



Effects of Dystocia on the Cardiac Biomarker Troponin I, Acid-Base Balance and Blood Gases Alongside the Hematobiochemical Profiles in Female Dromedary Camels

Mohamed Tharwat¹, Ahmed Ali^{1,2}, Derar Derar^{1,2}, Shin Oikawa³ and Tariq I. Almundarij^{1,*}

¹Department of Veterinary Medicine, College of Agriculture and Veterinary Medicine, Qassim University, P.O. Box 6622, Buraidah, 51452, Saudi Arabia

²Department of Theriogenology, Faculty of Veterinary Medicine, Assiut University, Assiut, Egypt

³Department of Veterinary Herd Health, School of Veterinary Medicine, Rakuno Gakuen University, 582 Bunkyo-dai-Midorimachi, Ebetsu, Hokkaido 069-8501, Japan

*Corresponding author: tmndrj@qu.edu.sa

Article History: 23-215

Received: 24-May-23

Revised: 26-Jun-23

Accepted: 02-Jul-23

ABSTRACT

This experiment was aimed to document the effect of dystocia in female camels on acid-base elements and blood gas parameters alongside the hemato-biochemical profiles compared to those with eutocia. Eighteen dystotic female dromedary camels were examined. Animals were received within 24, 48, 72, and >72h of birth. Signs included depression, anorexia, distress, colic, straining, and exhaustion. Ten eutocic females were used as controls. Compared to a mean value of 7.37 ± 0.01 in the control group, the blood pH in dystotic females was 7.32 ± 0.13 . The PO_2 was lower in dystotic females than in controls (61 ± 5 mmHg/L versus 183 ± 15 mmHg/L). The BE was also lower in dystotic females than controls (-8.8 ± 6.0 mmol/L versus -3.7 ± 1.2 mmol/L). The HCO_3 was lower in dystotic females than the controls (18 ± 5 mmol/L versus 21.4 ± 1.5 mmol/L). The TCO_2 was also lower in dystotic females than in controls (19 ± 5.0 mmol/L versus 22.6 ± 1.7 mmol/L). The SO_2 decreased significantly in dystotic females than in controls. The PCO_2 and lactate concentrations did not change in a significant manner between the 2 groups. It is concluded that female camels with dystocia have metabolic acidosis compared to those with normal parturition. Changes in blood gases were remarkable that included significant decreases in PO_2 , TCO_2 , and SO_2 values when compared to eutocic camels.

Key words: Animals; Biomarkers; Blood; Pathophysiology; Ruminant.

INTRODUCTION

As a result of the high variability of gestation lengths in camelids, the dromedary camel's gestation can last 315 days to 440 days (Tibary et al. 2008; Nagy and Juhász 2019). There are two basic stages of parturition in camelids: the first is variable (2-6 h) and the second is short (10 - 45 min) and there has been a reported total period of 373.9 ± 38.2 min for the entire parturition process (Elias and Cohen 1986). Each species has its own direct cause of dystocia. An abnormal presentation, position, or posture of mares is mostly the common etiology of difficult birth (McCue and Ferris 2012). Feto-pelvic disproportion is common in pregnant cows, especially in primipara (Mee et al. 2013). Dystocia in camels is uncommon as most births are presented in an anterior longitudinal position (Hussein et al. 1991; Purohit 2012).

Deviation or flexion of the exceptionally long necks and limbs may jeopardize normal birth (Nagy et al. 2021; Nagy et al. 2023). Generally, it was reported that the incidence of difficult birth in camels ranged from as 2-5% (Tibary et al. 2008).

Most body functions in different species including biological mechanisms necessitate a constantly settled acid-base equilibrium (Quade et al. 2021). Imbalance in this criterion inside the animal's body associated with water deprivation or exhaustion endangers its life (Abdoun et al. 2012; Okab et al. 2012). One of the most threatening factors for this balance is the reduction in the blood PH due to increase in the production of NH_4Cl in young dromedaries (Elkhair and Hartmann 2010). Manipulation of camels during semen collection or high parasitic infestation were found also to deteriorate this balance and risks the general health of this species

Cite This Article as: Tharwat M, Ali A, Derar D, Oikawa S and Almundarij TI, 2024. Effects of dystocia on the cardiac biomarker troponin I, acid-base balance and blood gases alongside the hematobiochemical profiles in female dromedary camels. International Journal of Veterinary Science 13(1): 115-119. <https://doi.org/10.47278/journal.ijvs/2023.070>

(Tharwat et al. 2014; Tharwat and Al-Sobayil 2014). Several studies have investigated the gas contents of the blood of the dromedary during health and disease as well as during the act of labor (Tharwat 2015; Tharwat 2021a). In addition, the cardiac biomarker troponin I (cTnI) has been used in camels either in sound or non-sound states to monitor the health status of the camel as well as in deciding its prognosis (Tharwat 2020; 2023a). The present investigation reported the effects of dystocia on cTnI, acid-base status and blood gases in female dromedary camels, along with their hematobiochemical data compared to those that had normal parturition.

MATERIALS AND METHODS

The committee of Experimental Animal Care and Welfare of the Scientific Research Deanship at the University Qassim approved the experimental procedures (ethical code number 213293).

Camels, history, clinical examination and blood sampling

The experimental design has previously been described (Ali et al. 2016). To summarize, eighteen female camels suffering from difficult parturition were admitted to the Qassim University Veterinary Hospital. The animals arrived at the clinic after twenty-four, forty-eight, seventy-two, and over seventy-two h of parturition suffering. Except for five animals, all others were full-term (12 to 13 months of pregnancy). Clinical manifestations included depression, anorexia, distress, alternating stance, and sit-down positions, rolling, exaggerated straining, abnormal vaginal discharges, and fading signs of parturition. Upon entrance, the females were tested for adequate soft and bony birth ways for normal fetal passage. An evaluation of the fetus's position, position, posture, and viability was performed. Dystotic cases with inaccessible fetuses due to insufficiently dilated soft birth canal, were evaluated after laparohysterotomy. Forcible pulling, cutting of the dead fetus or laparohysterotomy were used to resolve dystocia. Ten eutocic female camels were assigned as a control group. All investigated animals including controls were venipunctured and blood was received in; EDTA tubes (2mL), heparinized tubes (2mL) and plain tubes (6mL for serum).

Determination of acid-base indexes, cardiac troponin I, blood gas elements and lactate concentration

The blood samples in heparin tubes were analyzed at once using a clinical veterinary device (I-STAT[®], Abaxis, California, USA) to determine the acid-base elements and blood gas variables. Blood pH, carbon dioxide partial pressure (PCO₂), oxygen partial pressure (PO₂), bicarbonate (HCO₃), total carbon dioxide (TCO₂), oxygen saturation (SO₂), and lactic acid (LA) were all immediately measured. Estimation of acid-base elements, cTnI, blood gases, and measurement of lactate was carried according to Tharwat et al. (2014), Tharwat and Al-Sobayil (2014a,b,c), Tharwat (2015), Tharwat (2021a, b), Tharwat and Al-Sobayil (2022) and Tharwat (2023b).

Determination of haemato-biochemical profiles

The blood samples in EDTA tubes were tested to a total blood count including total white blood cell (WBCs)

count, red blood cell (RBCs) count, packed cell volume or hematocrit (HCT), hemoglobin, and RBCs indices including mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) using the VetScan HM5, Abaxis, California, USA. The concentrations of albumin, globulin, total protein, creatinine, blood urea nitrogen (BUN), glucose, magnesium and calcium in serum were evaluated using an automated analyzer (VetScan VS2, Abaxis, California, USA). The VetScan VS2 analyser also measured enzymatic activity of creatine kinase (CK), glutamyl transferase (GGT), alkaline phosphatase (ALP) and aspartate aminotransferase (AST).

Statistical analysis

The results are expressed as mean±SD, and these were analyzed using the SPSS statistical program, number 25, 2017. Student's *t* test was applied for comparisons, and the statistical significance was set at P<0.05.

RESULTS

Table 1 illustrate the mean±SD values of blood pH, PCO₂, BE, HCO₃, TCO₂, and SO₂ alongside the 25, 50, 75, 95, and 99 percentiles in the female camels with dystocia compared to healthy females with normal parturition. Compared to a mean value of 7.37±0.01 in the control group, the blood pH in female camels with dystocia was 7.32±0.13, with a statistically insignificant difference (P=0.2). The PO₂ was lower in camels with dystocia than in control animals (61±58mmHg/L versus 183±15mmHg/L, P<0.0001). The BE was also lower in camels with difficult birth than control ones (-8.8±6.0mmol/L versus -3.7±1.2mmol/L, P=0.01). Likewise, the HCO₃ was lower in females with difficult birth than the controls (18±5mmol/L versus 21.4±1.5mmol/L, P=0.03). The TCO₂ was also lower in female camels with dystocia than in control camels (19±5.0mmol/L versus 22.6±1.7mmol/L) but with a non-significant difference (P=0.7). The SO₂ decreased significantly in females with difficult birth than normal parturition (66±25mmol/L versus 100mmol/L in healthy camels, P<0.0001). The PCO₂ and LA concentrations did not differ significantly between the 2 groups (P=0.5 and P=0.8, respectively).

Hematological parameters in female camels with difficult birth compared to healthy camels alongside the 25, 50, 75, 95, and 99 percentiles are presented in Table 2. Significant hematological alterations in the females with difficult birth compared to the healthy group included lymphopenia (P=0.002), and decreased values of RBCs, hemoglobin, and HCT (P=0.02, 0.03, and 0.007, respectively). Other values that included WBCs, neutrophils, MCV, MCH, and MCHC did not differ significantly between females with dystocia and that of controls (P>0.05). Table 3 describes biochemical parameters in camels with dystocia compared to healthy camels alongside the 25, 50, 75, 95, and 99 percentiles. Most of the tested variables that included TP, ALB, ALP, AST, calcium, globulin, BUN, CK, and phosphorus, differed significantly between the 2 groups (P<0.05). Only GGT and magnesium mean values did not differ significantly between camels with difficult birth and those

Table 1: Acid-base balance, blood gases and lactic acid concentration in female camels with dystocia versus normal parturition

Parameters	Dystocia (n=18)						Normal parturition (n=10)						P value
	Mean±SD	Percentiles					Mean±SD	Percentiles					
		25	50	75	95	99		25	50	75	95	99	
pH	7.32±0.13	7.26	7.32	7.37	7.49	7.50	7.37±0.01	7.37	7.37	7.37	7.38	7.38	0.2
PCO ₂ mmHg	34.0±12.0	25.0	34.0	46.0	47.0	47.0	37.2±3.5	35.4	37.5	37.7	42.2	45.5	0.5
PO ₂ mmHg	61±58	27	30	74	149	165	183±15	174	185	192	203	210	<0.0001
BE mmol/L	-8.8±6.0	-15.0	-8.0	-3.7	-1.7	-1.1	-3.7±1.2	-4.3	-4.0	-3.1	-2.0	-1.2	0.01
HCO ₃ mmol/L	18.0±5.0	12.8	19.0	21.0	24.0	25.0	21.4±1.5	20.6	21.5	21.8	23.5	24.8	0.03
TCO ₂ mmol/L	19.0±5.0	14.1	20.3	21.7	25.9	26.8	22.6±1.7	21.8	23.0	23.0	25.0	26.6	0.7
SO ₂ %	66±25	46	59	86	98	99	100	100	100	100	100	100	<0.0001
LA mmol/L	4.2±3.0	2.0	4.0	5.4	8.2	8.9	4.3±3.3	2.3	3.0	5.4	11.7	11.7	0.8

PCO₂, partial pressure of carbon dioxide; PO₂, partial pressure of oxygen; BE, base excess; HCO₃, bicarbonate; TCO₂, total carbon dioxide; SO₂, oxygen saturation; LA, lactic acid.

Table 2: Hematological parameters in female camels with dystocia versus normal parturition

Parameters	Dystocia (n=18)						Normal parturition (n=10)						P value
	Mean±SD	Percentiles					Mean±SD	Percentiles					
		25%	50%	75%	95%	99%		25%	50%	75%	95%	99%	
WBCs (×10 ⁹ /L)	14.0±5.8	11.7	14.5	18.1	20.5	20.9	16.8±3.9	15.7	17.9	18.6	21.3	22.3	0.2
LYM (×10 ⁹ /L)	2.4±0.6	2.0	2.3	2.7	3.2	3.3	6.2±2.9	4.4	5.9	6.6	11.1	12.9	0.002
NEU (×10 ⁹ /L)	11.1±5.6	8.6	10.6	15.9	17.5	17.5	9.7±3.0	7.6	9.8	12.0	13.8	14.3	0.4
RBCs (×10 ¹² /L)	10.1±0.6	9.8	9.8	10.4	10.9	11.0	11.3±1.4	10.4	11.5	12.0	13.5	13.6	0.02
HB (g/dL)	13.4±2.7	12.2	14.1	14.8	16.5	17.1	16.4±2.8	14.6	16.0	18.0	21.0	23.0	0.03
HCT (%)	25.8±3.2	23.8	25.1	27.2	30.7	31.8	28.9±2.7	27.4	29.0	30.5	33.0	33.2	0.007
MCV (fl)	25.3±3.0	24.5	25.0	26.5	29.1	29.8	25.5±1.5	24.0	26.0	26.0	27.1	27.8	0.8
MCH (pg)	13.5±3.1	12.0	14.6	15.1	16.7	17.3	14.7±2.4	12.7	13.9	16.7	18.7	19.7	0.5
MCHC (g/dL)	53.5±12.7	46.1	54.4	59.6	69.4	72.6	57.6±9.0	50.6	53.7	64.3	74.3	74.9	0.6

WBCs, white blood cells; LYM, lymphocytes; MON, monocytes; NEU, neutrophils; RBCs, red blood cells; HB, hemoglobin; HCT, hematocrit; MCV, Mean corpuscular volume; MCH, Mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration.

Table 3: Biochemical parameters in female camels with dystocia versus normal parturition

Parameters	Dystocia (n=18)						Normal parturition (n=10)						P value
	Mean±SD	Percentiles					Mean±SD	Percentiles					
		25%	50%	75%	95%	99%		25%	50%	75%	95%	99%	
TP (G/L)	75.1±5.9	71.0	77.0	77.5	82.2	83.6	67.3±4.3	63.0	67.5	68.8	74.0	76.4	0.003
ALB (G/L)	56.1±8.7	49.5	59.0	63.0	65.0	65.0	60.39±3.0	60.8	61.5	62.0	64.3	64.9	0.09
ALP (U/L)	40.4±36.4	10.5	17.0	76.0	83.5	84.7	6.6±2.8	5.8	6.5	8.0	10.8	12.6	0.003
AST (U/L)	164.2±121	88.5	133.4	168.6	350.4	410.0	79.5±16.5	69.5	80.5	85.0	104.8	118.6	0.02
CA (mmol/L)	1.3±0.7	1.0	1.0	1.0	2.2	2.4	2.4±0.1	2.3	2.4	2.5	2.6	2.6	<0.0001
GGT (U/L)	19.4±14.1	8.5	10.0	29.0	38.8	42.2	12.2±5.3	8.8	12.5	13.0	19.8	26.4	0.1
GLOB (G/L)	20.4±10.3	14.0	23.0	24.0	32.0	33.6	7.0±3.8	5.0	7.0	9.0	12.5	15.3	0.001
BUN (mmol/L)	13.1±9.0	6.8	9.4	16.0	28.3	30.5	6.4±1.1	5.9	6.4	6.7	8.1	8.2	0.01
CK (U/L)	416.1±365.0	247.6	332.4	355.9	964.0	1169.5	139.0±21.6	127.0	136.0	148.8	171.8	178.4	0.01
PHOS (mmol/L)	1.6±0.9	1.1	1.4	2.0	2.9	3.0	2.6±0.4	2.6	2.7	2.8	3.0	3.1	0.001
MG (mmol/L)	0.24±0.2	0.14	0.20	0.21	0.54	0.64	0.3±0.0	0.2	0.3	0.3	0.3	0.3	0.7

TP, total protein; ALB, albumin; ALP, alkaline phosphatase; AST, aspartate aminotransferase; CA, calcium; GGT, γ-glutamyl transferase; GLOB, globulin; BUN, blood urea nitrogen; CK, creatine kinase; PHOS, phosphorus; MG, magnesium. +.

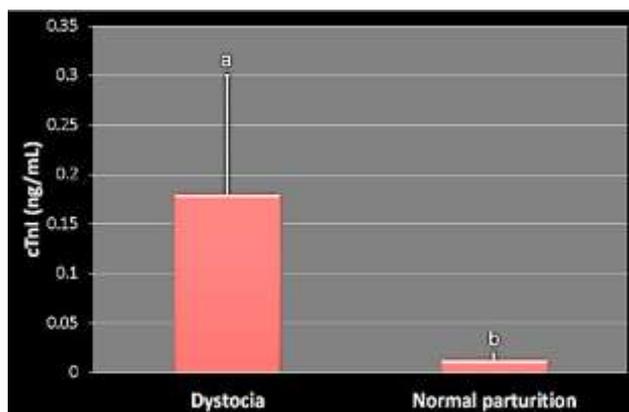


Fig. 1: Serum concentrations of cardiac troponin I in female camels with dystocia (n=18) compared to those with normal parturition (n=10). Different superscripts on bars indicate significant differences.

are healthy (P=0.1 and 0.7, respectively). The serum concentrations of cTnI differed significantly between camels with dystocia and control group (0.18±0.12ng/mL versus 0.03±0.02ng/mL, P=0.0007) (Fig. 1).

DISCUSSION

The dystocia of camels is a severe problem. It is more common in the more intensive systems than in the free less intensive systems. Generally, the most popular type of difficult parturition is postural abnormality. The most common cause of maternal dystocia was uterine torsion. Dystocia is also linked to a high fetal mortality rate (Ali et al. 2016; Nagy et al. 2021; Nagy et al. 2023). This study is the first one that documents the cTnI, acid-base elements, and blood gas variables in female camels with dystocia compared to those with normal parturition, alongside the hematobiochemical profiles.

In this study, camels with difficult parturition had significantly lower pH values than females with normal parturition. This decrease is easily justified by the measured low levels of HCO_3^- and BE values. The BE, which is the sum of all basic ingredients rather than just HCO_3^- , is an active and sensible tool for evaluating metabolic acidosis than HCO_3^- does alone (Sigaard-Andersen and Fogh-Andersen 1995; Tharwat and Al-Sobayil 2022; Tharwat 2023b). The low levels of BE and HCO_3^- values in this study could be attributed to metabolic acidosis; this is the apparent etiology of the passive BE values.

The cardiac biomarker cTnI is detected in serum within little hours of cardiac insult in humans and reaches its maximum between 12 and 18 hours (Bassand et al. 2007). Its blood levels rise following severe cardiac infarction due to seepage from injured cardiac cells (O'Brien et al. 2006). In this study, dystocia stress was linked to advanced failure of the organs, which has consequences for myocardial function, which usually appears as an elevation in the cardiac biomarker cTnI. In dromedary camels, the cardiac biomarker cTnI is used practically to monitor early myocardial damage and prognosis during several disorders (Tharwat 2020; 2023a).

In regard to the hematological alterations, significant hematological alterations compared to female camels at normal parturition included lymphopenia, erythrocytopenia, decreased hemoglobin concentration and HCT percent. Convening the biochemical changes, most of the tested variables that included TP, ALB, ALP, AST, calcium, globulin, BUN, CK and phosphorus, differed significantly between the 2 groups. These results agree well with findings published in camels with difficult parturition (Ali et al. 2016).

We can conclude from this study that female camels with dystocia have metabolic acidosis compared to those with normal parturition based on the measured values of HCO_3^- and BE. The observed metabolic acidosis in this study should be treated parallel with interference to manage cases of difficult parturition. Prolonged dystocia in female camels also lead to an injury in the myocardium as evidenced by the significant elevations in cTnI. Changes in blood gases were also remarkable that included significant decreases in PO_2 , TCO_2 and SO_2 values when compared to healthy camels with normal birth. Finally, the PCO_2 and lactate did not differ significantly between females with dystocia and controls.

Author Contributions

MT, AA and DD conceived, designed the experiments and carried out the practical work. TIA carried out the laboratory work. MT and DD wrote the manuscript draft, and prepared Figures/Tables. SO has revised the manuscript draft. All authors re-read, revised and approved the manuscript.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

Acknowledgment

The researcher would like to thank the Deanship of Scientific Research, Qassim University for funding the publication of this project.

REFERENCES

- Abdoun KA, Samara EM, Okab AB and Al-Haidary AA, 2012. State of Acid-base Balance in Dehydrated Camels (*Camelus dromedarius*). Asian Journal of Animal and Veterinary Advances 7: 420-426. <https://doi.org/10.3923/ajava.2012.420.426>
- Ali A, Derar D, Tharwat M, Zeitoun M and Alsobyil F, 2016. Dystocia in dromedary camels: Prevalence, forms, risks and hematobiochemical changes. Animal Reproduction Science 170: 149–156. <https://doi.org/10.1016/j.anireprosci.2016.05.004>
- Bassand JP, Hamm CW, Ardissino D, Boersma E, Budaj A, Fernández-Avilés F, Fox KA, Hasdai D, Ohman EM, Wallentin L and Wijns W, 2007. Guidelines for the diagnosis and treatment of non-ST-segment elevation acute coronary syndromes. European Heart Journal 28: 1598-1660. <https://doi.org/10.1093/eurheartj/ehm161>
- Elias E and Cohen D, 1986. Parturition in the camel (*Camelus dromedarius*) and some behavioral aspects of their newborn. Comparative Biochemistry Physiology Part A: Physiology 84: 413-419. [https://doi.org/10.1016/0300-9629\(86\)90339-7](https://doi.org/10.1016/0300-9629(86)90339-7)
- Elkhair N and Hartmann N, 2010. Studies on acid-base status (Stewart's model) of young camels (*Camelus dromedarius*) after acid-load with NH_4Cl . Berliner und Münchener tierärztliche Wochenschrift 123: 153-159.
- Hussein MF, Noseir MB, El-Bawab IE and Pacca-monti DL, 1991. Prenatal assessment of weight and dimensions of the camel conceptus (*Camelus dromedarius*). Animal Reproduction Science 26: 129-136. [https://doi.org/10.1016/0378-4320\(91\)90071-7](https://doi.org/10.1016/0378-4320(91)90071-7)
- McCue PM and Ferris RA, 2012. Parturition, dystocia and foal survival: a retrospective study of 1047 births. Equine Veterinary Journal 44: 22-25. <https://doi.org/10.1111/j.2042-3306.2011.00476.x>
- Mee JF, Grant J, Sánchez-Miguel C and Doherty M, 2013. Pre-Calving and calving management practices in dairy herds with a history of high or low bovine perinatal mortality. Animals (Basel) 3: 866-881. <https://doi.org/10.3390/ani3030866>
- Nagy P, and Juhász J, 2019. Pregnancy and parturition in dromedary camels I. Factors affecting gestation length, calf birth weight and timing of delivery. Theriogenology 134: 24-33. <https://doi.org/10.1016/j.theriogenology.2019.05.017>
- Nagy P, Reiczigel J, Barua R, Das Gupta A and Juhász J, 2023. Pregnancy and parturition in dromedary camels III. Incidence, timing and factors affecting abortions and perinatal mortality under intensive management. Theriogenology 197: 322-333. <https://doi.org/10.1016/j.theriogenology.2022.12.014>
- Nagy P, Reiczigel J, Gupta AD, Barua R and Juhász J. 2021. Pregnancy and parturition in dromedary camels II. Incidence, timing and factors affecting early pregnancy loss (EPL) and the outcome of twin pregnancies. Theriogenology 172: 289-299. <https://doi.org/10.1016/j.theriogenology.2021.07.004>
- O'Brien PJ, Smith DE, Knechtel TJ, Marchak MA, Pruiimboom-Brees I, Brees DJ, Spratt DP, Archer FJ, Butler P, Potter AN, Provost JP, Richard J, Snyder PA and Reagan WJ, 2006. Cardiac troponin I is a sensitive, specific biomarker of cardiac injury in laboratory animals. Laboratory Animals 40: 153–171. <https://doi.org/10.1258/002367706776319042>
- Okab AB, Abdoun KA, Samara EM and Al-Haidary AA, 2012. Acid-Base Balance in Camels (*Camelus dromedarius*): Effects of Exercise and Dehydration. The FASEB Journal Experimental Biology Meeting Abstracts, 01 April 2012 https://doi.org/10.1096/fasebj.26.1_supplement.lb739

- Purohit GN, 2012. Dystocia in camelids: The causes and approaches of management. *Open Journal of Animal Sciences* 2: 99-105. <https://doi.org/10.4236/ojas.2012.22013>
- Quade BN, Parker MD and Occhipinti R, 2021. The therapeutic importance of acid-base balance. *Biochemical Pharmacology* 183: 114278. <https://doi.org/10.1016/j.bcp.2020.114278>
- Sigaard-Andersen O and Fogh-Andersen N, 1995. Base excess or buffer base (strong ion difference) as measure of non-respiratory acid-base disturbance. *Acta Anaesthesiologica Scandinavica* 39: 123-128. <https://doi.org/10.1111/j.1399-6576.1995.tb04346.x>
- Tharwat M and Al-Sobayil F, 2014a. Cord and jugular blood acid-base and electrolyte status and haematobiochemical profiles in goats with naturally occurring pregnancy toxemia. *Small Ruminant Research* 117: 73-77. <https://doi.org/10.1016/j.smallrumres.2013.12.026>
- Tharwat M and Al-Sobayil F, 2014b. The effect of tick infestation on the serum concentrations of the cardiac biomarker troponin I, acid-base balance and haematobiochemical profiles in camels (*Camelus dromedarius*). *Tropical Animal Health and Production* 46: 139-144. <https://doi.org/10.1007/s11250-013-0464-6>
- Tharwat M and Al-Sobayil F, 2014c. Influence of the cardiac glycoside digoxin on cardiac troponin I, acid-base and electrolyte balance, and haematobiochemical profiles in healthy donkeys (*Equus asinus*). *BVC Veterinary Research* 10: 64. <https://doi.org/10.1186/1746-6148-10-64>
- Tharwat M and Al-Sobayil F, 2022. The Effects of acute blood loss on inflammatory and bone biomarkers, acid base balance, blood gases and hemato-biochemical profiles in sedated donkeys (*Equus asinus*). *International Journal of Veterinary Science* 11: 479-485. <https://doi.org/10.47278/journal.ijvs/2021.090>
- Tharwat M, 2015. Haematology, biochemistry and blood gas analysis in healthy female dromedary camels, their calves and umbilical cord blood at spontaneous parturition. *Journal of Camel Practice and Research* 22: 239-245. <https://doi.org/10.5958/2277-8934.2015.00039.9>
- Tharwat M, 2020. The cardiac biomarkers troponin I and creatine kinase myocardial band in camels (*Camelus dromedarius*) – a review. *Journal of Camel Practice and Research* 27: 121-128. <https://doi.org/10.5958/2277-8934.2020.00017.X>
- Tharwat M, 2021a. Acid-base balance, blood gases and haematobiochemical profiles in camels (*Camelus dromedarius*) with trypanosomiasis. *Journal of Camel Practice and Research* 28: 143-147. <https://doi.org/10.5958/2277-8934.2021.00024.2>
- Tharwat M, 2021b. Alterations in acid-base balance, blood gases and hemato-biochemical profiles of whole blood and thoracic fluid in goats with contagious caprine pleuropneumonia. *Veterinary World* 14: 1874-1878. <https://doi.org/10.14202/vetworld.2021.1874-1878>
- Tharwat M, 2023a. Advanced biomarkers and its usage in Arabian camel medicine – a review. *Journal of Applied Animal Research* 51: 350-357. <https://doi.org/10.1080/09712119.2023.2203749>
- Tharwat M, 2023b. Changes in acid-base balance, blood gases and hemato-biochemical parameters in Aarabian camels with different urinary tract disorders. *International Journal of Veterinary Science*. In press. <https://doi.org/10.47278/journal.ijvs/2023.026>
- Tharwat M, Ali A, Al-Sobayil F, Derar R and Al-Hawas A, 2014b. Influence of stimulation by electroejaculation on myocardial function, acid-base and electrolyte status and haematobiochemical profiles in male dromedary camels. *Theriogenology* 82: 800-806. <https://doi.org/10.1016/j.theriogenology.2014.06.023>
- Tibary A, Rodriguez J and Sandoval S, 2008. Reproductive emergencies in camelids. *Theriogenology* 70: 515-34. <https://doi.org/10.1016/j.theriogenology.2008.04.024>