Comparison of arterial and venous blood gas values in conscious dogs and dogs under anaesthesia induced by ketamine

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SUMMARY

The aim of the present study was to determine whether venous blood samples can be used as an alternative to arterial samples in conscious and in anaesthetised dogs. Blood gas parameters (blood pH, pCO2, HCO3-act, BEeff, ctCO2) were measured in the femoral artery and in the cephalic vein of 12 dogs before (conscious dogs) and during profound anaesthesia induced by ketamine (15 mg/kg IM) after sedation with xylazine (2 mg/kg IM). Anaesthesia induced significant increases of all arterial values of gas parameters except for pH values which have significantly decreased. Similarly venous values were also significantly modified except for BEeff and HCO3-act. Arterial pH values were significantly higher than venous values whereas all the other parameters were significantly lower in arterial blood in conscious and in anaesthetised dogs. High positive correlations were evidenced between arterial and venous values of a given parameter in conscious dogs (the correlation coefficients were comprised between 0.861 and 0.947) as well as in anaesthetised dogs although they were less intense (the correlation coefficients ranged from 0.824 to 0.895). During anaesthesia, the highest correlation rate (r>80%) was obtained between arterial and venous pH values. In conclusion, venous blood gas values can predict arterial values in healthy dogs with sufficient accuracy whereas only venous pH values may be used during ketamine anaesthesia.

Keywords: Artery, vein, blood gas, dog, ketamine, anaesthesia.

RÉSUMÉ

Le but de cette étude était de déterminer si des échantillons de sang veineux peuvent être employés comme alternative aux échantillons artérielles chez des chiens conscients ou anesthésiés. Les gaz sanguins (pH sanguin, pCO2, HCO3-act, BEeff, cCO2) ont été mesurés dans l’artère fémorale et dans la veine céphalique chez 12 chiens avant (animaux "conscients") et pendant une anesthésie profonde induite par la kétamine (15 mg/kg IM) après sédation par la xylazine (2 mg/kg, IM). Les valeurs artérielles ont été significativement plus élevées chez les chiens anesthésiés que chez les chiens conscients sauf le pH artériel qui a significativement diminué. De même, les valeurs veineuses à l’exception du BEeff et de la concentration en HCO3-act ont aussi été significativement altérées. Le pH artériel a été significativement plus élevé que le pH veineux alors que pour tous les autres paramètres sanguins, les valeurs artérielles ont été significativement plus faibles que les valeurs veineuses chez les chiens conscients et anesthésiés. Des fortes corrélations positives ont été obtenues entre les valeurs artérielles et veineuses d’un même paramètre avant et pendant l’anesthésie. Toutefois, en ce cas, elles sont apparues moins importantes: les coefficients de corrélation ont respectivement varié de 0.861 à 0.947 (avant) et de 0.824 à 0.895 (pendant l’anesthésie). Le taux de corrélation le plus élevé a été observé entre le pH artériel et le pH veineux chez les chiens anesthésiés (r>80%). En conclusion, les valeurs veineuses des gaz sanguins permettent de prédire les valeurs artérielles correspondants chez les chiens vigiles. En revanche, lors d’anesthésie induite par la kétamine, seul le pH veineux peut être utilisé dans cette optique.

Mots-clés : Artère, veine, gaz sanguin, chien, kétamine, anesthésie.

Introduction

Different anaesthetic drugs and their combinations alter blood gas and acid-base compositions [4, 5, 8, 12]. Anaesthesia is often accompanied by hypotension and hypothermia which adversely affect oxygen and fluid salt metabolism. The anaesthetics themselves can cause respiratory depression, alveolar hypoventilation and hypercapnia, which influence recovery from anaesthesia and can have undesirable results in critically ill patients [25].

Arterial blood sampling with subsequent analysis of blood gas parameters is of major importance in the assessment and management of a variety of clinical disorders in veterinary medicine and surgery [15, 18]. The clinical importance of the arterial blood analysis is to allow a better understanding of pathogenesis and to allow diagnosis of respiratory diseases, intoxications, anaemias, various diseases exerting primary or secondary effects on blood gas values and evaluation of the acid-base balance and blood gases [15]. Measurement of the partial pressure of carbon dioxide (pCO2) in sample of arterial blood by blood gas analysis is the best monitor of ventilation. Increasing in pCO2 (hypercapnia) is a direct consequence of hypoventilation and commonly occurs during anaesthesia [2, 4, 18, 20].

Frequent measurement of arterial blood gases is a routine component of intensive care management. Serial arterial blood gases are evaluated to monitor the patient progress to adjust oxygen and other medication regimens and make management decision concerning assisted ventilation, positive and expiratory pressure [16]. There are some differences between arterial and venous blood gas values. Blood pH and pO2 values obtained from venous blood show lower values than arterial blood. Venous pCO2 and HCO3 concentrations are also higher than in arterial blood [19]. It is usually admitted that the examination of venous blood does not yield complete information on the respiratory functions [20]. On the other hand, arterial punctures may require a considerable amount of restraint in small animals because they themselves can alter measured values. Furthermore, the arterial punctures are difficult to perform in small or obese animals and cannot be always carried out during surgical procedures because of inaccessibility of the puncture site [23]. In addition, arterial puncture is painful and carries risk for complications such as local haematoma, infection occlusion / embolisation of the artery with consequent ischemic injury to the digital extremities [10].

The aims of the present study were i) to determine the extent of correlation between acid-base parameters simultaneously obtained from venous and arterial samples in dogs prior to anaesthesia and under general anaesthesia and ii) to investigate whether venous samples can be used as an alternative to arterial values in conscious and anaesthetized patients.

Material and Methods

ANIMALS

Twelve clinically healthy mixed breed dogs (7 males and 5 females) which were admitted for ovario-hysterectomy or castration were included into the study. Their weight ranged from 12 to 21 kg (14.5 ± 2.1 kg), and they were 2 – 5 years old (mean 4.0 ± 0.3 year). Clinical and physical examinations were used to determine health status and ruled out any congenital and metabolic disorders.

EXPERIMENTAL PROTOCOL AND BIOCHEMICAL ANALYSIS

The study was approved by the local scientific ethics committee of Kafkas University.

Food was withheld for 12 hours before anaesthesia. Heart-respiratory rate and body temperature were recorded for each dog prior to and during anaesthesia. Before the beginning of anaesthesia, 2 ml of blood from the femoral artery and from the cephalic vein were withdrawn to compare the blood gas values. As soon as the blood sample was withdrawn through the femoral artery, cephalic venous blood samples were taken using a 22 to 23-gauge needle. Blood samples were stored in heparinized plastic syringes and analysed within 3 minutes of collection. The pH and pCO2 values were measured using a blood gas analyser (Chiron Diagnostics, Rapidlab 248, UK) according to their body temperature.

Values for actual bicarbonate (HCO3act), base excess of extracellular fluid (BEecf) and total carbon dioxide ctCO2 were derived by the same blood gas analyser.

After the initial blood gas analyses, dogs were sedated intramuscularly (IM) with xylazine (2 mg/kg) and 10 minutes after, they were anaesthetised by administration of ketamine (15 mg/kg, IM). Arterial and venous blood samples were taken when the dogs exhibited a profound anaesthesia (no reflexes and centrally positioned eyeballs which generally occurred 30 min after ketamine application). Measurements of venous and arterial blood gas values were repeated as described above.

STATISTICAL ANALYSES

The pH, pCO2, HCO3- and other values measured prior to and during anaesthesia from femoral and cephalic venous blood samples were first subjected to linear correlation analysis using Minitab statistical package programme (Version 11.2; 1996). Paired Student’s t-test was used to reveal statistical significance between the parameters of arterial and venous blood gas values. The relationship between arterial and venous values obtained before and during anaesthesia was examined using simple regression analysis. Statistical significance was considered at p<0.05. Results are expressed as means ± standard errors (s.e.).

Results

The mean heart and respiratory rates and body temperature were determined as 88.3 ± 5.1 battements / min , 22.8 ± 1.6 battements / min and 38.9 ± 0.1°C respectively before anaesthesia and as 71.8 ± 2.7 battements / min, 15.9 ± 1.0 battements / min and 38.3 ± 0.2°C during anaesthesia.

The mean ± s.e. values of arterial blood samples for pH, pCO2, HCO3act, BEecf, ctCO2 as well as the mean difference between arterial and venous values before and during anaesthesia were given in the Table I.

Table I and figures 1-3 present values of gas parameters obtained from femoral artery and from cephalic vein before and during anaesthesia. The values of all blood gas parameters measured in the artery except for the pH values were significantly lower than those obtained from venous blood before anaesthesia as well as during anaesthesia (pCO2, HCO3-act and ctCO2: p<0.001 and BEecf: p<0.01 in conscious dogs and p<0.05, in anaesthetised dogs except for BEecf). On the contrary, the pH values were significantly increased in the arterial blood compared to the venous blood (p<0.001) in conscious dogs as well as in anaesthetised dogs. Nevertheless, the mean differences between arterial and venous values of all gas parameters were depressed during anaesthesia.

Moreover, whereas arterial and venous pH values were significantly lowered in anaesthetised dogs compared to conscious dogs (p<0.001), ketamine anaesthesia has induced significant increases of the other gas parameters measured in arterial blood (p<0.001). Similarly, significant difference
was recorded for venous parameters except for HCO$_3$-act and BE$_{ecf}$ (p>0.05). In addition venous HCO$_3$-act and BE$_{ecf}$ values increased numerically during anaesthesia but were not statistically significant (Table I). Although there were significant differences between arterial and venous blood sampling for pH, pCO$_2$, HCO$_3$act, BE$_{ecf}$, ctCO$_2$ in both conscious and the anaesthetised dogs (p<0.001), the correlations between these parameters were higher in conscious dogs (r values: 0.947, 0.906, 0.914, 0.861 and 0.904 respectively) than in anaesthetised dogs (r values: 0.897, 0.854, 0.875, 0.824 and 0.867 respectively) (Table II). Despite the significant differences between arterial and venous values of gas parameters, arterial and venous values highly positively correlated together: in conscious dogs, the correlation coefficients were ranged from 0.861 for arterial vs. venous BE$_{ecf}$ to 0.947 for arterial vs. venous pH values (Table II). In anaesthetised dogs, arterial and venous parameters were also positively associated but with less intensity than prior anaesthesia: the coefficients of correlation varied from 0.824 to 0.895 (Table II).

### TABLE 1: Arterial and venous gas parameters measured in dogs (n = 12) before and during profound anaesthesia induced by ketamine (15 mg/kg, IM). Results are expressed as mean ± standard error.

<table>
<thead>
<tr>
<th>Gas parameter</th>
<th>Situation</th>
<th>Value</th>
<th>△</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>Before anaesthesia</td>
<td>7.411 ± 0.010$^{abA}$</td>
<td>7.376 ± 0.009$^{bA}$</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>7.351 ± 0.008$^{bB}$</td>
<td>7.326 ± 0.007$^{bB}$</td>
</tr>
<tr>
<td>pCO$_2$ (kPa)</td>
<td>Before anaesthesia</td>
<td>4.49 ± 0.13$^{bA}$</td>
<td>5.20 ± 0.14$^{bA}$</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>5.72 ± 0.13$^{bB}$</td>
<td>6.35 ± 0.12$^{bB}$</td>
</tr>
<tr>
<td>HCO$_3$-act (mmol/L)</td>
<td>Before anaesthesia</td>
<td>20.70 ± 0.46$^{abA}$</td>
<td>22.53 ± 0.53$^{b}$</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>22.06 ± 0.34$^{aB}$</td>
<td>23.20 ± 0.23$^{b}$</td>
</tr>
<tr>
<td>BE$_{ecf}$ (mmol/L)</td>
<td>Before anaesthesia</td>
<td>-4.01 ± 0.49$^{bA}$</td>
<td>-2.87 ± 0.53$^{b}$</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>-2.41 ± 0.27$^{bB}$</td>
<td>-3.07 ± 0.39$^{a}$</td>
</tr>
<tr>
<td>ctCO$_2$ (mmol/L)</td>
<td>Before anaesthesia</td>
<td>21.42 ± 0.35$^{abA}$</td>
<td>23.63 ± 0.46$^{bA}$</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>23.85 ± 0.39$^{bB}$</td>
<td>25.05 ± 0.44$^{bB}$</td>
</tr>
</tbody>
</table>

△: mean differences between arterial and venous values.
Different superscripts $a,b$ in a same line indicate significant differences (p<0.05) between arterial and venous values for a given gas parameter.
Different superscripts $A,B$ in a same row indicate significant differences (p<0.05) between conscious and anaesthetised dogs for a given gas parameter.

### TABLE 2: Correlations obtained between arterial and venous values of gas parameters measured in dogs (n = 12) before and during profound anaesthesia induced by ketamine (15 mg/kg, IM).

| Gas parameter | Situation | Value | r | p
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>pH</td>
<td>Before anaesthesia</td>
<td>pH$_a$ = -0.37 + 1.05 pH$_v$</td>
<td>r = 0.947</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>pH$_a$ = -0.10 + 1.02 pH$_v$</td>
<td>r = 0.897</td>
<td>0.001</td>
</tr>
<tr>
<td>pCO$_2$ (kPa)</td>
<td>Before anaesthesia</td>
<td>pCO$_2$a = -0.570 + 0.877 pCO$_2$v</td>
<td>r = 0.906</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>pCO$_2$a = -1.770 + 0.938 pCO$_2$v</td>
<td>r = 0.854</td>
<td>0.001</td>
</tr>
<tr>
<td>HCO$_3$-act (mmol/L)</td>
<td>Before anaesthesia</td>
<td>HCO$<em>3$$</em>{act}$$^a$ = 3.060 + 0.783 HCO$_3$-act$_v$</td>
<td>r = 0.914</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>HCO$<em>3$$</em>{act}$$^a$ = -8.150 + 1.300 HCO$_3$-act$_v$</td>
<td>r = 0.875</td>
<td>0.001</td>
</tr>
<tr>
<td>BE$_{ecf}$ (mmol/L)</td>
<td>Before anaesthesia</td>
<td>BE$<em>{ecf}$a = -1.730 + 0.795 BE$</em>{ecf}$v</td>
<td>r = 0.861</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>BE$<em>{ecf}$a = -0.659 + 0.570 BE$</em>{ecf}$v</td>
<td>r = 0.867</td>
<td>0.001</td>
</tr>
<tr>
<td>ctCO$_2$ (mmol/L)</td>
<td>Before anaesthesia</td>
<td>ctCO$_2$a = 5.190 + 0.687 ctCO$_2$v</td>
<td>r = 0.904</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>During anaesthesia</td>
<td>ctCO$_2$a = 4.400 + 0.777 ctCO$_2$v</td>
<td>r = 0.867</td>
<td>0.001</td>
</tr>
</tbody>
</table>

r: coefficient of correlation.

### Discussion

According to the literature [2, 21], anaesthesia induced decreases of the respiratory and heart rates as well as of the body temperature in the present study. In addition, depending on the decrease of the respiratory and heart rates, mean pH values decreased whereas pCO$_2$ and HCO$_3$- concentrations in arterial and venous blood significantly increased.

Anaesthesia agents markedly affect the respiratory center leading firstly to the decreases of the respiratory and heart rates and secondly to hypercapnia and to blood acidification.

Measurement of arterial blood gas values may reflect the effects of mechanical ventilation or of the metabolic and respiratory derangements that preceded the respiratory arrest.

Arterial blood gas analysis is the standard method of obtaining clinical acid-base assessment. However arterial sampling has some drawbacks such as painful and carries a small risk of vascular complications for the patients [15]. Therefore, the possibility of using venous blood gases as a substitute for arterial blood gases has been investigated in animal under general anaesthesia.

Studies have compared arterial and venous blood gas values and reported good correlations among arterial, capillary and venous samples in both humans and animals [6, 7, 9-11, 17, 24]. Studies in humans [3, 14, 26] and in dogs [9, 23] have reported that venous pH, pO2, pCO2, and HCO3-act measurements are in sufficient agreement with the arterial values if circulatory status is not impaired. In accordance with these previous studies, as pH values together with pCO2, HCO3-act, BEecf and ctCO2 of venous blood samples highly positively correlated with the corresponding arterial values in conscious dogs in the present experiment, they would be used for assessing blood gas chemistry.

Because a high positive correlation (r = 0.897) was observed between arterial and venous pH values in anaesthetised dogs, the present study suggested that only venous pH could substitute arterial pH values during anaesthesia. For the other blood parameters, the correlation rates were not as high as in conscious dogs (r<80%) (Table II). These findings were in agreement with those of MARTIN et al. [13] who examined the relationships between arterial and venous pH values in 24 adult dogs during open-chest surgery and concluded that venous pH is a sensitive indicator of arterial pH. However, BRANDENBURG and DIRE [1] and KELLY et al. [10, 11] found that also venous pCO2 can be used to screen for significant hypercapnia in emergency patients with acute respiratory diseases. In another study [4], venous pCO2 in anaesthetised patients were found to be a sensitive indicator.
for the same arterial values. These discrepancies with the present study may be attributed to the different drug combination used for anaesthesia (Diazepam + methohexital + pancuronium + fentanyl in [4] vs. ketamine in the present study). Since venous and arterial blood gas values would be influenced by the type of anaesthesia, the nature and the dosage of the drugs used [4], the possible substitution of arterial values with venous values would depend on the anaesthesia procedure. The effects of the other anaesthetic drug combination on arterial and venous blood gas values needs to be investigated in further studies. Arterial and venous pO2 values were not analysed in the present study. Because pO2 is higher in arterial blood, it would not be practical to use low venous pO2 values [15].

In conclusion, venous blood gas values may be used to predict the arterial pH, pCO2, HCO3-act, BEecf and ctCO2 blood gas values for healthy conscious dogs with a satisfactory level of accuracy but a lower accuracy in anaesthetised dogs except for pH compared to conscious dogs. The use of regression equations is possible, but such equations may be altered by the different types of anaesthesia used. Nevertheless, in necessary conditions venous pH estimation may be an acceptable substitute for arterial measurement for anaesthetised dogs and may reduce the risks of complications.

References