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RESEARCH ARTICLE
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Alterations of Acid-Base Balance, Blood Gases, and Hematobiochemical Parameters in Goats with Difficult Parturition

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ABSTRACT

This study was carried out to investigate the influence of difficult parturition on the alterations of acid-base balance, blood gases, and hematological and biochemical parameters in goats versus goats with normal parturition. Sixteen female full-term, local-breed goats showing prolonged and difficult parturition were used. Goats were presented 24-48h after the onset of parturition. Fourteen goats with normal birth were used as controls. Both groups collected blood samples to determine acid-base status, blood gases, and hematological and biochemical parameters. Compared to a value of 7.41±0.05 in goats with normal birth, the blood pH in the goats with difficult parturition was 7.33±0.18, with a non-significant difference. The PCO_2 in controls was 35.1±3.4mmHg versus 33.8±6.0mmHg in goats with dystocia. The PO_2 was 43.9±4.9mmHg in controls versus 42.4±25.7mmHg in goats with dystocia. The base excess was 6.8±7.9mmol/L in goats with dystocia versus 1.3±6.1mmol/L in controls, with a statistically significant difference. The HCO_3 was lower in goats with difficult birth compared to normal parturition (18.9±5.0mmol/L vs 26.2±6.2mmol/L). The TCO_2 was also lower in goats with difficult birth versus goats with normal birth (20.0±5.2mmol/L vs 25.9±3.9mmol/L). The lactic acid level was significantly higher in goats with dystocia versus those with normal birth (4.4±2.5mmol/L vs 1.4±0.5mmol/L). With the exception of mean corpuscular volume and mean corpuscular hemoglobin, no significant changes were encountered in the hematological parameters. The enzymatic activity of alkaline phosphatase and aspartate aminotransferase (AST) differed significantly between the goats with dystocia compared to those with normal parturition. The creatine kinase (CK) level was also significantly higher in goats with a difficult birth. On the contrary, the phosphorus and magnesium levels were significantly lower in goats with dystocia compared to those with normal birth. However, the glucose level was higher in goats with dystocia versus healthy controls. It is concluded that goats with difficult parturition had metabolic acidosis versus those with normal parturition based on the increased blood levels of HCO_3 and TCO_2. Differences in the blood lactate are also significant in goats with dystocia versus controls. Other remarkable findings are the differences in enzymatic activity of AST, CK, and ALP, the decreased minerals of phosphorus and magnesium, and increased levels of blood sugar. All these changes must be considered while managing goats with difficult parturition.

Keywords: Animals; Biomarkers; Blood; Dystocia; Goats.

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INTRODUCTION

Difficult parturition, lambing difficulty, or dystocia are common complications that sometimes accompany parturition. This condition requires fast intervention by experienced veterinarians to avoid associated suffering and birth injury and guarantee the survival of the mother and her offspring. Therefore, professional management of animals at parturition with complications is vital for field practitioners (Agerholm et al., 2024).

In general, the causes of dystocia are variable. In particular, each species owns its special etiologies that lead to dystocia. For example, in mares, abnormal posture, position, or presentation are the most common factors that lead to difficult parturition (McCue & Ferris 2012). In cows, the disparity between fetus and pelvic size, large fetuses, and thickened metacarpus and metatarsus of the fetuses are common predisposing factors (Mee et al., 2013; Vincze et al., 2018; Nava-Trujillo & Rivera, 2023; Tsaousioti et al., 2023). In camels, flexion or deviation of the extraordinarily long limbs and necks may endanger normal parturition (Ali et al., 2016; Tharwat et al., 2024a).

In small ruminants, difficult birth has been reported to be affected by different factors such as environmental factors, farm management, maternal behavior of the ewe, and the capacity of lamb for survival (Morris et al., 2000; Dwyer & Lawrence, 2005; Swalha et al., 2007). In a retrospective study carried out on 320 sheep with difficult parturition, it was found that 67.2% of the factors of dystocia were due to maternal causes, including inadequate dilatation of the cervix in 59.6% and uterine torsion in 29.6% of the cases. Speijers et al. (2010) also reported that difficult birth is encountered when implementing large-breed sires. Incomplete opening of the cervix was reported as a common cause of dystocia and, subsequently, surgical interventions in sheep and goats (Brounts et al., 2004).

Almost all animal biological functions require a stable acid-base status and blood gas parameters (Quade et al., 2021). Changes in the acid-base equilibrium and the level of blood gases will subsequently for sure affect the survival of the affected animal imbalance (Abdoun et al., 2012; Okab et al., 2012; Tharwat et al., 2014; Tharwat & Al-Sobayil, 2014a; Tharwat, 2015; Tharwat, 2021a). This research article clarified the influence of difficult parturition on the alterations of acid-base balance, blood gases, and hematological and biochemical parameters in goats versus goats with normal parturition.

MATERIALS & METHODS

Goats, Complaints, Physical Examination, and Sampling of Blood

Sixteen female full-term, local-breed goats showing prolonged and difficult parturition were examined at the Veterinary Hospital of Qassim University, Saudi Arabia. Goats were presented 24-48h of the onset of parturition. The owner's complaints consisted of anorexia, recumbency, rolling, straining, distress, depression, abnormal discharge from the vagina and weak symptoms of birth. Just after admission, a routine examination, including adequacy of bony and soft birth canals for the normal passage of the fetus, has been performed. Using transabdominal ultrasonography, fetal viability was assessed. Gentle traction and fetal manipulation succeeded in all cases with dystocia in helping dams during the process of parturition. No complications have been encountered in any goats with dystocia during the following 72h of parturition. Fourteen goats with normal birth were used as controls. Three jugular blood samples were collected from goats with dystocia and from the controls (2mL in EDTA tubes for hematological analyses, 2mL in heparin tubes for acid-base and blood gas estimation, and 6mL in plain tubes to harvest serum for determination of biochemical analytes).

Estimation of Acid-base Balance, Blood Gases, Lactate and Electrolytes

The heparinized blood samples were used immediately to estimate the acid-base status, blood gases, lactic acid, and electrolytes using a commercially available portable veterinary device (I-STAT®, Abaxis, California, USA). Blood pH, partial pressure of carbon dioxide (PCO_2), partial pressure of oxygen (PO_2), bicarbonate level (HCO_3), the total concentration of carbon dioxide (TCO_2), a saturation of oxygen (SO_2), lactic acid (LA), sodium, potassium, and chloride were all directly evaluated in blood samples according to Tharwat et al. (2014), Tharwat & Al-Sobayil (2014a,b,c), Tharwat (2015), Tharwat (2021a,b), Tharwat & Al-Sobayil (2022), Tharwat (2023) and Tharwat et al. (2024a,b,c).

Estimation of Hematobiochemical Parameters

EDTA-blood was used for the determination of total leukocytic count (WBCs), lymphocyte count, neutrophils count, red blood cells (RBCs) count, hematocrit (HCT) percent, hemoglobin concentration and indices of RBCs (mean corpuscular volume, MCV); mean corpuscular hemoglobin, MCH; mean corpuscular hemoglobin concentration, MCHC) by using the VetScan HM5, Abaxis, California, USA. The levels of albumin, alkaline phosphatase (ALP), aspartate aminotransferase (AST), calcium, glutamyl transferase (GGT), total protein, globulin, creatine kinase (CK), phosphorus, magnesium, and glucose were tested in sera using a veterinary analyzer (VetScan VS2, Abaxis, California, USA).

Statistical Analysis

Data are shown as mean±SD and were analyzed using the SPSS statistical package, no. 25, 2017. The student's *t* test was used to compare diseased goats with dystocia and the healthy goats with normal birth. Statistical significance was set at the level of $P<0.05$.

RESULTS

Table 1 shows the mean±SD blood values of pH, PCO_2, PO_2, BE, HCO_3, TCO_2, SO_2, LA, sodium, potassium, and chloride parallel with their percentiles (25th, 50th, 75th, 95th, and 99th) in goats with difficult birth versus data in the healthy control goats with normal parturition. Compared to a value of 7.41±0.05 in goats with normal birth,

Table 1: Acid-base changes, blood gas parameters, lactate concentration and electrolytes in goats with difficult parturition versus normal birth

Parameters	Difficult parturition (n=16)						Normal parturition (n=14)						P value
	Mean±SD	Percentiles					Mean±SD	Percentiles					
		25%	50%	75%	95%	99%		25%	50%	75%	95%	99%	
pH	7.33±0.18	7.30	7.36	7.42	7.52	7.54	7.41±0.05	7.39	7.43	7.44	7.47	7.48	0.15
PCO_2 (mmHg)	33.8±6.0	29.9	31.6	37.1	43.6	46.2	35.1±3.4	35.5	36.2	36.7	37.3	37.4	0.71
PO_2 (mmHg)	42.4±25.7	31.0	33.0	34.0	77.2	85.8	43.9±4.9	41.3	45.8	47.62	48.0	48.0	0.46
BE (mmol/L)	6.8±7.9	-7.25	-5	-2.75	1.0	1.0	1.3±6.1	-0.25	0.5	4.0	8.9	13.8	0.02
HCO_3 (mmol/L)	18.9±5.0	18.7	19.8	21.9	24.0	24.3	26.2±6.2	24.6	25.5	27.5	34.6	40.7	0.01
TCO_2 (mmol/L)	20.0±5.2	19.8	20.5	23.3	25.0	25.0	25.9±3.9	25.0	26.5	28.3	29.5	29.9	0.02
SO_2 (%)	73.7±19.2	63.5	69.0	88.0	97.8	98.8	65.3±3.7	63.3	64.0	66.3	70.8	71.8	0.29
Lactate (mmol/L)	4.4±2.5	3.0	3.9	5.2	8.0	8.8	1.4±0.5	1.03	1.4	1.8	2.0	2.1	0.009
Na (MMOL/L)	147±10	145	147	148	1601	164	149±5	150	150	150	152	153	0.6
K (MMOL/L)	3.5±0.5	3.2	3.4	3.9	4.1	4.2	4.0±0.9	3.8	4.1	4.3	5.2	5.5	0.2
Cl (MMOL/L)	114±11	108	114	116	127	130	113±2.3	112	114	115	116	116	0.9

PCO_2, partial pressure of carbon dioxide; PO_2, partial pressure of oxygen; BE, base excess; HCO_3, bicarbonate; TCO_2, total carbon dioxide; SO2, oxygen saturation; Na, sodium; K, potassium; Cl, chloride.

Table 2: Hematological changes in goats with difficult parturition versus normal birth

Parameters	Difficult parturition (n=16)						Normal parturition (n=14)						P value
	Mean±SD	Percentiles					Mean±SD	Percentiles					
		25%	50%	75%	95%	99%		25%	50%	75%	95%	99%	
WBCs ($\times 10^9$/L)	17.6±9.9	9.5	19.4	24.2	30.7	33.4	14.9±4.8	12.0	14.5	17.3	22.7	23.9	0.55
LYM ($\times 10^9$/L)	3.7±3.6	1.6	3.0	3.5	9.8	11.6	5.8±3.0	4.3	5.6	6.5	10.8	11.7	0.24
NEU ($\times 10^9$/L)	13.5±8.9	7.2	10.8	19.3	26.4	27.8	8.8±5.8	5.8	6.8	10.7	19.9	22.8	0.27
RBCs ($\times 10^{12}$/L)	13.4±2.4	11.7	13.5	15.0	16.9	17.8	15.4±1.6	14.3	15.5	16.4	17.7	17.8	0.06
HB (g/dL)	10.8±2.2	9.0	10.6	11.6	14.1	14.3	10.1±1.2	9.3	9.7	11.3	11.8	12.2	0.22
HCT (%)	27.3±5.7	24.3	26.4	31.7	36.3	36.7	25.1±3.6	22.8	24.4	27.4	30.8	32.3	0.21
MCV (fl)	20.3±6.4	16.0	20.0	22.0	30.6	30.9	16.2±1.6	15.0	16.0	17.0	18.7	19.7	0.02
MCH (pg)	8.2±2.3	6.4	8.1	9.6	11.6	12.2	6.6±0.5	6.3	6.5	6.9	7.3	7.5	0.01
MCHC (g/dL)	40.6±3.0	39.0	41.0	43.1	44.2	44.3	40.6±2.0	39.2	40.7	42.0	43.5	43.9	0.70

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

the blood pH in the goats with difficult parturition was 7.33±0.18, with a non-significant difference (P=0.15). The PCO_2 in controls was 35.1±3.4mmHg versus 33.8±6.0mmHg in goats with dystocia (P=0.71); the PO_2 was 43.9±4.9mmHg in controls versus 42.4±25.7mmHg in goats with dystocia (P=0.46). The BE was 6.8±7.9 mmol/L in goats with dystocia versus 1.3±6.1 mmol/L in controls, with a statistically significant difference (P=0.02).

The HCO_3 was lower in goats with difficult birth compared to normal parturition (18.9±5.0 mmol/L vs 26.2±6.2 mmol/L; P=0.01). The TCO_2 was also lower in goats with difficult birth versus goats with normal birth (20.0±5.2 mmol/L vs 25.9±3.9 mmol/L; P=0.02). No significant differences were found in SO_2 between goats with dystocia and healthy ones (73.7±19.2% vs 65.3±3.7%; P=0.29). The LA level was significantly higher in goats with dystocia versus those with normal birth (4.4±2.5mmol/L vs 1.4±0.5mmol/L; P=0.009). However, no significant differences were observed between the levels of sodium, potassium, and chloride in goats with difficult births and those with normal births (P>0.05) (Table 1).

Table 2 illustrates the mean±SD values of hematological variables parallel with their percentiles (25^{th}, 50^{th}, 75^{th}, $95^{th,}$ and 99^{th}) in goats with difficult parturition versus those in the healthy control goats with normal birth. Except for MCV and MCH (P=0.02 and 0.01, respectively), no significant changes were encountered in other hematological parameters, including WBCs, lymphocytes, neutrophils, RBCs, HCT, hemoglobin, and MCHC between goats with difficult parturition and goats with normal parturition (P>0.05).

The mean±SD values of the biochemical parameters, including albumin, ALP, AST, calcium, GGT, total protein, globulin, CK, phosphorus, magnesium, and glucose with their percentiles (25th, 50th, 75th, 95th, and 99^{th}) are summarized in Table 3. The enzymatic activity of ALP and AST differed significantly between the 2 groups of goats with dystocia compared to those with normal parturition (P=0.02, 0.04, respectively). The level of CK was significantly higher in goats with difficult birth versus those with normal parturition (P=0.04). The phosphorus and magnesium levels were significantly low in goats with dystocia compared to those with normal birth (P=0.002, 0.0002, respectively); however, calcium levels did not reach a statistically significant level (P=0.06). The glucose level was higher in goats with dystocia versus healthy controls (P=0.02). Other parameters, including total protein, albumin, and globulin, and the serum activity of GGT did not show significant changes (P>0.05).

DISCUSSION

In large ruminants, factors affecting dystocia are divided into 4 principal categories. The first category is direct factors such as uterine torsion and malpresentation.

Table 3: Biochemical parameters in goats with difficult parturition versus normal birth

Parameters	Difficult parturition (n=16)						Normal parturition (n=14)						P value
	Mean±SD	Percentiles					Mean±SD	Percentiles					
		25%	50%	75%	95%	99%		25%	50%	75%	95%	99%	
ALB (G/L)	41.7±5.8	39.5	44.0	45.0	45.8	45.9	43.6±2.3	43.0	44.0	44.3	46.3	46.9	0.4
ALP (U/L)	45±50	28	45	63	77	79	107±20	90	107	127	129	130	0.02
AST (U/L)	91±8	88	93	95	97	97	63±19	50	54	67	95	102	0.04
CA (MMOL/L)	2.1±0.1	2.1	2.2	2.2	2.2	2.2	2.2±0.1	2.2	2.3	2.4	2.4	2.4	0.06
GGT (U/L)	34±8	29	29	36	42	43	41±8	34.8	40.5	46.0	52.9	54.6	0.2
TP (G/L)	71.3±4.9	68.5	69.0	73.0	76.2	76.8	76.4±4.2	65.5	66.5	69.8	73.3	73.9	0.2
GLOB (G/L)	30.0±6.1	28.0	33.0	33.5	33.9	34.0	24.9±5.9	20.8	22.5	29.0	33.6	35.5	0.2
CK (U/L)	211±65	145	157	250	324	339	141±30	128	133	148	187	194	0.04
PHOS (MMOL/L)	1.0±0.7	0.8	1.0	1.3	1.4	1.5	2.5±0.4	2.2	2.5	2.8	2.9	3.0	0.002
MG (MMOL/L)	0.2±0.0	0.2	0.2	0.2	0.2	0.2	1.2±0.2	1.0	1.3	1.5	1.5	1.5	0.0002
GLU (MG/DL)	104±50	78	92	100	177	197	61±8	56	61	65	73	77	0.02

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

The second category is phenotypic factors related to the dam and its offspring, including offspring weight at birth, multiple parturition, perinatal deaths, pelvic size, dam body weight, scoring of the body condition at parturition, and length of gestation. The third factors include non-genetic causes, including damage and parity, season and year of parturition, place of parturition, managemental practices, disorders, nutrition, offspring sex, embryo cloning, periparturient hormonal level, and production of embryos in vitro. The fourth factors include genetic factors such as the dam, neonate, sire genotypes, inbreeding, selection, and muscle hypertrophy (Mee, 2008; Zaborski et al., 2009). It was also reported that difficult parturition can be estimated in cattle by comparing the width of the fetus's hoof to the longitudinal diameter of the dam pelvis before parturition (Maeda et al., 2022).

In small ruminants, difficult parturition and poor neonatal vigor are remarkable factors of perinatal mortalities. It was also reported that birth difficulties are observed in sheep due to genetic selection, such as special lamb adjustment, or as a consequence of managemental practices to fulfill selection aims, such as increased interference at parturition (Dwyer & Bünger, 2012). Breed type, fetus size, and husbandry were predisposing factors (Balasopoulou et al., 2022). In goats, it was reported that the most common cause of dystocia in goats is fetopelvic inequality (Brounts et al., 2004). To the authors' knowledge, this report is the first to discuss the alterations of acid-base balance, blood gases, electrolytes, and hematological and biochemical profiles due to difficult parturition in goats compared to those of normal parturition.

In this report, although the blood pH did not elevate significantly, it was lower in goats with difficult birth than those with normal parturition. This finding agrees well with data recently published (Tharwat et al., 2024a). This low blood pH in goats with dystocia may be explained based on low blood HCO3 and TCO2 levels. The decreased levels of HCO_3 and TCO_2 in this report could be due to metabolic acidosis (Tharwat & Al-Sobayil, 2022; Tharwat, 2023). The significantly increased levels of lactate in goats with dystocia when compared to those with normal parturition may be attributed to the incapability of metabolism of the pyruvate that is stored and, therefore, changed into lactate (Tharwat & Al-Sobayil, 2014b).

No significant changes were recorded regarding the alterations of the hematological parameters. However, several biochemical metabolites had significant differences between the 2 groups of goats with dystocia versus those with normal parturition. One of the main findings was the significant elevations of the enzymes CK and AST in goats with dystocia versus controls, indicating muscular insult. The minerals phosphorus and magnesium were also decreased, and the glucose level was increased in goats with difficult parturition versus those with normal birth. These results agree well with our recently published study in female dromedary camels with dystocia (Tharwat et al., 2024a).

Conclusion

It is concluded that goats with difficult parturition had metabolic acidosis versus those with normal parturition based on the increased blood levels of HCO_3 and TCO_2. One of the most important interventions is to treat this metabolic acidosis in conjunction with the manipulation of the goat with a difficult birth. Differences in the blood lactate are also significant in goats with dystocia versus controls. Other remarkable findings are the differences in enzymatic activity of AST, CK, and ALP, the decreased minerals of phosphorus and magnesium, and increased blood sugar levels. All these changes must be considered while managing goats with difficult parturition.

Author Contributions

MT conceived and designed the experiments and carried out the practical work. AA carried out the laboratory work. MT wrote the manuscript draft and prepared the Tables. MM 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.

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