BLOOD GAS AND ACID-BASE PARAMETERS IN NON-TRANQUILISED ARABIAN ORYX *(ORYX LEUCORYX)* IN THE U.A.E

Conor Kilgallon, MVB, MSc, **Tom Bailey, BVSc, DipECAMS, Barbara Arca-Ruibal, Lic. en Vet., MSc, Martha Misheff, DVM, and Declan O'Donovan, BSc, MSc.**

From the University of California, Davis, California, USA (Kilgallon), the Dubai Falcon Hospital, PO Box 23919, Dubai, U.A.E. (Bailey and Arca-Ruibal), the Dubai Equine Hospital, P.O Box 9373Dubai, U.A.E (Misheff), and the Wadi Al Safa Wildlife Centre, Dubai, U.A.E. (O'Donovan). Correspondence should be directed to Kilgallon (e-mail: conchubhair2001@yahoo.co.uk, tel.: 00-44-7951967240)

Abstract: We report arterial and venous blood gas and acid base values established from a herd (n=19, 14 male, 5 female) of semi-free ranging Arabian oryx (*Oryx leucoryx*) in the United Arab Emirates. The animals were restrained using a modified raceway incorporating a commercially available handling crate. Statistically significant differences were found between arterial and venous values for PO_2 ($p < 0.001$), PCO_2 ($p=0.0141$), SO_2 ($p<0.001$), and pH (0.048). The results compare favourably to those reported for the same species under field anaesthetic conditions, and to those reported from other species of wild bovidae, both tranquilised and non-tranquilised, established under similar methods of restraint. In addition, Bland and Altman plots suggest adequate levels of clinical agreement between venous and arterial pH but not between arterial and venous PCO_2.

Keywords: Arabian Oryx, Acid Base, Blood gases, Non-tranquilised, i -STAT.

INTRODUCTION

Blood gas and acid base analyses are an integral part of anaesthetic and critical care monitoring in veterinary medicine. They provide dynamic insights into patient respiratory and electrolyte homeostasis, and can document early changes that warrant ventilatory and/or circulatory support. [7] The increased availability of portable analysers has facilitated the incorporation of blood-gas and acid-base balance analyses as valuable adjuncts to anaesthetic monitoring during field immobilisation of captive and free-ranging wild hoofstock. These animals are prone to acute and delayed capture myopathy with the associated spectrum of deleterious lactic acidosis, electrolyte imbalance, circulatory compromise of the musculature, hyperthermia, free radical elaboration, compounded by chemical induced respiratory depression and sub-optimal ventilation-perfusion indices.[13] Monitoring blood gas and acid-base parameters allows for the early detection of metabolic derangements, a swift instigation and assessment of measures to rectify them, and can provide prognostic insights for recovery.[5] Acid base analyses have been used as comparative criteria on which determinations of both the safety and suitability of anaesthetic regimens are based.[8, 18-19]

Although post-immobilisation values have been documented for a variety of wild bovidae under anaesthesia, little published data is presently available which documents reference values from non-anaesthetised animals.[1] Such information; would be a closer representation of normal physiological values, and, would invariably serve as definitive references against which parameter deviation due to the effects of different anaesthetic regimens might be compared. As a trend develops away from chemical immobilisation towards the utilisation of portable species adapted handling units, and the habituation of captive and semi-free-ranging ungulates to their use, future opportunities may present from which this vital information can be harvested. These systems were pioneered for use in the red deer farming industry in the United Kingdom and New Zealand,[9] the game ranching industry in South Africa,[2] and adapted and modified for waipiti (*Cervus elaphus*) and white-tailed deer (*Odocoileus virginianus*) farming in North America.[5]
The benefits of drug free handling systems have been documented on the basis that they eliminate immobilisation-associated risk factors, reduce expensive drug costs, and allow greater animal numbers to be handled per unit time.[11] Habituation to such a method of restraint is a prerequisite because there is a well-founded consensus that repeated exposure to unrelated psychological stressors can sensitise the hypothalamic-pituitary adrenal cortex (HPA) and the sympathetic-adrenal medullary axes resulting in exaggerated stress responses to novel stimuli.[4] Cortisol and catecholamine mediated distortions of haematology and blood biochemistry have been reported in captured impala and red deer[17]. Once habituation is achieved, haematological and biochemical profiles procured by such means would represent a truer representation of normal homeostasis, than when drugs are employed.

Field acquisition of venous samples as opposed to the arterial counterpart is a much quicker and easier undertaking especially in animals with circulatory compromise and it would be advantageous if venous values could replace arterial samples for PCO_2 and pH. In human emergency and critical care medicine, the question of whether or not venous blood gas and acid base values are a substitute for their arterial counterparts is a contentious one. Medical researchers found similar mean values for, and strong direct correlations ($r = 0.9689$ and $r = 0.9543$) between arterial and venous pH and HCO_3^- respectively, in patients presenting with diabetic ketoacidosis.[3] A study conducted on patients with acute respiratory disease, reported a mean difference between the samples of –0.4 units, and also a high level of agreement with the 95% limits of agreement being –0.110 to 0.04 units.[15] Another study by the same authors found insufficient agreement between venous and arterial PCO_2 for venous values to replace arterial values as a clinical adjunct; reported venous values were on average 5.8 mmHg higher and had excessively wide limits at the 95% confidence level (-8.8 to +20 mmHg).[14]

The principal aim of the present study was to establish arterial and venous blood-gas and acid-base parameters reference ranges for non-immobilised /non-tranquillised Arabian Oryx (*Oryx leucoryx*) restrained via a modified raceway and drop floor apparatus using a commercially available point of care portable blood-gas analyser, and to compare the results with previously documented values. Haematological and biochemical parameters were also compared with local and published reference values as a preliminary means of identifying stress based responses and as indication of habituation. Additionally, we assessed the level of clinical agreement between arterial and venous blood samples for pCO_2 and pH.

MATERIALS AND METHODS

Study animals

Fourteen adult males and five non-pregnant adult females were available for this study carried out at Wadi Al Safa Wildlife Centre (N25^0 05.234' E 055^0 15.786'), Dubai, United Arab Emirates during March 2006. All but one of the males (eight years-old) were between one and two years old. All available females were non-pregnant and greater than five years of age. They were maintained together as a semi-free ranging herd segregated from a larger herd and were fed alfalfa hay and trough fed 0.5–cm herbivore pellets for a period of three weeks prior to commencement of this study.

Handling facilities and study animals

The availability of a handling facility comprising of a chute system which channels animals from a holding pen along a narrow corral, and subsequent entrapment by a manually operated drop-floor crate (Tamer, Fauna Research, Red Hook, NY), facilitated the rapid and chemical free handling of the study herd.

Sampling procedure and blood analysis

Caudal auricular arterial blood samples from all nineteen animals were collected first into pre-heparinised syringes (PROVENTâ, SIMS Portex Ltd., UK.) using 27 gauge needles. Venous samples were similarly taken one minute later from the distal jugular vein. Carotid penetration and admixing with arterial blood (owing to close apposition of jugular vein and carotid artery at more proximal jugular sites (J. Klinne, Central Veterinary Regional Laboratory pathologist, personal communication, May 2006) was thus avoided. Both arterial and venous samples were analysed using a portable apparatus (i-STAT® Portable Clinical Analyser; Heskra Corporation, Fort Collins, USA) and accompanying cartridges (i-STAT EG_7^+, Heskra Corporation, Fort Collins, USA). With this apparatus, pH, partial pressure of oxygen (PO_2), partial pressure of carbon dioxide (PCO_2), ionic sodium (Na^{2+}), potassium (K^+), ionised calcium (iCa^{2+}), glucose and haematocrit (HCT) are calculated directly. Bicarbonate (HCO_3^-), base excess (BEecf), saturated oxygen (SO_2), and haemoglobin (Hb) are calculated values based on the directly measured parameters.[18, 23] Additional jugular blood was also collected into both Edta and heparin lined evacuated tubes (Vacutainer Systems, Becton Dickinson, Franklin Lakes, New Jersey, USA). Differential white cell counts for all animals were attained from this sample using a Cell Dyn 3700 automated analyser (Abbot Diagnostics). Blood urea nitrogen (BUN), Creatine kinase (CK), creatinine, aspartate amino transferase (AST), alanine amino transaminase (ALT), and lactate dehydrogenase (LDH) were also measured using a wet chemistry Hitachi 90011 Analyser (Boehringer, Mannheim, Germany).

Statistical analysis

Arterial and venous mean, standard deviation [SD], and range values for various blood gas, acid base and certain haematological parameters were calculated. As the dataset did not meet criteria for normal distribution distributed, arterial and venous values were compared non-parametrically using the Wilcoxon Rank Sum test for paired samples. Agreement between arterial and venous values for PCO_2 and pH was assessed using Bland and Altman plots of the differences between venous and arterial values respectively, and the averages of the two. Medcalc 7.2 Statistical Software (Medcalc, Mariak-

Table1. Arterial and venous blood gas, acid-base, and electrolyte values (Mean +/- SD [range]) from non-anaesthetised adult Arabian oryx (n=19; 14 male, 5 female).

Parameter	*n*	Arterial	Venous
PCO_2 mmHg[a]	19	34.63 +/- 3.92 (32.74-36.52)	39.32 +/- 6.13 (36.36-42.27)
PO_2 mmHg[a]	19	56.10 +/- 8.71 (51.90-60.30)	32.31 +/- 6.51 (29.17-35.45)
SO_2 %[a]	19	87.84 +/- 4.96 (85.44-90.23)	58.42 +/- 12.69 (52.30-64.54)
HCO_3^- mmol/l	19	21.68 +/- 3.05 (20.21- 23.15)	22.06 +/- 3.42 (20.41-23.71)
pH[a]	19	7.40 +/- 0.05 (7.37- 7.42)	7.36 +/- 0.05 (7.33-7.39)
BEecF[b]	19	-2.78 +/- 3.52 (-4.48 - -1.09)	-3.42 +/- 3.80 (-5.25 - -1.58)
Glucose mg/dl[a]	19	169.94 +/- 42.62 (149.4 – 190.5)*	184.57 +/- 40.13 (165.23-203.92)
Na^+ mmol/l	19	138.36 +/- 2.62 (137.10 – 139.63)	138.11 +/- 7.50 (134.48 – 141.72)
K^+ mmol/l	19	4.75 +/- 0.82 (4.35 – 5.15)	4.32 +/- 0.67 (4.01-4.65)
Ca^{2+} mmol/l[a]	19	1.16 +/- 0.06 (1.13- 1.19)*	1.19 +/- 0.05 (1.17-1.22)

[a] Significant ($p < 0.05$) difference between arterial and venous samples.
[b] Base excess.

erte, Belgium) was used for all statistical analyses. Statistical significance was set at $p < 0.05$.

RESULTS

The mean, standard deviation (SD), and reference ranges for the mean are displayed in Table 1 for the blood gas, acid base and electrolyte parameters assessed. Statistically significant differences were found between arterial and venous pH ($p=0.0494$), PCO_2 ($p = 0.0141$), PO2 ($p<0.01$), SO_2 ($P<0.0001$), and glucose ($p<0.0001$). Values for haematocrit, and differential white cell counts, shown in Table 2 were for the most part similar to normal ranges established and used for the species by the Central Veterinary Regional Laboratories (CVRL) Dubai (Wernery, personal communication, March 2006) and published values.[24] The bias (Bland - Altman) plot for agreement between arterial and venous pH (Figure 1) shows an average difference of –0.033, (with venous pH lower than arterial pH) with the 95% limits of agreement being –0.151 and 0.084. A bias plot showed poor agreement between arterial and venous PCO_2 with a mean difference of 4.7 mmHg. The 95 % limits of agreement were -10.2 to 19.6mmHg (venous PCO_2 being greater than arterial PCO_2; Figure 2).

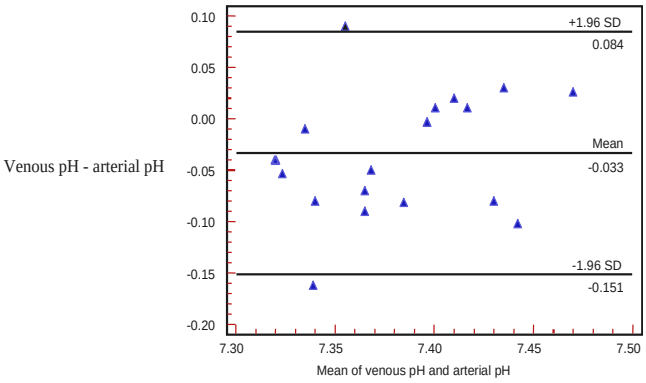

Figure 1. Plot of mean pH versus the difference between arterial and venous pH in a herd of non-anaesthetised Arabian Oryx (n=19; 14 male, 5 female)

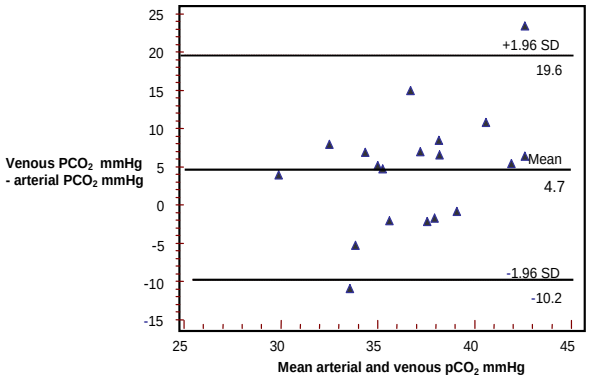

Figure 2. Plot of mean pCO_2 versus the difference between arterial and venous pCO_2 from a population of non-anaesthetised Arabian Oryx (n=19; 14 male, 5 female)

Table2. Comparison of haematology and blood chemistry values [mean ± SD (range)] in non-anaesthetized Arabian oryx (*n* = 19; 14 male, 5 female), with published reference ranges.

Parameter	Units	Study population	Reference range[b]	Published data from reference 24 [mean ± confidence interval at 5% (range)]	Units
Hematocrit	%	[A]45.11 ± 2.84 (43.72–46.47)	45.0–63.0	41.5 ± 1.3 (32.34–56.66)	%
		[V]41.79 ± 1.84 (40.90–42.68)			
White blood cell count	10^9/L	7.31 ± 1.99 (5.4–12.1)	4–12	3.48 ± 0.32 (0.95–6.01)	$10^3/mm^3$
Neutrophils	%	76.29 ± 9.02 (62.8–83.1)	60–80	75.2 ± 0.24 (56.5–93.5)	%
Lymphocytes	%	19.73 ± 7.85 (7.3–31.0)	5–30	20.56 ± 2.3 (2.87–38.25)	%
Eosinophils	%	0.33 ± 0.27 (0–0.9)	0–3	2.86 ± 0.5 (0–7.87)	%
Monocytes	%	3.08 ± 1.28 (0.3–5.0)	0–6	1.0 ± 0.29 (0–3.25)	%

[a] Superscript A, arterial; superscript V, venous.
[b] Central Veterinary Regional Laboratories, Dubai (Wernery, pers. comm.).

DISCUSSION

Blood gas and acid base reference values have been documented for only a few wild ungulate species.[1] Of those that have been published, the majority were established under chemical immobilisation (e.g. Bongo (*Tragelaphus eurycerus*) and Eland (*Tragelaphus oryx*)[1], White Rhinoceros (*Ceratotherium simum)*[8], as criteria for the comparison of different anaesthetic protocols,[3, 8, 16, 18] or from non-domestic species geographically and climatically removed from their natural environment.[20] The use of an i-STAT® Portable Clinical Analyser and pre-heparinised syringes in this study facilitated rapid generation of results. This apparatus has been shown to perform favourably with published performance standards in humans, [18] and in dogs, [23] even in the hands of operators lacking training in laboratory techniques.

As far as the authors are aware, these are the first blood gas and acid-base reference values for non-immobilised free-ranging Arabian oryx in their natural environment. Previously available data is based on studies involving anaesthetised animals. One such study documented arterial blood gas, acid base, and electrolyte parameters from translocated Arabian oryx immobilised using two different anaesthetic regimens.[19] The most remarkable differences are the low arterial SO_2 and PO_2 values we have documented compared to mean arterial PO_2 and SO_2 values (PO_2 : 98.7/109.3 mmHg and 84/115 mmHg, SO_2: 92.6/94.9 mmHg and 89.4/96.3 mmHg) before and after translocation with each regimen in the months of August and November respectively reported by the referenced study.[19]Supplemental oxygen under anaesthesia might account for such high values though the owners do not state whether or not such was the case. The authors do however report respiratory and stress induced lactic acidosis (PCO_2: 68.6/65.9 mmHg and 82.9/75.3 mmHg, pH: 7.205/7.24 and 7.191/7.23) for the two immobilisation regimens respectively. In contrast, the values for arterial and venous PCO_2, Base excess (BEecf) and pH reported in the present study are significantly lower and within normal ranges documented for domestic cattle.[10] We conclude this to be due to more effective buffering and elimination of CO_2 via compensatory hyperventilation (note the low mean value for PCO_2: 37.74-36.52 mmHg) in the crate restrained animals. Other workers have noted that high values for SO_2 alone do not imply satisfactory oxygenation and ventilatory status in immobilised antelope patients, as they can occur concurrently with hypercapnoea and respiratory acidosis. This would indeed appear to have occurred in the study referenced here.[13]

Though it is plausible to surmise that true differences exist attributable to sex and age, the nature of the available sample population where all available males bar one were less than two years, and all available females were greater than five year of age precludes statistical based conclusions in this regard. More evenly distributed age and sex ratios are required to elucidate the interactions of these two factors and their influence on the parameters being studied.

Cortisol was not analysed in the current study. We report differential haematological and blood chemistry values comparable to local established reference ranges and published normal data[24] which were inevitably derived from samples procured from immobilised animals as no published data procured by the means we describe here is currently available. There is a fair disparity between the absolute leucocyte count we report and the published values chosen as a comparison.[24]This may possibly be due to disparities between the automated methods we have used and the manual methods of cell counting in this other study. In actual fact, this total white blood cell count we have recorded is more comparable to those values presented by other workers (6.2 10^9/L).[16] However, as far as differential counts are concerned there is a fair degree of agreement between the relative percentage counts of haematocrit, neutrophils, and lymphocytes between the two studies and this is more important when interpreting stress mediated changes. There is no great evidence of lymphopenia and left shift neutrophilia similar to those which were reported from studies involving red deer (*Cervus elaphus*), and which were attributed to the effects of chronic captive stress and cortisol mediated responses.[17] Neither do we report significantly elevated arterial or venous haematocrit values, indicative of stress mediated α-adrenergic splenic contraction.[7] Both the mean, median and range for venous and arterial glucose we report are comparable to documented values (mean glucose, 1.95 g/l, range, 0.64-3.25 g/l, n=63).[24] These facts, in addition to the blood gas and acid base readings, suggest that these oryx were reasonably well adapted to multiple capture events involving the above handling system. This is further supported by alluding to the results of another study,[1] which incorporated a similar handling system when evaluating the physiological advantages of incorporating pre-capture haloperidol and oxygen supplementation to Bongo (*Tragelaphus eurycerus*) and Eland (*Tragelaphus oryx*). In this study on non-habituated animals, based upon caudal auricular arterial samples and incorporating a similar portable analyser (i-STAT), significant lactic acidosis was encountered in the non-tranquillised sample population. The mean arterial pH (7.19), and mean base excess values (-14.33) reported suggest that buffering systems in these excited animals were overwhelmed. The values we have reported are more comparable with the tranquilised and thus much less stressed subpopulation in the same study (mean arterial pH = 7.36, base excess = -8.95, PCO_2 = 24.6).

In our study significant differences existed between arterial and venous PCO_2 ($p=0.0141$), with a mean difference of 4.8 mmHg between the values, and 95 % limits of agreement that were too wide (-10.2 to 19.6 units) to be clinically trustworthy. With regard to pH values, though a slight statistically significant difference ($p=0.0494$) was found between paired arterial and venous samples, the 95% limits of agreement reported by the Bland –Altman bias plot were –0.151 to 0.08 mmHg, not much wider than those from human research.[15] We conclude that that in our population, venous sample values for pH matched arterial values closely enough to be a substitute on a clinical level.

CONCLUSIONS

We have reported arterial and venous blood gas, electrolyte and acid base values for semi-free ranging Arabian oryx manually restrained by a modified chute system incorporating a trap-door restraining crate. Prior habituation resulted in a mitigation of capture stress and lactic acidosis. Significant differences exist between venous and arterial samples for vital blood gas and acid base parameters. Hence venous samples cannot replace arterial ones for clinical decisions and management. There is evidence to suggest that despite restraint induced hypoxemia, compensatory ventilation and buffering responses successfully maintained acid–base homeostasis, comparing favourably with values from studies involving chemically immobilised free-ranging Arabian Oryx, and with those reported from other non-domestic bovidae (both tranquillised and non-tranquillised) subjected to manual handling systems. Similar studies incorporating the use of tranquillisers, and chronological analyses of plasma cortisol, muscle and kidney enzymology, and haematological responses would

embellish our understanding of acid-base and blood gas physiology in this species. They might also elucidate more completely the extent of stress or habituation accompanying such capture events as a means of evaluating manual handling systems from an animal welfare standpoint.

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