). There are a few papers which investigated within 3 weeks-old calf, in which is the critical period of life (2-4,11). However, there is no normal blood gas value in KNC. In this study, the normal values of arterial and venous blood gas, electrolytes, biochemical, and hematological variables in healthy KNC were determined.

There have been several studies of the feasibility of collecting blood samples from different arteries in cattle (1,12, 13,15). The blood gas and acid-base values obtained varied only slightly with the location of the artery used (5,6,13). The values for pH, pO_2 and SO_2 in blood from the axillary artery were lower than those in blood from the caudal auricular artery, whereas the pCO_2, HCO_3^- and base excess were higher in blood from the auricular artery. However, the differences were not considered biologically relevant (13). In this study, arterial blood samples from the caudal auricular artery of the pinna were collected. Collecting blood samples from the caudal auricular artery usually requires only one person, which is a distinct advantage. In contrast, for the collection of blood from a limb artery, the calf must be restrainted in lateral recumbency, increasing the risk of injury and hematoma formation at the site of puncture (7). Arterial thrombosis with life-threatening ischemia and necrosis of the non-perfused area is also a risk associated with blood collection. The consequences of this type of complication are less disastrous in an ear than in a limb (2). There were no cases of thrombosis of the caudal auricular artery or the jugular vein during this study.

Measurement of the pO_2 and pCO_2 of arterial blood are required to evaluate the calves' quality of ventilation and pulmonary function. Furthermore, the extent of respiratory compensation of metabolic acidosis can only be determined using arterial blood (2). The production of bicarbonate is directly linked to the concentration of CO_2 by the intermediate formation of H_2CO_3 as it reacts with intracellular water. H_2CO_3 is a weak acid that easily dissociates into H^+ and HCO_3^-. The increase of HCO_3^- coincides with the increase in pCO_2, and the decrease in lactate concentration (9).

The mean arterial and venous values of blood gas, electrolytes, biochemical, and hematological variables in healthy KNC in the present study are in general agreement with the normal values listed in the literature (4,9,16,17). The mean venous values of blood gas variables (pH, pCO_2, and base excess) in this study are relatively higher than those of newborn calves (2-4). However, the mean arterial values of blood gas variables (pH, pCO_2, and base excess) in this study are similar with those of arterial values of 3 weeks old of calves (4). In this study, blood gas values according to weeks of age within 3 weeks-old of arterial and venous blood variables were not significantly different ($P > 0.05$).

The normal values for clinical biochemistry variables determined in this study agree with other published values for normal calves (9,17). And the some difference could be due to the different analytical methods. However, the mean concentration of glucose and lactate within 3 weeks old of KNC is higher than those of adult cattle (9,17).

In study of Bluel *et al* (2), normal arterial blood pH, HCO_3^-, base excess of 41 normal calves (brown Swiss, Simmental,

Holstein-Friesian) 24 hours after birth were 7.43 ± 0.04, 28.3 ± 3.3 mmol/L, 4.4 ± 3.6 mmol/L, respectively and those values were increased as time goes by. Furthermore, Bluel *et al* (2) stated that strong correlation between the pH, HCO_3^- and base excess values of arterial and venous blood and the differences between the values for arterial and venous blood were so small. This means that metabolic imbalances, which are routinely diagnosed by analyzing venous blood, can also be reliably diagnosed by analyzing arterial blood samples. In contrast, the pO_2, pCO_2 and cSO_2 of venous blood had only a weak correlation with the values for arterial blood, and were therefore not reliable for the evaluation of pulmonary gas change. Reliable measurements of these variables can only be obtained from arterial blood samples. In this study, the correlations between arterial and venous blood gas variables of KNC were very similar with results of Bluel *et al* (2).

In this study, the normal blood gas values of KNC within 3 weeks-old was investigated. Although this investigation makes no claim of being complete, we hope our results will serve as a stepping stone towards the establishment of normal values of blood gas and clinical chemistry variables of KNC.

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건강한 한우 송아지의 동맥과 정맥 혈액의 혈액가스, 전해질, 생화학 및 혈액학적 측정치

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요 약 : 본 연구의 목적은 건강한 한우 송아지의 동맥과 정맥혈액의 혈액가스, 전해질, 생화학 및 혈액학적 측정치를 조사하는 것이다. 건강한 3주령 이내의 62두 송아지를 본 연구에 공시하였으며 동맥혈액은 귀(이)동맥에서, 정맥혈액은 경정맥에서 채취하였다. 채혈한 혈액은 현장에서 즉시 휴대용 혈액가스분석기(EPOC® blood analysis, Woodly Equipment Company Ltd, Lancashire, UK)를 이용하여 pH, pO_2, pCO_2, $cHCO_3^-$, BE, cSO_2, Na^+, Ca^{2+}, Cl^-, anion gap potassium (AgapK), Hct, cHgb, glucose, lactate 및 creatinine을 측정하였다. 한우 송아지의 동맥과 정맥의 혈액가스, 전해질, 생화학 및 혈액학적 측정치는 기존에 발표된 정상 송아지의 측정치와 유사한 범위 내에 있었으며 glucose와 lactate의 평균 농도는 성우의 농도보다 높았다. 3주령 이내 송아지의 각 주령별 측정치 사이에는 통계적인 유의차가 나타나지 않았다($P > 0.05$). 포도당 농도는 동맥과 정맥 혈액 사이에 가장 높은 상관관계를 보여주었으며($r = 0.927$), creatinine ($r = 0.925$), lactate ($r = 0.815$), Ca^{2+} ($r = 0.806$), Hct ($r = 0.799$), Na^+ ($r = 0.790$), cHgb ($r = 0.786$), base excess ($r = 0.749$), pH ($r = 0.710$), HCO_3^- ($r = 0.710$), 및 $cTCO_2$ (0.663)도 높은 상관관계를 나타내었다. 휴대용 혈액가스분석기로 목장현장에서 혈액을 검사하는 것은 빠른 측정 결과를 얻을 수 있으며 소임상에서 유용하게 활용될 수 있을 것으로 생각된다.

주요어 : 혈액가스, 동맥, 정맥, 한우송아지