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Original article

An attempt to use the peritoneal cavity fluid in the diagnostics of acid-base balance disorders in dogs

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Abstract

The acid-base balance parameters (ABB) of blood are used in the diagnostics and therapy of acidosis or alkalosis type disorders. Nowadays, some reports on the attempts to use the body cavity fluid for the diagnostics of the ABB disorders have appeared in the human medicine. The study has aimed at comparing the acid-base balance parameters (ABB): pH, pCO_2, and HCO_3^- determined in the arterial blood and the fluid from the peritoneal cavity in dogs. The study was carried out on 20 dogs suffering from ascites developed as a result of the chronic renal failure. 1 ml of full blood was drawn from each dog from its femoral artery to a heparinized syringe equipped with a needle with an internal diameter of 0.7 mm and the puncture of the abdominal cavity was carried out in the white line. In the sample of arterial blood and the sample of the abdominal cavity fluid drawn the ABB parameters were determined. In the group examined, the ABB parameters determined for the arterial blood and the fluid had comparable numeric values and the same nature of the ABB disorder diagnosed on the basis of them. The conclusions are as follows: the results of the effusion fluid gasometry depend on the mechanism of the fluid formation and, in the case when it comes from the developed capillary network, a pressure of gases and remaining ABB parameters are similar to those determined for the arterial blood.

Key words: acid-base balance, dogs, peritoneal cavity fluid

Introduction

The acid-base balance parameters (ABB) of blood: pH, bicarbonate concentration (HCO_3^-) and the partial pressure of carbon dioxide (pCO_2) are used in the diagnostics and therapy of system body homeostasis disorders of acidosis or alkalosis type. Performing of an arterial blood test enables the most reliable insight into the current state of ABB, and, in dogs, the blood is most often collected from the femoral artery and the capillary blood is drawn from the back edge of an ear (Rodkey et al. 1978, Pomianowski et al. 2004) or the vascular bed of a claw (Solter et al. 1988, Quandt et al. 1991, Sławuta et al. 2008). Typically, the acid-base balance is described by the Henderson-Hasselbach equation (HH), where the

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blood pH is the resultant of the metabolic component expressed by the HCO_3^- concentration and the respiratory component – pCO_2, being carbonic acid anhydride (Di Bartola 2006a):

$$pH = 6.11 + \log \frac{[HCO_3^-]}{pCO_2 \times 0.226}$$

Changes of blood pH caused by a primary increase or decrease of pCO_2 are called respiratory acidosis or alkalosis, respectively. If, despite the change of pCO_2, the arterial blood pH is within the norm, it is called compensated respiratory acidosis or alkalosis. Metabolic acidosis or alkalosis result, in turn, from an original decrease or an increase in the HCO_3^- concentration in blood, and, if the blood pH is within the norm, the disorder is compensated (Constable 2000, Di Bartola 2006a, Morris and Low 2008). In the 80s, Peter Stewart stated that a better insight into the organism ABB is provided by an analysis of: pCO_2, the difference of levels of strong cations and anions in the blood serum – SID (strong ion difference) and the total level of nonvolatile weak acids – Atot (Acid total). He counted the following cations as the most important strong ions: Na^+, K^+, Ca^{2+}, Mg^{2+} and anions: Cl^- and lactate. Atot is a total of the buffer ions derived from plasma weak acids, and its value comprises mainly proteins and phosphates (Stewart 1978, Stewart 1983, Constable 2003).

Comparing a sum of strong cations with a sum of strong anions we obtain a surface mathematical difference which was named SID by Stewart (Di Bartola 2006b). This is of course a conventional term as a sum of cations and anions must be equal according to the law of electroneutrality. The Stewart model, its application and interpretation of the results for dogs, as well as methods of computing Atot in those animals (both simplified value and value including phosphate value) were described in detail (Sławuta et al. 2010, Sławuta and Glińska 2012). The ABB disorders in dogs result most often from the loss of buffer bases and buffer ions through the alimentary tract or kidneys (diarrhoea, vomiting, poliuria), they may also result from obturation of the lower or upper respiratory tract and the circulatory system diseases (Cornelius and Rawlings 1981, Nappert et al. 2002, Elliot et al. 2003a,b, Uchikov et al. 2003, Sławuta et al. 2010).

Ascites is a symptom that accompanies a lot of diseases of different aetiology and a differential diagnostics of its causes remains a crucial clinical issue. Examination of the fluid in the peritoneal cavity and its analysis is a method that provides a lot of precious information enabling the diagnosis of a primary disease and recognition of a nature of the disorders (Glińska 2009). In the literature, there have been reports on determination of the ABB parameters in the fluid from the body cavities performed during the diagnosis of causes of the ascites. (Simmen and Blaster 1993, Vaupel et al. 2001, Noh 2003). In the veterinary medicine, the comparative analysis of the acid-base balance parameters determined for arterial blood and the fluid from the body cavities, has not been carried out yet. The study has aimed at comparing the acid-base balance parameters i.e. pH, pCO_2 and HCO_3^- determined in the arterial blood and peritoneal cavity fluid, as well as comparison of ABB disorder type diagnosed on their basis.

Materials and Methods

The study has been carried out on 20 dogs of different breeds and sex (12 male dogs and 8 female dogs numbered from 1 to 20 in the Tables) in which the ascites resulted from hypoalbuminaemia developed in the course of chronic renal failure, which was diagnosed on the basis of clinical examination, laboratory tests, and kidney ultrasound examination. For each dog, a complete blood cell count with a smear was performed as well as the biochemical examination of the blood serum, in which the following was determined: aspartate aminotransferase activity (AST) and alanine aminotransferase activity (ALT), the concentration of urea, creatinine, total protein, electrolytes: Na^+, K^+, Cl^-, $P_{inorganic}$, albumins and lactic acid. In the urine of the dogs examined total protein concentration and the urine protein to creatinine ratio (UPC) were determined. 1 ml of full blood was drawn from each dog from femoral artery to a heparinized syringe equipped with a needle with an internal diameter of 0.7 mm and the puncture of the abdominal cavity was performed. In the sample of arterial blood and the sample of the abdominal cavity fluid drawn into the syringe without access of air, using Osmotech OPTI CCA Blood Gas Analyser, the following acid-base balance (ABB) parameters were determined: pH, pCO_2 and HCO_3^- concentration. Abdominocentesis was performed caudally on dogs laid on their right or left side, in the right or left caudal abdominal square (assuming a navel as the central point). Prior to puncture the needle insertion place was shaved and disinfected twice with alcohol iodine solution. During the puncture of the abdominal cavity, approximately 45 ml of fluid was collected, out of which: 20 ml – for anticoagulant (heparin) probes for examination of the physicochemical properties of the fluid, 20 ml – for probes with silicone balls for examination of its biochemical parameters (total protein concentration) and 2-5 ml of the fluid for the heparinized syringe

equipped with a needle with an internal diameter of 0.7 mm. A cytological examination of the fluid sediment was also carried out. An analysis of the acid-base balance and its disorders was performed by means of the classic method i.e. on the basis of the HH equation, including the concentration of HCO_3^- and pCO_2 as shown in Table 1.

Table 1. The compensation diagram of the acid-base disorders acc. to Di Bartola*.

Disorder	pH	Primary change	Compensation
Respiratory acidosis	↓	↑ pCO_2	↑ HCO_3^-
Respiratory alkalosis	↓	↑ pCO_2	↑ HCO_3^-
Metabolic acidosis	↓	↓ HCO_3^-	↓ pCO_2
Metabolic alkalosis	↑	↑ HCO_3^-	↑ pCO_2

* Di Bartola S.P. Fluid, electrolyte and acid base disorders in small animal practice. Saunders Elsevier 2006 St Louis

Assuming, as the norm for the dogs, the following values provided by Di Bartola (2006a): pH-7.35-7.46, pCO_2 – 30.8 – 42.8 mmHg, HCO_3^- – 18.8 – 25.6 mmol/l. In addition, in order to confirm the nature of a disorder, elements of the Stewart model were applied by calculating the value of a difference between strong cation concentration and strong anion concentration in the blood serum – SID (strong ion difference) according to the following equations:

$SID_3 = (Na^+) + (K^+) – (Cl^-)$ (Siegling-Vlitakis et al. 2007),

$SID_4 = [(Na^+) + (K^+)] – [(Cl^-) + (lactate^-)]$ (Siegling-Vlitakis et al. 2007)

assuming the following mean values calculated by Siegling-Vlitakis et al. (2007) as the norm for healthy dogs: SID_3 – 42 ± 4.4 mmol/L and SID_4 – 40.7 ± 4.6 mol/L. The analysis of the ABB disorders was performed according to the rules of interpretation of the Stewart model provided by Correy (2005), as shown in Table 2.

Based on obtained data the mean value, standard deviation and a range of obtained values were calculated. For finding statistical significance between arterial and peritoneal cavity fluid ABB parameters, Student t-test was used.

Results

In all the examined animals the ultra-sound examination of the kidneys revealed degenerative traits. Increased cortex echogenicity and blurring of the cortex-medulla border were observed. No changes were found in the remaining abdominal organs.

Table 2. Classification of ABB disturbances according to the Stewart approach acc. to Corey*.

Acid-base disturbances	Dis ease state
Metabolic acidosis	Low SID and high SIG**
	Low SID and low SIG
Metabolic alkalosis	Low serum albumin
	High SID

* Corey H.E. (2005) Bench-to – bedside review: Fundamental principles of acid-base physiology. Critical Care 9: 184-192

** SIG (strong ions gap) = (SID4) – (SIDe) (Siegling-Vlitakis et al. 2007), where:
SIDe (SID effective) = HCO_3^- + (albumin x [0.123 x pH – 0.631]) + (Pinorganic x [0.309 x pH – 0.469])

For the group of dogs examined, ALT activity was slightly raised, AST activity and the concentration of electrolytes and lactic acid were within the norm, the concentrations of urea and creatinine were raised, whereas total protein, albumins and $P_{inorganic}$ were lower compared to the reference values – Table 3 and 4. The high SD value in ALT and AST findings is a result of a wide reference values range. In the case of urea and creatinine concentration, it is related to an increase in these parameters in kidney failure. Albuminuria occurred in all dogs examined (an average content of total protein in urine amounted to 16.31 ± 8.42 g/l); and an average value of UPC amounted to 9.42 ± 4.0. The fluid drawn from the peritoneal cavity in all cases studied had the properties of an effusion fluid. It was characterized by its colour from water-bright to straw-coloured, a specific weight of 1006 ± 0.003, a total protein concentration of 1 ± 0.6 g/L, and the number of inflammatory cells 0.7 ± 0.3 10^9/L. For all cases examined, mononuclear cells i.e. white blood cells, macrophages, and peritoneal cells were dominant in the cytological examination of the fluid sediment. In dogs with renal failure pH and pCO_2 values determined in their arterial blood and the peritoneal cavity fluid differed statistically significantly. However, they had similar numeric values and demonstrated the same ABB disorder i.e. an increase in pH and pCO_2 as well as the HCO_3^- concentration at the upper limit of the norm indicated metabolic alkalosis (Di Bartola 2006b) (Table 5). In order to confirm character of the diagnosed ABB disorder in the group examined, it was necessary to apply elements of the Stewart model. According to Constable's suggestion (2000), the classic model of the ABB disorder diagnosis should be used only when the concentration of albumins and $P_{inorganic}$ is within the norm, because Atot value comprises plasma, albumin and phosphate which is in a simplified way calculated in human

Table 3. Results of the biochemical examination of the blood serum of the dogs examined (average values, n = 20).

	Examined dogs		Reference values*
ALT U/l	57.27	± 25.01	3-50
AST U/l	24.12	± 14.41	1-37
Urea mmol/l	19.50	± 10.37	3.32-7.47
Creatinine mmol/l	240.66	± 45.30	88.4-150.3
Total protein g/l	49.33	± 2.88	55-70
Albumins g/l	17.33	± 0.67	33.00-56.00
P_i mmol/l	1.15	± 0.04	1.35-2.87

* Winnicka A (1997) Badanie biochemiczne krwi. In: Winnicka A (ed) Wartości referencyjne podstawowych badań laboratoryjnych w weterynarii. Wydawnictwo SGGW, Warszawa.

Table 4. Concentration of ions, lactate, and albumins determined in the blood serum of the dogs and the calculated values of SID_3, SID_4 and UPC.

Item	Na^+ mmol/l	K^+ mmol/l	Cl^- mmol/l	Lactate mmol/l	Albumins g/l	UPC	SID_3 mmol/l	SID_4 mmol/l
1.	153.90	4.72	107.20	2.89	17	3.1	51.42	48.53
2.	151.10	4.81	108.00	2.26	18	1.2	47.91	45.65
3.	151.40	4.19	98.80	2.14	17	4.8	56.79	54.65
4.	154.20	4.23	101.70	1.43	18	13.1	56.73	55.30
5.	153.10	4.47	102.00	2.00	18	9.6	55.57	53.57
6.	150.30	4.18	98.80	1.98	17	9.3	55.48	53.50
7.	149.80	4.89	100.10	2.11	17	8.5	54.59	52.48
8.	152.30	4.12	99.70	2.61	18	11.5	56.72	54.11
9.	151.90	4.74	101.00	1.92	17	6.8	55.64	53.72
10.	154.10	4.72	99.10	2.69	17	8.3	59.72	57.03
11.	152.80	4.19	100.00	2.23	16	9.2	56.99	54.76
12.	153.40	4.16	99.21	1.98	19	8.4	58.35	56.37
13.	154.80	4.28	101.20	2.45	17	13.1	57.88	55.43
14.	152.40	4.32	102.21	2.12	17	5.2	54.51	52.39
15.	151.90	4.15	100.10	2.18	18	14.2	55.95	53.77
16.	150.00	4.28	99.87	1.89	17	12.8	54.41	52.52
17.	153.20	4.19	101.34	1.82	18	7.4	56.05	54.23
18.	149.20	4.31	100.25	2.00	17	17.2	53.26	51.26
19.	152.70	4.19	99.21	2.14	17	12.6	57.68	55.54
20.	151.90	4.72	98.91	2.11	17	12.1	57.71	55.60
Average values ±SD	152.22 ± 1.56	4.39 ± 0.26	100.93 ± 2.52	2.14 ± 0.32	17.35 ± 0.67	9.42 ± 4.0	55.66 ± 2.61	53.52 ± 2.66
Maximum value	154.80	4.89	108.00	2.89	19	1.2	59.22	57.03
Minimum value	149.20	4.12	88.80	1.43	16	17.2	47.91	45.65

SID_3 (strong ion difference) = $(Na^+) + (K^+) - (Cl^-)$
SID_4 (strong ion difference) = $[(Na^+) + (K^+)] - [(Cl^-) + (lactate^-)]$

Table 5. Values of the ABB parameters determined for the arterial blood and the peritoneal cavity fluid of the dogs.

	Arterial blood			Fluid		
Item	pH*	pCO_2** mmHg	HCO_3^- mmol/l	pH*	pCO_2** mmHg	HCO_3^- mmol/l
1.	7.54	35.00	21.40	7.53	39.00	23.40
2.	7.53	37.00	22.10	7.51	42.00	25.10
3.	7.57	39.00	26.00	7.59	42.00	28.80
4.	7.52	37.00	23.40	7.57	40.00	27.60
5.	7.54	36.00	22.80	7.56	39.00	24.00
6.	7.53	37.00	27.60	7.55	41.00	24.90
7.	7.50	33.00	27.20	7.52	37.00	22.80
8.	7.54	36.00	26.20	7.54	39.00	24.00
9.	7.54	37.00	26.80	7.55	39.00	24.80
10.	7.53	36.00	25.80	7.51	38.00	23.80
11.	7.54	37.00	26.10	7.55	41.00	24.90
12.	7.52	35.00	24.10	7.54	39.00	24.00
13.	7.54	36.00	25.10	7.57	40.00	24.80
14.	7.53	35.00	25.00	7.54	38.00	23.00
15.	7.53	35.00	24.80	7.52	39.00	23.00
16.	7.54	37.00	26.40	7.55	42.00	25.20
17.	7.52	37.00	25.80	7.54	43.00	26.00
18.	7.53	37.00	26.00	7.57	41.00	24.80
19.	7.54	38.00	26.30	7.56	40.00	25.80
20.	7.54	37.00	26.50	7.55	39.00	26.00
Average values ± SD	7.53 ± 0.01	36.35 ± 1.30	25.98 ± 1.69	7.54 ± 0.02	39.90 ± 1.58	24.52 ± 1.51
Maximum value	7.57	39.00	27.60	7.59	43.00	28.80
Minimum value	7.50	33.00	21.40	7.51	37.00	22.80

* p = 0.005
** p = 0.001

plasma according to the formula Atot = 2.43 x (total protein) (Constable 2001). The values of SID_3 and SID_4 exceeding the values calculated for the dogs (Siegling-Vlitakis et al. 2007) and a low concentration of albumins, according to the interpretation of Stewart model provided by Corey (2005), also proved the occurrence of the metabolic alkalosis.

Discussion

Despite the fact that the obtained pH and pCO_2 values determined in the arterial blood and peritoneal cavity fluid differed significantly, the ABB disorder diagnosed on their basis was of metabolic acidosis nature. For a comparison of the results between the arterial blood and the punctate from the peritoneal cavity a classical method was used. In the authors' opinion, the Stewart model would not be reliable in the case of fluid of transudate nature. The advantage of the Stewart model is that it includes mechanisms regulating pH inside the cell related to Na^+ and Cl^- ions and albumins. Intracellular pH regulation is mainly based on equilibrium between molecular mechanisms which cause constant inflow to and removal of H^+ from the cell. Removal of H^+ takes place through exchange with Na^+ and requires some energy, whereas inflow of H^+ is a passive process and is involved in an exchange with Cl^- (Boron 2004, Balakrishnan et al. 2007, Celotto et al. 2008). Our own research showed that concentration of ions serving for calculation of SID and Atot in the peritoneal cavity fluid is very variable. At present, the authors of the presented article are working on the answer to the question, when calculation of SID and Atot on the basis of concentration of ions determined in a punc-

tate would be reliable. The numeric values of pCO_2 and HCO_3^- reflect their concentration in the blood serum (Di Bartola 2006a) and the fluid which accumulates in the peritoneal cavity in the course of renal failure has the nature of an effusion fluid (Glińska 2009), therefore the ABB parameters determined in the arterial blood and in the fluid should be as different as their values determined in the arterial and venous blood (Pomianowski et al. 2004, Sławuta et al. 2008). The results of the study presented in this paper can be explained by the ascites formation mechanism.

Migration of fluid through the capillary vessels wall into the peritoneal cavity is caused by changes in intravascular and tissue hydrostatic and oncotic pressure. The fluid leaks outside blood vessels because of an increase in intracapillary pressure and/or an increase in vessels permeability or a decrease in blood plasma oncotic pressure (McHutchison 1997). Albumins are proteins maintaining proper oncotic pressure in the vascular system. Moderate hypoalbuminemia does not cause leaking of fluid into the body cavities. Only severe hypoalbuminemia leads to such a significant decrease in oncotic pressure that it results in escape of fluid into extravascular space. In dogs with chronic kidney insufficiency a negative protein balance is caused by an excessive loss of protein with urine (Kjeldsberg at al. 1993). As a result, oncotic pressure decreases and there occur disorders in location of fluid in the intravascular and interstitial space. The amount of intravascular fluid declines and hypovolemia develops. In consequence, the renin-angiotensin-aldosteron system and the sympathetic system become subject to compensatory activation, accompanied by increased vasopressin secretion, which in turn result in retention of water and sodium in the body and initiation of a vicious disease cycle. The described mechanism of ascites formation in dogs with chronic renal insufficiency may lead to a situation in which transudate fluid accumulating in the peritoneal cavity is in fact similar to the arterial or capillary blood plasma, or their mixture, and the buffer system, bicarbonate-carbonic acid, analysed in the present study is related to the blood plasma. The studies of Pomianowski et al. (2004) and Sławuta et al. (2008) prove that the values of pCO_2 and HCO_3^- determined in the arterial blood and the capillary blood of the dogs are virtually the same despite drawing the capillary blood from different spots by the authors i.e. from the ear edge (Pomianowski et al. 2004) and the vascular bed of a claw (Sławuta et al. 2008). Hence, similar pH, pCO_2 and HCO_3^- values in the arterial blood andtransudate fluid may indicate that the vessel of which transudateoriginates is a fundamental factor determining these parameters.

The relationship between pH and SID was determined by Constable (2003), who observed that a decrease in SID by 1 mmol/L causes a decrease in pH by 0.016 – i.e. acidosis. Consequently, in accordance with the conclusions presented by Corey (2005), one may assume that an increase in SID value over the normal limit shows metabolic alkalosis. However, he did not give a ratio of SID numerical increase to pH increase. It is known that mathematical SID value depends on which ions are taken into account while calculating an apparent lack of anions. Constable (2003) and Corey (2005) did not mention which ions had been taken into consideration and that is why the present work contains SID_3 and SID_4 values whose norms for dogs are known (Siegling-Vlitakis et al. 2007). The SID_3 and SID_4 values obtained in this study corresponded with findings in dogs in which metabolic alkalosis was diagnosed in the right-sided heart failure (Sławuta i Glińska 2012).

Conclusions

1) In the case when the developed capillary network is a source of the fluid, the examined ABB parameters: pH, pCO_2 and HCO_3^- are similar to those determined for the arterial blood.

2) When it is impossible to collect the arterial blood, in the case of renal failure, the body cavity fluid may be used for the quick diagnosis of the ABB disorders.

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