State of Acid-base Balance in Dehydrated Camels (Camelus dromedarius)

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ABSTRACT
There is a lack of information pertaining to the normal levels of acid-base parameters and the effects of dehydration on the acid-base balance in camels. The effect of water deprivation on acid-base balance was studied using five (2-years old) male dromedary camels. The camels were deprived of water for 7 days. Respiratory rate and blood gases were determined before the commencement and at the end of water deprivation period and during the first 48 h post rehydration. Blood pH did not differ significantly (p = 0.14) due to water deprivation in camels. However, respiratory rate was significantly (p = 0.001) elevated, while blood partial pressure of CO₂ (pCO₂), total CO₂ (tCO₂) and bicarbonate (HCO₃⁻) were significantly (p<0.1) reduced in water deprived camels. This study demonstrates that although blood pH remains within normal range in water deprived camels, the primary challenge to water deprived camels is a mild respiratory alkalosis induced by reduced blood pCO₂ which may be the result of an accelerated respiratory rate.

Key words: Acid-base, blood gases, blood pH, camel, dehydration

INTRODUCTION
Camel is a suitable desert animal that inhabits arid and semi-arid environments which are characterized by long periods of intense heat load and drought. Thermo-physiological mechanisms that enable camels to cope with water deprivation are well documented (Ayoub and Saleh, 1998; Al-Haidary, 2005, 2006; Abdoun et al., 2010). To our knowledge there is only one report (Yagil et al., 1975) on the impact of dehydration on acid-base status in camel. This report included only blood pH and pCO₂ as respiratory acid-base parameters. The vital limits of pH variation for mammals are between pH 7.36 and 7.44 (Houpt, 1989). Animal’s body utilizes three basic mechanisms: Chemical buffering, respiratory adjustment of blood carbonic acid and excretion of H⁺ or HCO₃⁻ by the kidneys to combat any changes in the normal acid-base balance (Houpt, 1989). Water deprivation and dehydration are known to affect the concentration of plasma albumin (Al-Haidary, 2005) and blood hemoglobin concentration (Ayoub and Saleh, 1998) which could alter the blood buffering capacity. Further, dehydration affects renal function (Yagki, 1998) and is associated with increased urine osmolality, reduced urine production and increased Na excretion (Ben Goumi et al., 1993). Moreover, dehydration is known to increase respiratory frequency and minute ventilation in camels (Schroter et al., 1987). It has also been reported that dehydration could result in changes of plasma cations and anions concentrations (Ayoub and Saleh, 1998;
Al-Haidary, 2005) which will be reflected on the alteration of Anionic Gap (AG). Anionic gap that contributes to the acid-base balance varies in response to changes in plasma concentrations of these components (Kirschbaum et al., 1999). These effects of dehydration might have impact on the acid-base balance. Therefore, the intention of this study was to investigate whether camels could maintain their acid-base balance under prolonged water deprivation conditions.

MATERIALS AND METHODS

Five (2-years old) clinically healthy male dromedary camels were purchased from the local market and transported to Experimental Farm Unit affiliated to Animal Production Department, College of Food and Agriculture Sciences, King Saud University, Riyadh. Camels were housed individually in shaded pens, fed at 2.5% of their body weight twice a day at 7:00 and 16:00 h on a commercial mix formulated pellets diet (ME 1950 kcal kg⁻¹, Crude protein 13%, Crude fat 2%, Crude fiber 10%, Ash 8% on DM basis) and had free access to clean tap water. During the experimental period water was withheld for 7 days.

Ambient temperature (Tₐ) was recorded continuously at 30 min interval using 2 data loggers (HOBO Pro Series data logger, Model H08-032-08, ONSET Co., USA) mounted at a height of approximately 2 m from the ground and placed away from direct sources of heat, sunlight and water. Special data logging software (BoxCar Pro 4, ONSET Co., USA) was applied for programming the loggers and for data analysis. The average daily ambient temperature (Tₐ) prevailed during the experimental period had a minimum value of 18.90±0.48°C and a maximum value of 39.21±0.75°C with an overall mean of 28.55±0.51°C.

Determination of the levels of blood acid-base parameters (blood pH, pCO₂, pO₂, HCO₃⁻, tCO₂, BE, O₂ saturation) was carried on whole venous blood samples (~2.5 mL) collected by jugular venipuncture using heparin coated syringes (Terumo Co., Japan). Whole blood samples were analyzed within 1 h of collection using blood gas analyzer (Rapid System, Somense, USA). Respiratory rate was counted at the space from 9th to 11th rib using stethoscope (Littmann Stethoscope, USA) and expressed as breath min⁻¹.

Statistical analysis: Statistical analysis of the data was performed using the software program SigmaPlot Statistics (SigmaPlot 11.0, Systat Software, Inc., San Jose, CA, USA). The changes in respiratory rate and acid-base parameters which occur after experimental dehydration on the same individuals was tested using paired t-test to determine whether or not the treatment (water deprivation) had a significant effect. By concentrating on the changes produced by the treatment instead of the values observed before and after the treatment, paired t-test eliminate the differences due to individual reactions which gives a more sensitive (or more powerful) test for finding an effect. The overall level for statistical significance was set at p<0.05. All values were presented as means±standard error of the means (Means±SEM).

RESULTS

Acid-base parameters of camels: During this study the blood acid-base parameters of dromedary camels was determined using venous blood samples collected from five adult apparently healthy camels. Table 1 shows the normal values of blood acid-base parameters of dromedary camel. Blood pH ranged from 7.28-7.44 with mean value of 7.35±0.03, pCO₂ ranged from 41.40-57.90 with mean
Table 1: Normal values of acid-base parameters in dromedary camels

<table>
<thead>
<tr>
<th>Acid-base parameters</th>
<th>Range</th>
<th>Mean±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (unit)</td>
<td>7.28-7.44</td>
<td>7.35±0.03</td>
</tr>
<tr>
<td>pCO₂ (mmHg)</td>
<td>41.40-57.90</td>
<td>49.50±4.46</td>
</tr>
<tr>
<td>tCO₂ (mmol L⁻¹)</td>
<td>25.00-30.00</td>
<td>28.25±1.11</td>
</tr>
<tr>
<td>HCO₃⁻ (mmol L⁻¹)</td>
<td>23.50-28.30</td>
<td>26.78±1.11</td>
</tr>
<tr>
<td>BE (mEq L⁻¹)</td>
<td>-2.00-4.00</td>
<td>1.25±1.25</td>
</tr>
<tr>
<td>pO₂ (mmHg)</td>
<td>23.00-26.00</td>
<td>24.25±0.63</td>
</tr>
<tr>
<td>O₂ saturation (%)</td>
<td>32.00-49.00</td>
<td>39.00±3.63</td>
</tr>
</tbody>
</table>

Fig. 1(a-b): Post rehydration recovery of (a) respiratory rate and (b) blood pH

value of 49.50±4.46 mmHg. tCO₂ ranged from 25.00-30.00 with mean value of 28.25±1.11 mmol L⁻¹, bicarbonate ion concentration ranged from 23.50-28.30 with mean value of 26.78±1.11 mmol L⁻¹, base excess ranged from -2.00-4.00 with mean value of 1.25±1.25 mEq L⁻¹, pO₂ ranged from 23.00-26.00 with mean value of 24.25±0.63 mmHg and O₂ saturation ranged from 32.00-49.00 with mean value of 39.00±3.63%.

Effects of dehydration on acid-base parameters: Water deprivation for 7 days resulted in a significant (p<0.01) elevation of the Respiratory Rate (RR) from 17.66±0.13 to 39.36±1.85 breath/min which is reflected in a significant (p<0.1) reduction of blood partial pressure of CO₂ (pCO₂) from 49.50±4.46 to 41.25±1.51 mmHg, blood total CO₂ (tCO₂) from 28.25±1.11 to 27.00±1.08 mmol L⁻¹ and blood bicarbonate (HCO₃⁻) concentration from 26.78±1.11 to 25.63±1.14 mmol L⁻¹. While, Base Excess (BE) was insignificantly reduced from 1.25±1.25 to 0.50±1.32 mEq L⁻¹. These resulted in a slight insignificant increase, albeit within the physiological range of blood pH from 7.35±0.03 to 7.40±0.01. Dehydration also resulted in a slight insignificant elevation of blood partial pressure of O₂ (pO₂) from 24.25±0.63 to 25.75±2.10 mmHg and that of O₂ saturation from 39.00±3.63 to 46.25±5.25% (Table 2).

Post rehydration recovery of acid-base parameters: Rehydration of camels resulted in a fast recovery of respiratory rate (from 39.36±1.85 breath/min) and blood pH (from 7.40±0.01) to the pre-dehydration levels (18.71±0.26 breath/min and 7.35±0.03, respectively) within 3 to 6 hours post rehydration (Fig. 1). However, other acid-base parameters (pCO₂, tCO₂, HCO₃⁻, BE, pO₂ and O₂ saturation) did not completely recover to pre-dehydration levels till 48 h post rehydration (Fig. 2a-f).
Table 2: Effects of dehydration on Respiratory Rate (RR) and acid-base parameters in dromedary camels (Means±SE)

<table>
<thead>
<tr>
<th></th>
<th>Euhydrated</th>
<th>Dehydrated</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR (breath/min)</td>
<td>17.66±0.13</td>
<td>39.96±1.85</td>
<td>0.001</td>
</tr>
<tr>
<td>pH (unit)</td>
<td>7.35±0.03</td>
<td>7.40±0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>pCO₂ (mmHg)</td>
<td>49.50±4.46</td>
<td>41.25±1.51</td>
<td>0.07</td>
</tr>
<tr>
<td>tCO₂ (mmol L⁻¹)</td>
<td>28.25±1.11</td>
<td>27.00±1.08</td>
<td>0.02</td>
</tr>
<tr>
<td>HCO₃⁻ (mmol L⁻¹)</td>
<td>26.78±1.11</td>
<td>25.63±1.14</td>
<td>0.03</td>
</tr>
<tr>
<td>BE (mEq L⁻¹)</td>
<td>1.25±1.25</td>
<td>0.50±1.32</td>
<td>0.32</td>
</tr>
<tr>
<td>pO₂ (mmHg)</td>
<td>24.25±0.63</td>
<td>25.75±2.10</td>
<td>0.06</td>
</tr>
<tr>
<td>O₂ saturation (%)</td>
<td>39.00±3.63</td>
<td>46.25±6.25</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Fig. 2(a-f): Post rehydration recovery of (a) pCO₂, (b) pO₂, (c) O₂ saturation, (d) tCO₂, (e) HCO₃⁻ and (f) BE
DISCUSSION

Knowledge of the acid-base status of camels is important for evaluating the physiological and health status of this species. Apart from isolated references to blood pH, pCO₂ and Stewart variables (Yagil et al., 1975; Elkhair and Hartmann, 2010) little is known about acid-base status in camels. Blood acid-base parameters of camels are reported for the first time in this study. The blood acid-base parameters of camels reported in this study were revealed using venous blood. It has been reported that venous blood samples are in most cases sufficient for the evaluation of uncomplicated acid-base disorders (Meintjes and Engelbrecht, 1995). The reported levels of blood acid-base parameters in camels differ from that reported in arterial blood of cows (Piccione et al., 2004), venous blood of steers (Parker et al., 2003) and venous blood of sheep (Srikanthakumar et al., 2003; Sobiech et al., 2005). However, similar to that reported in venous blood of white-tailed deer (DelGiudice et al., 1994).

Since the increase in body core temperature is known to stimulate both minute ventilation and respiratory rate (Schröter et al., 1987, 1989). The observed water deprivation induced significant (p = 0.001) increase in respiratory rate of camels could be a reflection of the dehydration induced elevation of body core temperature (Al-Haidary, 2005). Precise regulation of blood acid-base balance is vital because the activities of almost all enzyme systems in the body are influenced by the H⁺ concentration (Fraser, 1991). Although water deprivation tended to elevate blood pH (p = 0.14) in dromedary camels, the increase is within the normal range reported in this study (Table 1). However, water deprivation caused a tendency towards respiratory alkalosis and is most probably due to hyperventilation and the subsequent significant (p = 0.07) decrease in pCO₂ due to increased elimination of CO₂ (Table 2). The CO₂ eliminated is derived from carbonic acid (H₂CO₃) which dissociates to form CO₂ and H₂O. The HCO₃⁻ is converted to H₂CO₃ by receiving H⁺ from the buffer systems, such as hemoglobin, plasma proteins and extra cellular fluid phosphates which resulted in the observed significant (p = 0.03) reduction of HCO₃⁻ concentration. During respiratory alkalosis, a decrease in plasma HCO₃⁻ would be expected. Where, the body tries to compensate for the respiratory alkalosis by excreting HCO₃⁻ through the kidneys and retaining H⁺ ions. This could be supported by the reported elevation of aldosterone concentration in the blood of water deprived camels (Abdoun et al., 2010) which is known to stimulate H⁺ secretion by intercalated cells in the collecting duct, regulating plasma bicarbonate (HCO₃⁻) levels and its acid/base balance (Rector and Brenner, 2004). To support respiratory alkalosis, urine samples should have been collected for urine pH analysis.

Physiological systems attempt to maintain homeostasis so that BE (the deviation of buffer base of blood from the normal value) remains near zero. In this study Base Excess (BE) was maintained near zero after 7 days of water deprivation. Venous blood pO₂ and O₂ saturation tended to increase due to water deprivation. This could be the result of the reported reduction in feed intake and metabolic rate in water deprived camels (Fowler, 2010). Although, respiratory rate and blood pH returned to control values within 3 h of rehydration, respiratory acid-base parameters did not completely return to control values during 48 h post rehydration.

CONCLUSION

The results reported in this study identified reference values of acid-base parameters that can be used for the clinical diagnosis of acid-base disturbances in camels. Further, when dromedary camels were subjected to water deprivation, they were still able to maintain a normal acid-base balance despite the significant acceleration of their respiratory rate.
ACKNOWLEDGMENTS

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REFERENCES


