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Point of Care Blood Gas and Electrolyte Analysis in Anesthetized Olive Baboons (*Papio anubis*) in a Field Setting

Maureen W. Kamau[1,3] · James M. Hassell[1] · Ellie L. Milnes[1] · Lee-Ann C. Hayek[2] · Mathew M. Mutinda[8] · Roi Harel[4,5,7] · Akiko Matsumoto-Oda[9] · Jennifer H. Yu[1] · Dawn Zimmerman[1] · Margaret Crofoot[4,5,6,7] · Suzan Murray[1]

Abstract

Biotelemetry requires animal captures to deploy collars. Capture raises ethical concerns, as field chemical immobilizations are complex procedures, during which respiratory and metabolic disturbances frequently occur, which can disrupt cardiovascular, neurologic, and respiratory function. The use of tools and techniques to maximize animal safety and maintain physiological stability in anesthetized primates is crucial. We examined the use of blood gas and electrolyte analysis to enhance basic anesthesia monitoring in a field setting. We provide preliminary values for venous blood gas and electrolyte parameters (pH, partial pressure of CO_2, base excess, bicarbonate, total CO_2, sodium, potassium, ionized calcium, glucose, hematocrit, and hemoglobin) obtained using the iSTAT-1 analyzer and iSTAT CG8+ cartridges from 23 olive baboons (*Papio anubis*) captured in July 14–18, 2019, at Mpala Research Centre in Laikipia County, Kenya. We also tested for age and sex differences in the blood gas and electrolyte values. The reference values showed that some of the olive baboons experienced metabolic alkalosis with respiratory compensation, presumably as a result of chloride depletion through sweat from the high ambient temperatures. None of the measures showed significant variation by age or sex. We recommend providing shaded baited cage traps during capture to minimize risk of hyperthermia. Our findings suggest that rapid provision of blood gas and electrolyte parameters in a field setting augments basic anesthetic monitoring and translates to improved anesthetic protocols and safety of immobilized primates.

Keywords Baboons · Blood gas · Electrolytes · Free ranging · Olive baboons · *Papio anubis* · Reference intervals

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✉ Maureen W. Kamau
maureen.wanjiku.k@gmail.com

Extended author information available on the last page of the article

Introduction

Primates are commonly immobilized in field conditions for biomedical research, disease surveillance, health checks, translocations, clinical treatment, and to fit monitoring aids for ecological research (Crofoot *et al.* 2009; Glander 2013; Sleeman *et al.* 2000; Unwin *et al.* 2011). Wildlife research using biotelemetry requires animal captures to deploy collars, providing an opportunity to study physiology, behavior, ecology, and evolution (Hebblewhite and Haydon 2010; Kays *et al.* 2015; Tomkiewicz *et al.* 2010). Primate field capture raises ethical concerns, as field chemical immobilizations are complex procedures during which respiratory and metabolic disturbances are common (Fedigan 2010; West *et al.* 2014). Ensuring the survival and physiological stability of primates during anesthesia using tools and techniques that maximize animal safety is crucial (Chinnadurai *et al.* 2016).

Basic anesthetic monitoring entails measuring temperature, heart rate, and respiratory rate and assessing the color of mucous membranes using simple noninvasive equipment: a stethoscope, thermometer, and the anesthetist's eyes and ears (Chinnadurai *et al.* 2016). Additional monitoring equipment such as capnographs and pulse oximetry are also increasingly used in the field (West *et al.* 2014). The development of cost-effective, portable point of care blood gas analyzers has led to the adoption of blood gas analysis for field wildlife immobilizations (Montesinos and Ardiaca 2013). These machines measure a range of blood parameters including partial pressures of oxygen (pO_2) and carbon dioxide (pCO_2), pH, total carbon dioxide (tCO_2), base excess of extracellular fluid (BEecf), oxygen saturation (sO_2), and bicarbonate (HCO_3^-) in small volumes of blood at the patient's side, thus reducing time between collection and analysis of samples.

Reference values, which describe the dispersion of variables (all possible values between and including an upper and lower limit) in well-characterized groups of individuals, are used to interpret results from routinely used tests such as blood gas and electrolyte analysis (Harris and Boyd 1990; Friedrichs *et al.* 2012). Reference values are influenced by many factors, such as endogenous, exogenous, genetic, statistical, and laboratory factors, making one set of reference values inapplicable to all individuals in a population (Harris and Boyd 1990). Age and sex differences have been reported in long-tailed macaque (*Macaca fascicularis*) blood gas and electrolyte parameters and olive baboons' blood chemistry parameters, as a result of age-dependent declines in the cardiorespiratory system and sex-dependent metabolic differences (Mutinda *et al.* 2019; Nakayama *et al.* 2017). To improve the usefulness of population-based reference values, partitioning into subclasses based on physiological differences (e.g., age and sex) when there are documented differences between subgroups is recommended.

Olive baboons (*Papio anubis*) are widely distributed through most of central sub-Saharan Africa (Kingdon *et al.* 2008). Their geographic spread and ecological flexibility, ranging from savanna, grassland, shrubland, and forest, make them important study subjects for behavioral ecology (Johnson *et al.* 2015). Their tendency to live in close association with humans poses a significant public health risk, given that *ca.* 75% of human zoonotic emerging infectious diseases have a wildlife source (Cutler *et al.* 2010). Humans and olive baboons also share many anatomical and physiological similarities, making olive baboons valuable models for human infectious diseases

and translational medicine (Gurung *et al*. 2018). The olive baboon is commonly immobilized in field settings and use of blood gas analyzers can enhance their safety and physiological stability while anesthetized.

We monitored blood gas and electrolyte status in anesthetized primates in a field setting and provide preliminary values for 11 venous blood gas and electrolyte parameters from anesthetized free-ranging olive baboons. We also tested for age and sex differences in the baboon's blood gas and electrolyte values.

Methods

Study Site

We conducted the study at Mpala Research Centre (36.88599°N, 00.30644°E), located at the equator in Laikipia County, Kenya. The region is characterized by arid- and semiarid savannas and woodlands. Olive baboons are numerous in the conservancy and surrounding settlements. Despite the drastic decline in most wildlife populations due to illegal poaching, habitat loss, land fragmentation, and climate change, olive baboon populations in Kenya are on the rise and the species is listed as being of least concern (Kingdon *et al*. 2008).

Study Design and Sample Collection

We collected venous blood samples from 23 olive baboons, including 12 females and 11 males in July 14–18, 2019, as part of a larger study on baboon behavioral ecology. Two weeks prior to capture, we habituated baboons to baited walk-in wire cage traps (1 m × 1 m × 1.8 m, $L \times W \times H$), set close to their sleeping sites. The traps are designed to close automatically after the baboons pull on the bait releasing the vertical sliding door. On the day of capture, we baited traps in the early morning or late evening to capture the baboons as they foraged to and from their sleeping sites. We processed the baboons as soon as most baited cage traps had captured a baboon (i.e., within *ca*. 1 h). If more than one baboon was captured in a single trap (except for females with dependent infants), we set one of the baboons free to allow for safe sedation.

Once captured, we estimated visually the baboon's body mass to determine anesthetic drug dosages. We anesthetized the baboons in batches of two or three individuals, prioritizing females with dependent infants and subadults. We released any captured baboons that had not yet been processed at mid-day when ambient temperatures were high to reduce risks of hyperthermia.

We used a combination of 10 mg/kg of ketamine hydrochloride (Ketamin 10%, Bremer Pharma GmbH, Warburg, Germany) and 0.03 mg/kg of medetomidine (Domitor, Zoetis Ltd., Parssipany-Troy Hills, NJ, USA to anesthetize the baboons). We passed wooden rods on either side of the baited cage traps to serve as squeeze panels for the baboons and administered the anesthetic drugs by deep intramuscular injection using a hand syringe through the wires of the cage. We determined a baboon's actual body mass once it was recumbent using large animal scales (Proship XL, Abcon, Essex, UK). We divided the baboons into 3 age classes: 8 adults, 11 subadults, and 4 juveniles, as determined by body size and development of secondary sexual characteristics (Altmann *et al*. 1981). We fitted all individuals, except juveniles, with GPS

collars (e-Obs Digital Telemetry, Gruenwald, Germany). The GPS collars were equipped with automated breakaway units (SureDrop, Advanced Telemetry Systems, Isanti, MI, USA) preprogrammed to fall off after 1 mo.

We deemed all individuals to be healthy based on full physical examination. We maintained anesthesia at the first plane of the third stage of anesthesia (Guedel 1937). We monitored anesthesia by assessing the vital parameters (temperature, heart rate, respiratory rate, and arterial oxygen saturation of hemoglobin) at recumbency and every 5 min thereafter for 15 min. We recorded heart rate and arterial oxygen saturation of hemoglobin simultaneously using a pulse oximeter (Masimo Rad-5v, Masimo Corp., Irvine, CA, USA) with the probe placed on the baboon's tongue. We obtained body temperature from a veterinary digital thermometer placed in the rectum and respiratory rate by counting chest movements. Some of the baboons were observed to be sweaty at recumbency and we doused baboons with a rectal temperature higher than 39.5°C with water to prevent hyperthermia from environmental conditions.

Within 5 min of recumbency, we collected 1 mL of venous blood from the femoral vein of each baboon, using a plain syringe and needle, and emptied it into a 1.3-mL lithium heparin tube, according to the user manual for the iSTAT 1 portable point of care blood gas analyzer (Abbott Laboratories, Chicago, IL, USA). This ensured that the blood was not diluted more than 5% and concentration of lithium heparin was at 200 IU/mL of blood, so as not to interfere with some analytes (Higgins 2007). We capped the lithium heparin tubes immediately after pouring blood into them and opened them only during analysis, thus limiting diffusion of room air oxygen and carbon dioxide.

When we completed collaring and sample collection, we moved the baboons to individual recovery cages in the shade, where we continued to monitor respiratory rate at regular intervals. Further monitoring of other vital parameters was not possible for human safety reasons. We reversed the anesthesia with atipamezole (Antisedan, Zoetis Ltd., Parsippany-Troy Hills, NJ, USA) at five times the medetomidine dose by intramuscular injection, 45 min after the administration of ketamine and medetomidine. We allowed the baboons to cover individually in shaded cage traps before releasing them to rejoin the rest of the baboon group.

Sample Analysis

We analyzed the venous blood for blood gases and electrolytes within 5 min of collection, using the i-STAT 1 portable point of care blood gas analyzer and i-STAT CG8+ cartridges (Abaxis, Union City, CA, USA). We kept the CG8+ cartridges refrigerated until transport to the field when we stored them on cool packs in a cool box. Prior to use, we kept the CG8+ cartridge at room temperature for 5 min, as indicated by the manufacturer. The cartridge provided results for pO_2, pCO_2, pH, bicarbonate (HCO_3), total carbon dioxide (tCO_2), oxygen saturations (O_2), base excess (BE), sodium (Na), potassium (K), free ionized calcium (iCa), glucose (GLU), hematocrit, and hemoglobin. pO_2, pCO_2, pH, Na, K, iCa, glucose, and hematocrit are measured directly from blood within the machine, while values for tCO, HCO_3, BE, sO_2, and hemoglobin are calculated via an algorithm.

Since venous blood was collected, we deemed that the pO_2 and sO_2 values were not clinically useful and eliminated them from further analysis. We calculated the blood gas parameters in this study from venous blood samples collected from the femoral vein, a

commonly used venipuncture site in nonhuman primates (West *et al*. 2014). Although arterial blood gas analysis is the gold standard in clinical practice and arterial blood can be sampled in field anesthesia, venous blood samples are much more easily collected from immobilized wildlife in a field setting. Venous pH, bicarbonate, base excess, and electrolyte values are comparable to those calculated from arterial samples (Malatesha *et al*. 2007; Onmaz *et al*. 2009).

Statistical Analysis

We calculated descriptive statistics for the 11 blood gas measures and tested assumptions of normality with fitted histograms, Kolmogorov–Smirnov tests, and Shapiro–Wilks tests. We used Levene's test to test the assumption of homogeneity of variance. We transformed each measure that showed nonnormality or heterogeneity of variance such that all tests performed were parametric. The natural log satisfied both heteroscedasticity of variance and normality. We used general linear models (GLMs) developed to test for significant effects of sex, age, and their interaction, both with and without body mass as a covariate. We used Scheffé's tests to test for multiple group differences. We report statistics as raw measures for ease of understanding.

We determined reference intervals and 90% confidence intervals around the upper and lower reference limits for each measure to provide an estimate of uncertainty of the limits using Reference Value Advisor (Geffré *et al*. 2011). As the sample size was <40 and the population variances were unknown for each set of results, we estimated the sampling distribution of the mean for each variable using the Student's *t*-distribution, as required by the program.

We attempted to take measurements of temperature, heart rate, respiratory rate, and arterial oxygen saturation of hemoglobin four times for each individual: 0, 5, 10, and 15 min but were unable to obtain a complete data set. We were unable to measure all individuals for each variable at each time for a variety of reasons, most notably because the priority was fitting of GPS collars. Missing data ranged from 35% (heart rate, temperature), and 48% for oxygen saturation to 57% for respiratory rate. The monitoring data was also nonrandomly collected because other measurements were given priority and taken concurrently with these four. Thus if an animal posed a problematic situation the monitoring values would not have been recorded; consequently, there was a large amount of nonrandom missing data

A repeated measures model within the GLM procedure uses listwise deletion for missing data and therefore was not possible for assessing the remaining longitudinal values. A mixed linear model is a currently popular generalization of the GLM that allows the data to have a covariance structure and nonconstant variability and can handle some missing values. However, the excessive proportion of nonrandom missing data here pose serious estimation problems for longitudinal/monitoring studies so that even when the procedure can converge the parameter estimates are known to be biased. We therefore examined the data with a descriptive approach.

Ethical Note

All procedures were subject to ethical review and were carried out in accordance with the approved guidelines set out by the National Commission for Science, Technology

and Innovation of the Republic of Kenya (NACOSTI/P/19/55517/24299). Baboon collaring and tracking was approved by the University of California, Davis (IACUC No. 20442) and the Kenyan Wildlife Service (KWS/BRM/5001). The authors declare that they have no conflict of interest.

Data Availability The datasets analyzed during this study are available from the corresponding author on reasonable request.

Results

The baboons' respiratory rate decreased over the 0–5-min interval and remained stable thereafter. The temperature decreased throughout the first 15 min of anesthesia. The heart rate increased over the 0–5-min interval followed by a decline while the oxygen saturation of hemoglobin fluctuated throughout the first 15 min of anesthesia (Fig. 1).

Reference intervals and 90% confidence intervals around the upper and lower reference limit on Table I were calculated by Reference Value Advisor on the endpoints (Geffre *et al*. 2011). For these measures no significant sexual dimorphism (Table II) or age differences (Table III) were detected.

Discussion

This pilot study shows potential use of point of care equipment to provide rapid assessment of blood gas, electrolyte, and acid–base status of anesthetized primates in a field setting to augment basic anesthesia monitoring. The baboon's vital parameters remained stable, except for temperature where temperature decreased at the 10-min and 15-min time intervals. A pH higher than 7.45, increased HCO_3 and a decrease in the pCO_2 relative to published data suggest that some of the baboons were experiencing metabolic alkalosis with respiratory compensation as a result of chloride depletion through sweat from the high ambient temperatures. We did not administer oxygen supplementation and fluid therapy because oflogistical constraints in our pilot study, but we recommend providing shade over the baited cage traps to minimize risk of hyperthermia, oxygen supplementation, and parenteral administration of fluids as future corrective measures. We also provide a set of preliminary values that can be used to monitor the physiological status of free-ranging olive baboons under anesthesia.

The heart rate of the anesthetized olive baboons was within normal limits (Tatoyan and Cherkovich 1972). The decrease in the baboons' temperature is likely to be a result of dousing the baboons with water and the ketamine–medetomidine drug combination (Alsobayil *et al.* 2018). The arterial oxygen saturation of hemoglobin fluctuated at values <85%, indicating hypoxemia and thus we recommend oxygen supplementation for future field baboon immobilizations using the ketamine–medetomidine drug combination. The elevated respiratory rate at recumbency may have been a result of hyperventilation in response to high ambient temperatures coupled with stress from cage capture (Hiley 1976).

Blood gas and electrolyte values obtained on this pilot study were comparable to those obtained from captive baboons (*Papio* spp.), chimpanzees (*Pan troglodytes*),

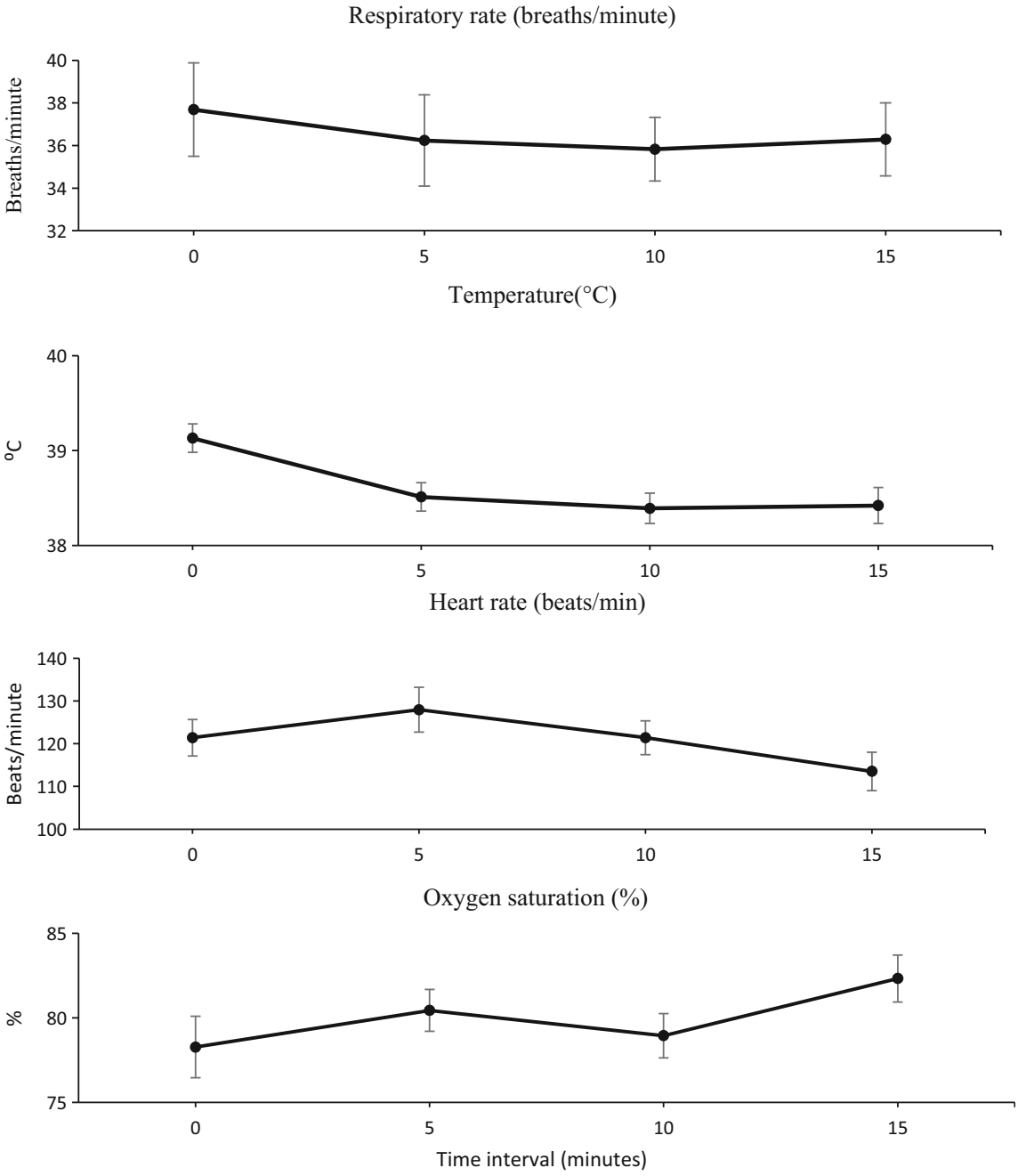

Fig. 1 Trends in vital parameters of 23 olive baboons (Papio anubis) anesthetized with a combination of ketamine hydrochloride and medetomidine, July 14–18, 2019, at Mpala Research Centre in Laikipia County Kenya. The standard error of mean is plotted as a measure of variation.

rhesus macaques (*Macaca mulatta*), and long-tailed macaques. However, measures for HCO_3 and BEecf in this study were higher while pCO_2 was lower than published data (Hainsey *et al.* 1993; Lee *et al.* 2012; Nakayama *et al.* 2017; Schuurman *et al.* 2004). The olive baboons' venous blood gas pCO_2 values were comparable to values obtained from hamadryas baboons (*Papio hamadryas*) (Alsobayil *et al.* 2018) (Table IV). The values reported from captive baboons, chimpanzees, rhesus macaques, and long-tailed macaques were obtained from arterial samples while values reported from the hamadryas baboons were obtained from venous samples baboons (Alsobayil *et al.* 2018; Hainsey *et al.* 1993; Lee *et al.* 2012; Nakayama *et al.* 2017; Schuurman *et al.* 2004). Owing to differences in the physiology of venous and arterial CO_2 and O_2

Table I Blood gas and electrolyte descriptive statistics and reference intervals for 23 free ranging olive baboons (*Papio anubis*) captured in July 14–18, 2019, at Mpala Research Centre in Laikipia County Kenya

Analyte	Units	Mean	SD	Median	Min	Max	Reference interval	90% CI for lower reference limit	90% CI for upper reference limit	Distribution	Method
pH		7.49	0.410	7.50	7.41	7.55	7.4057–7.5829	7.3799–7.4385	7.5612–7.6037	Non-Gaussian	Robust
pCO_2	mm Hg	36.62	4.65	39.90	29.90	48.80	30.10–49.83	26.71–33.72	46.78–52.43	Non-Gaussian	Robust
BE	mmol/L	6.96	4.073	9.00	0	13	−1.7 to 15.6	−3.4 to 1	13.8–16.7	Gaussian	Parametric
HCO_3	mmol/L	30.37	3.754	32.30	24.80	35.70	22.42–38.33	20.98–24.77	36.63–39.27	Gaussian	Parametric
TCO_2	mmol/L	31.61	3.811	34.00	28	37	23.5–39.7	22.1–25.9	37.9–40.7	Gaussian	Parametric
Na	mmol/L	145.65	2.690	146.00	141	152	140–151.4	138.5–141.6	149.7–153	Gaussian	Parametric
K	mmol/L	3.52	0.533	3.30	2.80	4.40	2.39–4.65	2.25–2.61	4.27–4.93	Gaussian	Parametric
iCa	mmol/L	1.11	0.098	1.11	0.77	1.26	0.905–1.321	0.794–1.022	1.234–1.385	Gaussian	Parametric
GLU	mmol/L	6.33	1.74	5.94	4	10.49	2.66–10.01	2–3.61	8.32–11.38	Gaussian	Parametric
HCT	%	38.91	2.275	39.00	35	44	34–43.68	NE	NE	Non-Gaussian	Robust
Hgb	g/dL	13.23	0.773	13.30	11.90	15.00	NE–14.64	NE	14.06–15.01	Gaussian	Parametric after Box–Cox transformation

CI = confidence interval; NE = variable could not be estimated

Table II Comparison of blood gases and electrolytes between male and female free ranging olive baboons (*Papio anubis*) captured in July 14–18, 2019, at Mpala Research Centre in Laikipia County Kenya

		Females (N = 12)			Males (N = 11)			F(1,21)	P
	Units	Mean	SD	95% CI	Mean	SD	95% CI		
pH		7.494	0.49	7.469–7.519	7.491	0.032	7.464–7.517	0.039	0.846
pCO2	mmHg	38.44	5.38	35.69–41.19	40.9	3.51	38.03–43.77	1.651	0.213
BE	mmol/L	6.17	4.37	3.72–8.62	7.82	3.74	5.26–10.38	0.941	0.343
HCO3	mmol/L	29.55	4.02	27.31–31.79	31.27	3.4	28.93–33.62	1.221	0.282
tCO2	mmol/L	30.75	4	30.17–34.92	32.55	3.53	28.48–33.02	1.291	0.269
Na	mmol/L	145.83	2.86	143.73–147.18	145.45	2.62	144.19–147.82	0.109	0.744
K	mmol/L	3.43	0.58	3.11–3.76	3.62	0.49	3.28–3.96	0.681	0.418
iCa	mmol/L	1.12	0.08	1.06–1.18	1.11	0.12	1.05–1.17	0.026	0.874
GLU	mmol/L	5.63	1.04	5.04–6.22	7.1	2.05	5.88 – 8.33	4.531	0.050
HCT	%	38.08	2.07	36.80–39.37	39.82	2.23	38.47–41.16	3.757	0.066
Hbg	g/dL	12.94	0.7	12.51–13.38	13.55	0.75	13.09–14.00	3.974	0.059

Sex was tested with unpaired data in the GLM model. The F-test had degrees of freedom (1,21) with corrected total 23 for each analyte. P is the observed probability level. GLU was transformed by natural logarithm. CI = confidence interval

exchange in the lungs, the partial pressures and saturation of O_2 and CO_2 are not comparable between venous and arterial samples. Pulse oximetry has been suggested as a noninvasive alternative means of calculating the arterial partial pressure of oxygen from arterial oxygen saturation of hemoglobin, through examination of the oxygen dissociation curve (Collins *et al.* 2015). Arterial blood gas would provide information about ventilation and oxygenation. Where arterial blood samples are unavailable, we recommend use of serial pulse oximetry measurements to assess trends and venous blood gas analyses to assess whether values for the partial pressure and saturation of O_2 and CO_2 are within normal range.

The baboons' pH was higher than 7.45, pCO_2 was lower while HCO_3, and BEecf were higher than previously published data, suggesting that some of the baboons might have been experiencing a metabolic alkalosis with respiratory compensation resulting in hyperventilation, presumably due to chloride depletion in sweat through the skin. Metabolic alkalosis can result in adverse effects such as decreased myocardial contractility, mental obtundation, and hypoxemia as a result of impaired peripheral oxygen unloading (Soifer and Kim 2014). Correction of respiratory and metabolic disturbances during anesthesia depends on data obtained during anesthesia monitoring. We recommend trapping baboons in shaded baited cage traps to prevent adverse effects associated with hyperthermia and the resulting metabolic alkalosis. We also recommend parenteral administration of a crystalloid (normosol, lactated Ringer's solution) during anesthesia for fluid and electrolyte restoration (Grimm *et al.* 2015). Owing to the dynamic physiological status of anesthetized animals, serial blood gas analysis can aid in assessing response to proper treatment over time. The immobilization did not result in any veterinary concerns or death, based on signals returned from the baboons' GPS collars following release.

Table III Comparison of blood gas and electrolyte values by age class for free ranging olive baboons (*Papio anubis*) captured in July 14–18, 2019, at Mpala Research Centre in Laikipia County Kenya

		Adults ($N = 8$)			Subadults ($N = 11$)			Juveniles ($N = 4$)			$F(2,20)$	P
	Units	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI		
pH		7.5	0.03	7.48–7.52	7.49	0.04	7.446–7.514	7.49	0.05	7.441–7.539	0.430	0.657
pCO2	mmHg	41.8	3.12	39.6 – 44	38.25	5.5	35.00–41.50	39.03	3.84	35.27–42.79	1.449	0.258
BE	mmol/L	9.5	2.45	7.8–11.2	5.36	4.25	2.85–7.87	6.25	4.5	1.84–10.66	2.883	0.079
HCO3	mmol/L	32.85	2.17	31.35–34.35	28.86	3.96	26.52–31.20	29.58	3.82	25.84–33.32	3.287	0.058
tCO2	mmol/L	34.13	2.3	32.54–35.72	30.09	3.96	27.75–32.43	30.75	3.95	26.88–34.62	3.282	0.059
Na	mmol/L	145	2.62	143.18–146.82	145.91	3.11	144.07–147.75	146.25	1.71	144.57–148.03	0.362	0.701
K	mmol/L	3.76	0.49	3.27–4.25	3.45	0.58	3.11–3.79	3.23	0.31	2.93–3.53	1.611	0.225
iCa	mmol/L	1.07	0.12	0.99–1.15	1.12	0.07	1.08–1.16	1.18	0.09	1.09–1.27	2.066	0.153
GLU	mmol/L	6.79	2.46	5.09 – 8.50	6.24	1.40	5.40–7.07	5.69	0.5	5.2 – 6.18	0.549	0.586
HCT	%	40.13	2.59	38.34–41.92	38.18	1.94	37.03–39.33	38.5	1.91	36.63–40.37	1.918	0.173
Hgb	g/dL	13.64	0.89	13.02–14.26	12.98	0.66	12.59–13.37	13.1	0.63	12.48–13.72	1.872	0.180

Test for age class performed with GLM F test has degrees of freedom of 2 and 20, with corrected total 22, and P is the observed probability level. CI = confidence interval

Table IV Comparison of blood gas and electrolyte values reported from olive baboons (Papio anubis) in Laikipia, Kenya, with values published for other nonhuman primates

	Unit	Wild olive baboons (*Papio anubis*) (this study)			Rhesus macaques (*Macaca mulatta*) (Lee *et al*. 2012)			Long-tailed macaques (*Macaca fascicularis*) (Nakayama *et al*. 2017)			Baboons (*Papio* species) and chimpanzees (*Pan troglodytes*) (Hainsey *et al*. 1993)			Captive bred and wild caught baboons (Schuurman *et al*. 2004)			Hamadryas baboons (*Papio hamadryas)* (Alsobayil *et al*. 2018)		
		N	Mean	SD	*N*	mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SD	*N*	Mean	SEM
pH		24	7.49	0.041	70	7.45	0.04	55	7.40	0.05	87	7.38	0.03	NA	NA	NA	6	7.52	1.0
pCO2	mmHg	24	24	4.65	70	35.06	4.25	55	36.24	4.23	89	38	4	NA	NA	NA	6	21	1.3
BE	mmol/L	24	6.96	4.07	70	0.18	4.47	55	−2.16	4.09	NA	NA	NA	NA	NA	NA	NA	NA	NA
HCO3	mmol/L	24	30.37	3.75	70	24.28	3.89	55	22.97	3.33	NA	NA	NA	NA	NA	NA	NA	NA	NA
tCO2	mmol/L	24	31.61	3.81	70	25.26	4.02	55	23.20	3.98	NA	NA	NA	NA	NA	NA	NA	NA	NA
Na	mmol/L	24	145.65	2.69	70	145.27	3.83	55	148.02	3.21	25	149	3	67	149.8	3.3	6	148	2
K	mmol/L	24	3.52	0.53	70	3.57	0.44	55	3.70	0.40	25	3.9	0.6	67	4.99	0.54	6	4.3	2
iCa	mmol/L	24	1.11	0.1	70	1.18	0.05	55	1.20	0.07	25	9	0.6	67	10.16	0.52	6	0.93	0.5
GLU	mmol/L	24	6.33	1.74	70	4.75	2.42		NA		24	4.61	0.72	67	4.88	0.94	NA	NA	NA
HCT	%	24	38.91	2.27	70	35.49	3.85	62	43.08	5.33	89	38.2	2.5	85	40.2	2.1	NA	NA	NA
Hbg	g/dL	24	13.23	0.77	70	12.10	1.52	62	12.48	1.65	89	12.6	0.9	85	12.98	0.70	NA	NA	NA

NA = not available.

Although we expected to find significant differences based on age and sex of individual subjects based on the literature (Byrne *et al.* 2014; Nakayama *et al*. 2017), we did not find any. This may be explained by our small sample size ($N = 23$), which was due to baboon group size and capture success. A minimum of 40 individuals for each subclass is recommended for reference interval partitioning by physiological traits (Friedrichs *et al.* 2012). We also advise caution in interpreting the values we provide on base excess, bicarbonate, potassium, and glucose. The 90% confidence intervals around the upper and lower reference limits for these values exceeded 0.2 times the reference interval and may therefore be imprecise (Friedrichs *et al.* 2012). The collection of reference samples from additional baboon individuals will help account for individual differences in stress response and body temperature. Sample collection from across their range is warranted to improve the reliability of these measures for olive baboons due to genetic and environmental differences.

In conclusion, this study shows that analysis of blood gas and electrolyte status using a portable point of care blood gas analyzer can provide rapid diagnosis of metabolic disturbance, such as metabolic alkalosis in primates. Rapid provision of oxygenation, ventilation, acid–base status, and electrolyte measures in a field setting translates to improved anesthetic protocols and safety of immobilized primates. We recommend quantitative monitoring of field anesthetic procedures be used more widely to improve the safety of anesthetized primates. As point of care analyzers such as the i-STAT machine we used are used more regularly in the field, we recommend initiation of a centralized database in which metabolic parameters from anesthetized patients can be collected and used to generate reliable reference ranges for wild primates across the world.

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Author Contributions AM-O and RH habituated the baboons for ecological study and baited the cage traps; MC and SM formulated the idea; MWK, JMH, ELM, MMM, RH, and JHY conducted the fieldwork; LH and MWK analyzed the data; MWK, JMH, LH, and ELM wrote the manuscript and the other coauthors provided editorial advice.

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Affiliations

Maureen W. Kamau[1,3] · James M. Hassell[1] · Ellie L. Milnes[1] · Lee-Ann C. Hayek[2] · Mathew M. Mutinda[8] · Roi Harel[4,5,7] · Akiko Matsumoto-Oda[9] · Jennifer H. Yu[1] · Dawn Zimmerman[1] · Margaret Crofoot[4,5,6,7] · Suzan Murray[1]

[1] Global Health Program, Smithsonian Conservation Biology Institute, Washington, DC, USA

[2] National Museum of Natural History, Washington, DC, USA

[3] Mpala Research Centre, Nanyuki, Kenya

[4] Department for the Ecology of Animal Societies, Max Planck Institute of Animal Behavior, Konstanz, Germany

[5] Department of Biology, University of Konstanz, Konstanz, Germany

[6] Smithsonian Tropical Research Institute, Panamá, República de Panamá

[7] Department of Anthropology, University of California, Davis, CA, USA

[8] Department of Capture and Veterinary Services, Kenya Wildlife Service, Nairobi, Kenya

[9] Graduate School of Tourism Sciences, University of the Ryukyus, Okinawa, Japan