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ACID-BASE BALANCE PARAMETERS OF ARTERIAL, VENOUS AND CAPILLARY BLOOD IN SHEEP

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Abstract

The acid-base balance parameters of arterial, venous and capillary blood in clinically healthy adult sheep were compared. It was found that the acid-base balance parameters of venous blood differed from those of arterial blood, whereas the parameters of capillary and arterial blood were similar.

Key words: sheep, arterial blood, capillary blood, acid-base balance.

The determination of the acid-base balance or gasometry involves the estimation of the degree of arterial blood saturation with oxygen and carbon dioxide, and the activity of H^+ ions, i.e. the blood pH. These determinations are referred to as the so called "critical parameters", so they must meet certain clinical requirements. The acid-base balance parameters are determined in blood with anticoagulants. A recommended anticoagulant is heparin, as it does not interfere with the assay (3). Analysis of the acid-base balance parameters should be made in samples of arterial blood or the "arterialized" blood from capillary vessels (10, 15). The state of the acid-base balance is reflected to the highest extent by arterial blood parameters (3, 6). They enable precise determination of the level of blood oxygenation and alveolar ventilation of carbon dioxide. This is of primary importance in the diagnostics of respiratory tract diseases and determination of the degree of pulmonary compensation of acid-base balance disturbances (1, 6).

In medical and veterinary practice the acid-base balance is usually determined in venous blood samples. However, this assay is burdened with a potential error resulting from haemostasis caused by vein compression and activity of skeletal muscles during immobilisation. This may wrongly suggest acidosis. Furthermore, it makes it impossible to determine the value of partial pressure of carbon dioxide, i.e. the respiratory component. On the other hand, venous blood samples are in most cases sufficient for the evaluation of uncomplicated metabolic disorders (10).

Arterial blood collection in sheep is quite difficult and may result in complications, such as intravascular clots, excessive bleeding and haematoma formation. Therefore, it is considered permissible to collect capillary blood from the posterior edge of the ear, although results obtained in this way arouse controversy. According to some authors, capillary blood does not reflect arterial blood indices (14), whereas others claim that capillary and arterial blood is characterised by similar concentration of bicarbonate ions and partial pressure of carbon dioxide, but different partial pressure of oxygen; differences in the pH of capillary blood were also reported (7, 11, 15).

Due to the fact that literature provides scant information on the acid-base balance of arterial, venous and capillary blood in sheep, the aim of the present study was to compare the above parameters.

Material and Methods

The experiment was performed on 10 Polish Longwool sheep variety Kamieniecka, aged 2 to 3 years, clinically healthy and free from ecto- and endoparasites. The animals were housed and treated in accordance with the rules approved by the local Ethical Commission (conforming to principles of Laboratory Animal Care, NIH publication No. 86-23, revised in 1985).

Blood was collected for analyses in the morning, before the sheep were put to graze, in the following order: venous, arterial and capillary. Venous blood was taken from the jugular vein, arterial blood - from the left femoral artery of animals placed in the lateral position. The needle, 0.8 mm in diameter, was inserted on the medial side of the left leg, at the half height of the thigh. Capillary blood was taken from an incision of the posterior edge of the ear, made with a scalpel at a depth of 2 mm, proceeded by the so called "arterialisation" of the network of capillary vessels in this region (5 min before blood collection the preparation Histadermin was applied to the ear). The sites of blood collection were depilated and disinfected. Blood was collected directly to 100 µl glass heparinised tubes (it was flowing freely to the tubes for 10 s). When the capillary tubes were filled up with blood, a thin steel wire 1 cm in length was put inside, under anaerobic conditions. Both ends of the tube were closed with plastic caps and the contents was stirred using a small magnet, shifted along the tube ca. 20 times. To prevent plasma separation, the tubes with blood were transported in the horizontal position and the determinations were made within 15 min.

The following acid-base balance parameters were determined: pH, partial pressure of carbon dioxide (pCO_2), partial pressure of oxygen (pO_2), concentration of bicarbonate ions (HCO_3^-), base excess (BE), level of haemoglobin saturation with oxygen (O_2SAT) and total carbon dioxide content ($ctCO_2$). These parameters were determined using a Corning 248 analyser. The results were analysed statistically with the Student's *t*-test and presented in Table 1.

Results

The average pH of arterial blood was significantly higher than the average pH of venous blood, and similar to that of capillary blood (Table 1). The average level of partial pressure of carbon dioxide in arterial and capillary blood was lower than in venous blood. The difference was statistically significant. Partial pressure of CO_2 in capillary blood was similar to that noted in arterial blood. The oxygen partial pressure in capillary and arterial blood was statistically significantly higher than in venous blood.

Table 1
Mean values of gasometry and acid-base balance parameters in sheep blood

	pH	pCO_2 kPa	pO_2 kPa	HCO_3 act mmol/l	BE mmol/l	O_2SAT %	$ctCO_2$ mmol/l
arterial blood	7. 37	4.91	11.54	20.43	-2.12	94.94	21.63
SD	0.04	0.46	1.56	3.22	2.15	2.13	1.07
venous blood	7.33^A	6.19^a	6.12^A	24.61^a	-1.15	69.78^A	25.98^a
SD	0.03	0.41	0.97	3.12	2.26	5.67	2.47
capillary blood	7.38	4.83	11.99	20.01	- 0.35	96.26	21.96
SD	0.04	0.52	1.34	2.97	3.11	2.78	3.11

a – differences statistically important to $P \leq 0.05$
A - differences statistically important to $P \leq 0.01$

Statistically highly significant differences were observed between arterial and venous blood as regards the level of haemoglobin saturation with oxygen (O_2SAT). This parameter reached a much higher value in arterial and capillary blood.

The average values of HCO_3^- and $ctCO_2$ were lower in arterial and capillary blood, compared with venous blood; in the case of arterial blood this difference was statistically significant and correlated with pCO_2.

There were no statistically significant differences in the BE (base excess) index between particular types of blood samples.

Discussion

The average pH of arterial blood was similar to its value reported by other authors (6, 9). In veterinary diagnostics the blood pH is an important indicator of homeostasis. Its value should be measured in arterial or capillary blood, but not in venous blood due to the effect of blood oxygenation on particular acid-base balance parameters (4, 5, 15).

Partial pressure of carbon dioxide in arterial blood is the best indicator of respiration-related changes in the acid-base balance. Partial pressure of CO_2 in capillary blood was similar to its level noted in arterial blood. Higher partial pressure of carbon dioxide observed in venous blood resulted from the production of this gas during cell metabolism, its transportation to the lungs with venous blood and excretion with expired air. Under conditions of a normal blood flow through the lungs (perfusion) partial pressure of carbon dioxide in arterial blood depends almost entirely on alveolar ventilation (it increases as alveolar ventilation decreases, and decreases with the ventilation increase) (9).

Oxygen partial pressure in blood (pO_2) is a parameter used for the determination of its availability to tissues. In the present study, the oxygen partial pressure in capillary and arterial blood was statistically significantly higher than in venous blood. Similar results were obtained by other authors for calves and sheep (4, 13, 16). The gradient of oxygen partial pressure is the "driving force" for its uptake, transportation and supply to tissues. However, partial pressure does not determine the amount of oxygen supplied to tissues. Its volume depends on its blood content and haemoglobin affinity to oxygen. Both reduced haemoglobin and oxyhaemoglobin can be found in blood. The percentage of oxyhaemoglobin, compared with its total content, is referred to as haemoglobin saturation with oxygen (O_2SAT). This parameter was similar in arterial and capillary blood. This index is of primary importance while determining the efficiency of tissue respiration (8, 12).

According to the Henderson-Haselbalch equation, the pCO_2 pressure is a measure of the respiratory component, affecting changes in the plasma pH. The index of non-respiratory (metabolic) component is the actual concentration of bicarbonate ions (HCO_3^-act) and alternative, total concentration of CO_2 constituting a sum of concentrations of bicarbonate ions and carbon dioxide dissolved in plasma ($ctCO_2$). Lower values of HCO_3^- and $ctCO_2$ in arterial and capillary blood compared with venous blood were correlated with pCO_2. This is connected with the fact that the concentration of dissolved CO_2 remains in equilibrium with its partial pressure, so an increase in pCO_2 results in an increase in the concentration of dissolved carbon dioxide, and a decrease in pCO_2 – in its decrease. Dissolved carbon dioxide and water form carbonic acid which dissociates into H^+ and HCO_3^-. This indicates that changes in the respiratory components affect the actual concentration of bicarbonate ions. The actual concentration of HCO_3^- anions in plasma is also determined by the level of haemoglobin saturation with oxygen (O_2SAT). Haemoglobin reduction in tissues is accompanied by an increase in the concentration of bicarbonate ions in erythrocytes and, consistently with the gradient of concentration, they diffuse through the cell membrane to plasma (2, 3). This explains why the concentration of bicarbonates is higher in venous blood. Red blood cells penetrate with blood into the lungs, where reversed phenomena take place. Reduced haemoglobin undergoes oxygenation, and its acidity increases. As a result, released hydrogen ions are buffered by HCO_3^- anions, forming CO_2 and H_2O which are excreted to alveolar air, due to the gradient of partial pressures. Depletion of HCO_3^- ions produces a gradient between the plasma and red blood cell, which makes bicarbonate ions diffuse from plasma to erythrocytes, maintaining the buffering of hydrogen ions. This results in a decrease in the arterial blood concentration of HCO_3^-.

BE value was decreasing slightly only in arterial blood, due to lower concentration of bicarbonate anions.

The acid-base balance parameters of venous, capillary and arterial blood of sheep were considerably different. Samples of capillary and arterial blood were characterised by higher pH, higher oxygen partial pressure and a higher level of haemoglobin oxygenation, lower concentration of bicarbonate anions and a lower total carbon dioxide content, compared with venous blood.

The results obtained allow to formulate the following conclusions: i) the acid-base balance parameters of venous blood differ from those of arterial blood; ii) the acid-base balance parameters of capillary blood in clinically healthy sheep are similar to those of arterial blood, so blood from capillary vessels may be used for evaluation of the acid-base balance in these animals.

References

1. Adams R., Holland M.D., Aldridge B., Gary F.B., Odde K.G.: Arterial blood sample collection from the newborn calf. Vet Res Commun 1991, **15**, 387-394.
2. Brashear R.E., Oei T.O., Rhodes M.L., Futty D.E., Hosteller M.L.: Relationship between arterial and venous bicarbonate values. Arch Intern Med 1979, **139**, 440-442.
3. Breen P.H.: Arterial blood gas and pH analysis. Clinical approach and interpretation. Anesthesiol Clin North Am 2001, **19**, 885-906.
4. Cambier C., Clerbaux T., Detry B., Marville V., Frans A., Gustin P.: Blood oxygen binding in hypoxaemic calves. Vet Res 2002, **33**, 283 –290.
5. Cambier C., Clerbaux T., Amory H., Detry B., Florquin S., Marville V., Frans A., Gustin P.: Mechanisms controlling the oxygen consumption in experimentally induced hypochloremic alkalosis in calves. Vet Res 2002, **33**, 697-708.
6. Dinev D.: Peritoneal dialysis in healthy sheep: changes in acid base balance, blood electrolytes and some parameters of carbohydrate metabolism. Bulg J Vet Med 2003, **6**, 159-167.
7. Gustin P., De Groote A., Dhem A.R., Bakima M., Lomba F., Lekeux P.: A comparison of pO_2, pCO_2, pH and bicarbonate in blood from the carotid and coccygeal arteries of calves. Vet Res Commun 1988, **12**, 343-346.
8. Kastner S.B., von Rechenberg B., Keller K., Bettschart-Wolfensberger R.: Comparison of medetomidine and dexmedetomidine as premedication in isoflurane anaesthesia for orthopedic surgery in domestic sheep. J Vet Med A, 2001, **48**, 231-241.
9. Lahiri S., Edelman N.H., Cherniack N.S., Fishman A.P.: Role of carotid chemoreflex in respiratory acclimatization to hypoxemia in goat and sheep. Respir Physiol 1981, **46**, 367-382.
10. Meintjes R.A., Engelbrecht H.: The role of the large intestine in acid-base balance in sheep. South Afr J Sci 1995, **91**, 352-354.
11. Nagy O., Kovac G., Seidel H., Weissova T.: The effect of arterial blood sampling sites on blood gases and acid-base balance parameters in calves. Acta Vet Hung 2001, **49**, 331-340.
12. Nagy O., Sedovic M., Slanina L.: Acid-base profile in central and peripheral arterial and venous blood in cattle. Vet Med (Praha) 1994, **39**, 1-9.
13. Smith C.A., Bisgard G.E., Nielsen A.M., Daristotle L., Kressin N.A., Forster H.V., Dempsey J.A.: Carotid bodies are required for ventilatory acclimatization to chronic hypoxia. J Appl Physiol 1986, **60**, 1003-1010.
14. Speirs V.C.: Arteriovenous and arteriocentral venous relationships for mpH, pCO_2, and actual bicarbonate in equine blood samples. Am J Vet Res 1980, **41**, 199-203.
15. Tvedten H., Kopcia M., Haines C.: Mixed venous blood and arterial blood in bovine coccygeal vessel samples for blood gas analysis. Vet Clin Pathol 2000, **29**, 4-6.
16. Van Cappellen van Walsum A.M., Jongsma H.W., Wevers R.A., Nijhuis J.G., Crevels J., Engelke U.F., De Abreu R.A., Moolenaar S.H., Oeseburg B., Nijland R.: 1H-NMR spectroscopy of cerebrospinal fluid of fetal sheep during hypoxia-induced acidemia and recovery. Pediatr Res 2002, **52**, 56-62.