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Red urine syndrome in dromedary camels: Clinical, etiological, hematobiochemical sonographic, and pathologic findings

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ABSTRACT

Background: Although blood urine is frequently observed in dromedary camels, little attention is gained and only it was reported as case reports.

Aim: This study was carried out to examine dromedary camels suffering from red urine syndrome from the points of clinical, etiological, hematobiochemical, ultrasonographic, and pathological characteristics.

Methods: Thirty-one camels with red urine and fifteen controls were enrolled. With a duration ranging from five days to nine months, clinical manifestations included weakness, red discoloration of the urine, dribbling of urine, straining during urination, and abdominal pain. Blood was sampled in ethylenediaminetetraacetic acid and plain tubes.

Results: The urine red color intensity was marked in 23 camels. In five camels discolored red urine was moderate while red urine was voided intermittently in the remaining three camels. The wide stance of the hind legs and pain reactions during urination were recorded in 18 camels. In all 31 camels, urine samples were centrifuged and sedimentation of red deposits was found. Nephrolithiasis was detected in three animals. One female camel had bilateral hydronephrosis. Hyperechoic urine was imaged within the renal pelvis in seven camels. In addition, hypoechoic fluid was imaged within the peritoneal cavity in 8 animals. A ruptured and collapsed urinary bladder was found in two male camels. In addition, bilateral pyelonephritis was found in another male camel. Abscessation of the left and right kidneys confirmed by ultrasound-guided aspiration was confirmed in 3 and 2 females, respectively. Peri-renal abscessation of the right kidney was detected in a female camel. A large, misshaped hypoechoic mass involving the right kidney was found in 1 female. A large mass king neoplasia was also imaged in a female camel distal to and compressing the left kidney, which proved histologically to be a leiomyoma. Moderate to severe thickening and corrugation of the urinary bladder mucosa were detected in 18 of the diseased camels.

Conclusion: This study's syndrome of red urine in camels resulted mainly from hematuria. The existing etiologies were nephrolithiasis, cystitis, pyelonephritis, peri-renal and renal abscessation, and renal neoplasia. Ultrasonography was superior in assessing the renal parenchyma and urinary bladder for the verification of the existing nephrolithiasis, hydronephrosis, pyelonephritis, peri-renal and renal abscessation, cystitis, and ruptured or perforated bladder.

Keywords: Camel, Diagnostic imaging, Diseases, Pathology, Ultrasound.

Introduction

Red urine syndrome is a condition frequently observed in farm animals. Several factors are involved in the etiopathogenesis of this syndrome. Babesiosis caused by *Babesia bovis*, *Babesia bigemina, Babesia orientalis, Babesia ovata, Babesia major, Babesia motasi, Babesia U sp. Kashi,* and *Babesia venatorum* are a very common cause of hemoglobinuria in cattle and buffaloes (Mtshali and Mtshali, 2013; Mahmmod, 2013; Bal *et al*., 2016; He *et al*., 2021). In cattle, red water disease (bacillary hemoglobinuria) is a fatal condition caused by *Clostridium hemolyticum* and is characterized clinically by fever, icterus, and hemoglobinuria (Takagi *et al*., 2009; Shinozuka *et al*., 2011; Navarro *et al*., 2017). Post-parturient hemoglobinuria due to hypophosphatemia during the early lactation phase in dairy cows is also associated with discoloration of urine (Grünberg, 2014; Abramowicz *et al*., 2022). Transient hemoglobinuria as a consequence of water intoxication was also documented in four female Japanese cattle

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of 16 to 25 months of age (Kawahara *et al*., 2016). Bladder neoplasia due to feeding on bracken fern for a long time and infection of papilloma type 2 leading to chronic enzootic hematuria syndrome is occasionally reported in cattle (Di Loria *et al*., 2012).

In horses, urine discoloration is reported mostly in cases suffering from hematuria and pigmenturia (hemoglobinuria and myoglobinuria) (Schumacher, 2007; Delvescovo *et al*., 2022). Although it seems to be low in horses, urolithiasis, if found, is always accompanied by hematuria (Duesterdieck-Zellmer, 2007). Copper toxicity resulting in hemolytic anemia and hemoglobinuria was reported in four horses (Belli *et al*., 2021). Similarly, chronic copper toxicity was reported in sheep and goats as a cause of hemoglobinuria (Bozynski *et al*., 2009; Borobia *et al*., 2022).

In camels, urine discoloration has gained little attention in veterinary literature and has only been reported as case reports. A case report of chronic hematuria with undetermined etiology in a six-year-old camel suffering from anemia, weakness, and light-red to dark-red urine was reported (Bhandare, 2009). Concurrent *Salmonella enterica* and *Theileria* infections were reported to be the causative agents of severe hematuria in two young racing dromedary camels in the United Arab Emirates (Abdelwahab *et al*., 2019). Hematuria was also reported in a 12-year-old male dromedary camel with abscessation of both kidneys and *Escherichia coli* was isolated from the lesions (Tharwat *et al*., 2018). In addition, hematuria was also reported in a female camel lasting for six months; calculi were detected sonographically in the kidneys as acoustic enhancement and acoustic distal shadowing (Tharwat, 2020a). Renal cell carcinoma was also documented as a cause of hematuria in a thirteen-year-old female dromedary camel (Tharwat *et al*., 2017). This research was carried out to shed light on red urine syndrome in dromedary camels from the points of clinical, etiological, hematobiochemical, ultrasonographic, and pathological characteristics.

Materials and Methods

Camels, history, clinical examination, and blood sampling

Thirty-one camels (23 females and 8 males) of 2 to 15 years were admitted to the University of Qassim Veterinary Hospital between 2016 and 2024. They were referred because of weakness, red discoloration of the urine, dribbling, straining during urination, and abdominal pain. The duration of the disease ranged from 5 days to 9 months. Each animal obtained a detailed examination, including vital signs of respiration, pulse and temperature, color of visible mucosae, and auscultation of the heart, lungs, and digestive system, and careful examination was applied to examine the urinary system. Fifteen healthy camels were used as controls. Blood sampling was carried out from both groups in ethylenediaminetetraacetic acid (EDTA) tubes and plain tubes.

Determination of hematobiochemical profiles

Hematological parameters were analyzed in the EDTA blood sample, including white blood cells, neutrophils, lymphocytes, erythrocytes (RBCs), hematocrit (HCT), hemoglobin (Hg), and RBCs indices (VetScan HM5, Abaxis, CA). The serum concentrations of albumin, total protein, globulin, creatinine, blood urea nitrogen (BUN), magnesium, calcium, and glucose, and the activities of aspartate aminotransferase (AST) and alkaline phosphatase (ALP) were measured (VetScan VS2, Abaxis, CA).

Ultrasonographic examination

The urinary system was scanned using 3.5 sectors and 5.0 and 7.5 MHz linear transducers (SonoScape, Sonoscape Medical Corporation, China). Through the skin, the right kidney was examined in the upper part of the right flank while the left kidney was scanned either from the caudal part of the left flank or transrectally, and per rectum, the bladder was examined. When necessary, the respiratory, cardiovascular, digestive, and liver were scanned.

Postmortem and histological examinations

Necropsy was carried out on 4 animals (two males and two females) where thoracic and abdominal organs were examined, and careful attention was directed to the urinary system. Ultrasound-guided biopsy of the mass distal to the left kidney was obtained from the diseased female number 26 using a 14G biopsy needle. Tissue samples were also collected from cases no 9 and 21. Immediately after sampling, the tissue was fixed in 10% neutral buffered formalin for 24 hours before being routinely processed and embedded in paraffin. For histopathological diagnosis, consecutive 5-µm-thick sections were cut with a microtome and stained with hematoxylin and eosin.

Statistical analysis

Data are expressed as means ± standard deviations where analysis was performed using the Statistical Package for the Social Sciences statistical package (2017). Student's t-test was implemented for comparisons, and the significance was adjusted at $p \leq 0.05$.

Ethical approval

Camels were manipulated according to the Laboratory Animal Control Guidelines of Qassim University, which basically conforms to the Guide for the Care and Use of Laboratory Animals of the National Institutes of Health in the USA (NIH publications No. 86 to 23, revised 1996).

Results

Table 1 summarizes the clinical presentation in the thirty-one camels with urine discoloration. With a duration ranging from five days to nine months, clinical manifestations included weakness, red discoloration of the urine, dribbling of urine, straining during urination, and abdominal pain.

The red color intensity was marked in 23 (74.2%) camels. In 5 (16.1%) camels, discolored red urine was moderate. Red urine was voided intermittently in the

Table 1. Clinical presentation and ultrasonographic findings in 31 camels with discolored urine.

No.	Sex	Age (Y)	Severity	Clinical presentation	Ultrasonographic findings
1	Female	14	Severe	Hematuria for 2 weeks	Severely distended urinary bladder with blood clots
2	Female	10	Severe	Hematuria for 1 month	Severely distended urinary bladder with blood clots, nephrolithiasis Hydronephrosis
3	Male	12	Mild	Hematuria for 1 week and dribbling on admission	Ruptured urinary bladder Uroperitoneum, nephrolithiasis
4	Male	15	Severe	Hematuria for 2 weeks	Severely distended urinary bladder, nephrolithiasis
5	Female	11	Moderate	Hematuria for 5 months	Urinary bladder contains echogenic deposits
6	Female	7	Severe	Hematuria for 2 months	Severely distended urinary bladder with blood clots
7	Female	5	Severe	Hematuria for 3 months	Severely distended urinary bladder with blood clots
8	Male	2	Severe	Hematuria for 5 days	Cystitis, blood clots within the urinary bladder
9	Male	13	Mild	Hematuria for 9 months	Bilateral pyelonephritis
10	Female	3	Severe	Hematuria for 6 days	Chronic cystitis Corrugated bladder wall Echogenic urine within the bladder
11	Male	7	Severe	Hematuria for 3 weeks, dribbling on presentations	Chronic cystitis Corrugated and thickened bladder wall Echogenic urine within the bladder
12	Female	10	Severe	Hematuria for 15 days	Massive urinary sediment in the urinary bladder
13	Female	6	Severe	Hematuria for 10 days	Moderate urinary sediment in the urinary bladder
14	Female	7	Severe	Hematuria for 20 days	Moderate urinary sediment in the urinary bladder
15	Female	4	Severe	Hematuria for 1 month	Severe corrugation and thickening of the bladder wall
16	Female	3	Severe	Hematuria for 2 months	Severe corrugation and thickening of the bladder wall Abscessation of the left kidney Massive urinary sediment in the urinary bladder
17	Male	3	Moderate	Hematuria for 3 months	Corrugation and thickening of the bladder wall Massive urinary sedimentation
18	Male	9	Severe	Hematuria for 1 week	Corrugation of the bladder wall Moderate urinary sediment in the urinary bladder
19	Female	13	Mild	Hematuria for 20 days	Enlarged kidneys Echogenic urine within the renal pelvis
20	Female	8	Severe	Hematuria for 7 days	Thickened bladder wall Echogenic urine within the bladder
21	Female	6	Severe	Hematuria for 1 month	Large, irregular shaped, hypoechoic mass involved the right kidney
22	Female	14	Moderate	Hematuria for 3 months	Abscessation of the left kidney Corrugation and thickening of the bladder wall
23	Female	10	Moderate	Hematuria for 4 months	Abscessation of the left kidney

continue...

Table 1. Continued...

No.	Sex	Age (Y)	Severity	Clinical presentation	Ultrasonographic findings
24	Male	5	Severe	Dribbling of red urine, proved hematuria	Uroperitoneum
					Echogenic deposits within the bladder lumen
					Shirked urinary bladder
					Intestines floating in a hypoechoic fluid
25	Female	9	Severe	Hematuria for 4 weeks	Peri-renal abscessation of the right kidney compressing its parenchyma
26	Female	11	Severe	Hematuria for 2 months	A large mass mimics neoplasia distal to and compressing the left kidney
27	Female	15	Severe	Hematuria for 2 months	Abscessation of the right kidney
28	Female	6	Severe	Hematuria for 1 month	Abscessation of the right kidney
29	Female	14	Severe	Hematuria for 2 months	Hyperechoic urine within the bladder
					Massive urinary sediment in the urinary bladder
					Corrugation and thickening of the bladder wall
					Echogenic deposits within the urinary bladder
30	Female	8	Moderate	Hematuria for 3 months	Echogenic urine within the bladder
					Massive urinary sediment in the urinary bladder
					Severe corrugation and thickening of the bladder wall
31	Female	13	Severe	Hematuria for 2 months	Echogenic urine within the bladder
					Massive urinary sediment in the urinary bladder
					Corrugation and thickening of the bladder wall
					Echogenic deposits within the urinary bladder

remaining 3 (9.7%) camels. The wide stance of the hind legs and pain reactions during urination were recorded in 18 (58.1%) camels, and the affected animal remained in the urination position for a long time after urination ended (Fig. 1). In all 31 camels, urine samples were centrifuged and sedimentation of red deposits was found (Fig. 2).

Table 2 shows major ultrasonographic findings in the 31 camels with bloody urine. Severely distended urinary bladder containing blood clots was found in 5 (16.1%) of the 31 diseased camels. Nephrolithiasis was detected in 3 (9.7%) animals (one male and two female). Ultrasonographically, the calculus appeared as acoustic enhancement with distal acoustic shadowing. Bilateral hydronephrosis was detected in one female camel (Fig. 3). Hyperechoic urine was imaged within the renal pelvis in 7 (22.6%) of the 31 diseased camels. In addition, hypoechoic fluid was imaged within the peritoneal cavity in 8 (25.8%) animals (Fig. 4). Ruptured and collapsed urinary bladder was found in two male camels (6.5%). In addition, bilateral pyelonephritis was found in another male camel (3.2%). Abscessation of the left kidney confirmed by ultrasound-guided aspiration was reported in 3(9.7%) females. Similarly, abscessation of the right kidney confirmed by ultrasound-guided aspiration was detected in 2 (6.5%) females. Peri-renal abscessation of the right kidney was detected in one female camel (3.2%). A large, misshaped hypoechoic mass involving the right kidney was found in one female (3.2%). A large mass mimicking neoplasia was also imaged in one female camel (3.2%) distal to and compressing the left kidney, which proved histologically a leiomyoma. Moderate to severe thickening and corrugation of the urinary bladder mucosa were detected in 18 (58.1%) diseased camels. Echogenic bladder sediments of moderate to intense echogenicity were also found in 13 (41.9%) 31 camels (Fig. 5).

The means ± SD of the hematobiochemical parameters in diseased camels with red urine compared to healthy camels are displayed in Table 3. Significant hematological alterations included leukocytosis ($p = 0.002$), lymphopenia ($p = 0.006$), neutrophilia ($p = 0.0003$), and decreased erythrocytes ($p < 0.0001$), Hg ($p = 0.002$), and HCT ($p < 0.0001$). Other parameters that included mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) did not differ significantly between diseased and control groups

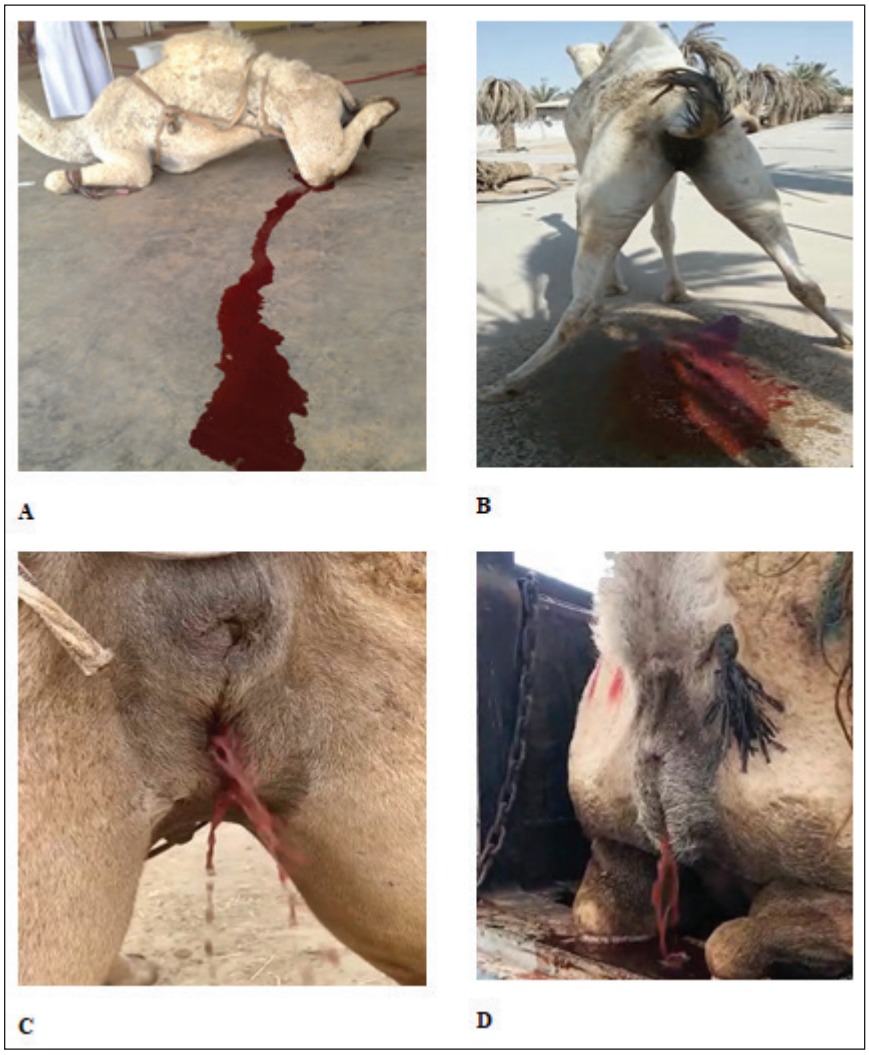

Fig. 1. Red urine in a male (**A**) and 3 female (**B–D**) dromedary camels. In images (**A)** and (**B**), the urine was dark red. In image (**B**), wide stance of the hind legs was remained for a long time after urination ending. In images (**C**) and (**D**), the urine was moderate red in color.

($p > 0.05$). Regarding the biochemical variables, hypoproteinemia ($p = 0.006$), hypoalbuminemia ($p < 0.0001$), hyperglobulinemia ($p = 0.02$), increased BUN and creatinine concentration ($p = 0.03$, 0.02, respectively) and hyperglycemia ($p = 0.002$) were detected. Other variables, including AST, calcium, and magnesium, did not show significant levels between diseased and healthy camels ($p > 0.05$).

Postmortem examination has been conducted on four cases (numbers 3, 9, 11, and 21). Necropsy findings of case number 9 included kidney enlargement renal and peri-renal abscessations with pyelonephritis. The right kidney weighed 4.1 kg while the left kidney weighed 18kg and the abscess surrounding the right kidney contained 10.5 l of pus. Histological findings of renal tissue revealed congested glomeruli and renal tubules contained colloid casts and fibrous and granulation tissue at the periphery. The interstitial tissue shows active and chronic inflammatory cell infiltration. A diagnosis of chronic bilateral active pyelonephritis was made. Figure 6 shows necropsy findings in the male camel number 11 with chronic hematuria. The urinary bladder wall is thickened and, severely congested and hemorrhagic. Unfortunately, no histopathological examination was performed. Figure 7 shows postmortem findings in the male camel number 3 with urolithiasis. Massive amounts of blood-stained uroperitoneum evacuated by catheterization were found. The bladder wall was perforated, clotted blood with a calculus was found within the bladder lumen and the penile body contained four calculi. No abnormal findings were found in any of the control healthy

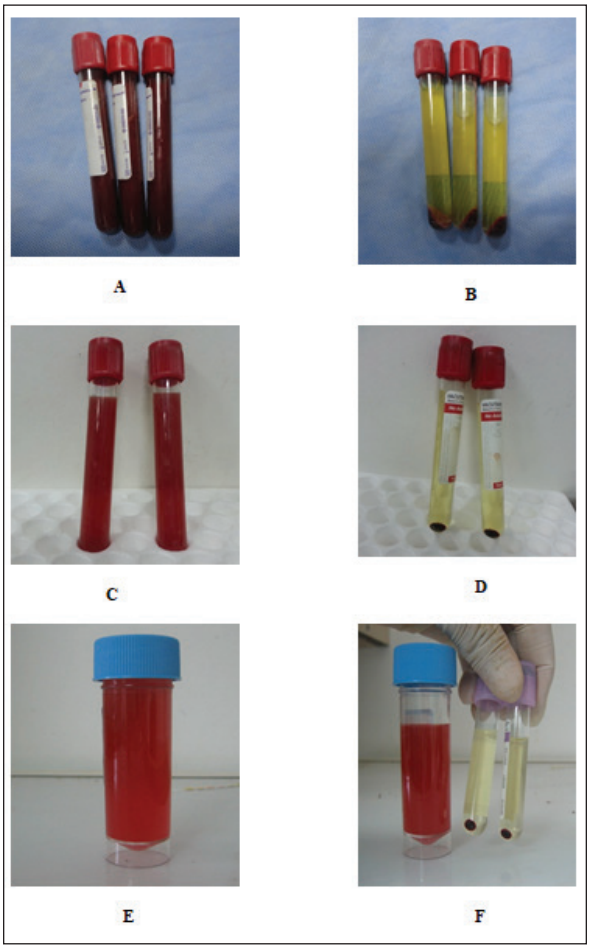

Fig. 2. Discolored urine in 3 camels (**A**, **C,** and **E**). Pictures on the opposite side (**B**, **D,** and **F**) refer to urine sedimentation after centrifugation of the same urine sampling thus confirming hematuria.

camels. In the female camel number 21, postmortem findings showed a large (18 kg), misshaped, and hemorrhagic right kidney. A final histological diagnosis of renal cell carcinoma was made. In the female case number 26, histopathological findings of the biopsy specimen showed thick-walled vessels at the pedicle with multiple infarct necrosis areas with hemorrhage and focal rim of viable smooth muscle tissue.

Discussion

To the best of the authors' knowledge, this is the first document that sheds light on this topic in dromedary camel medicine, as all reports in veterinary literature are published as case reports. The clinical, etiological, hematobiochemical, ultrasonographic, and pathological characteristics are described. The occurrence of clinical findings in this study ranged from only five days up to nine months, which was why the presentations differed greatly among referred camels. In addition, the hematological and biochemical

Table 2. Major ultrasonographic findings in 31 camels with bloody urine.

	Finding	Number (%)
1	Blood clots within the urinary bladder	20 (64.5)
2	Thicken and corrugated urinary bladder wall	15 (48.4)
3	Renal abscessations	5 (16.1)
4	Distended urinary bladder	5 (16.1)
5	Cystitis	3 (9.7)
6	Nephrolithiasis	3 (9.7)
7	Hydronephrosis	2 (6.5)
8	Ruptured urinary bladder	2 (6.5)
9	Uroperitoneum	2 (6.5)
10	Renal neoplasia	2 (6.5)
11	Pyelonephritis	1 (3.2)
12	Enlarged kidneys	1 (3.2)
13	Echogenic urine within the renal pelvis	1 (3.2)
14	Floating intestines in a hypoechoic fluid	1 (3.2)
15	Peri-renal abscessation	1 (3.2)

alterations detected here were a normal sequence for the prolonged hematuria that was concurrent in some cases with infections. The detected hyperglobulinemia in the diseased camels points to the chronic nature of the disease (Tharwat *et al*., 2017; Tharwat *et al*., 2018). The syndrome of urine discoloration is classified in farm animals as hematuria or pigmenturia, including hemoglobinuria and myoglobinuria. Hematuria (presence of intact erythrocytes in urine) is usually seen in cattle as a result of neoplasia of the urinary bladder (chronic enzootic hematuria syndrome) (Di Loria *et al*., 2012). In addition, hemoglobinuria and hemoglobinuria syndrome are more frequently observed in cattle due to different causes. Of these etiologies, the blood parasite is babesiosis (Mtshali and Mtshali, 2013; Mahmmod, 2013; Bal *et al*., 2016; He *et al*., 2021), *Clostridium hemolyticum* infection (Takagi *et al*., 2009; Shinozuka *et al*., 2011; Navarro *et al*., 2017), hypophosphatemia (Grünberg, 2014; Abramowicz *et al*., 2022), and water intoxication (Kawahara *et al*., 2016).

In the horse, urethritis, bacterial cystitis, urolithiasis, pyelonephritis, verminous nephritis, renal and vesicular neoplasia, and idiopathic hematuria are major causes of hematuria (Duesterdieck-Zellmer, 2007; Schumacher, 2007; Delvescovo *et al*., 2022). Hemoglobinuria due to intravascular hemolysis also occurs in horses due to toxins, immune-mediated illnesses, babesiosis, equine infectious anemia, and copper toxicities (Schumacher, 2007; Belli *et al*., 2021). Myoglobinuria is also reported

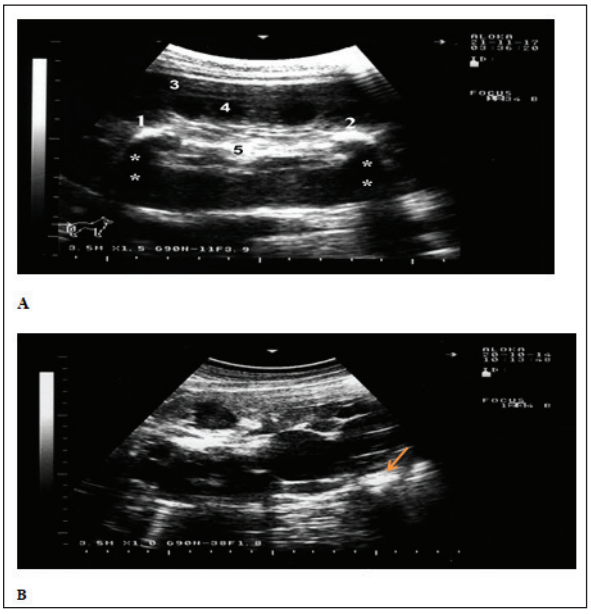

Fig. 3. Image (A) Nephrolithiasis (**1** and **2**) in a female camel with red urine for a 6-month period. **3**, renal cortex; **4**, renal medulla; **5**, renal sinus. Stars point to acoustic shadowing under the calculi. In a female camel with bilateral hydronephrosis, image (**B**) shows a small calculus within the right kidney pelvis with distal acoustic shadowing (arrow).

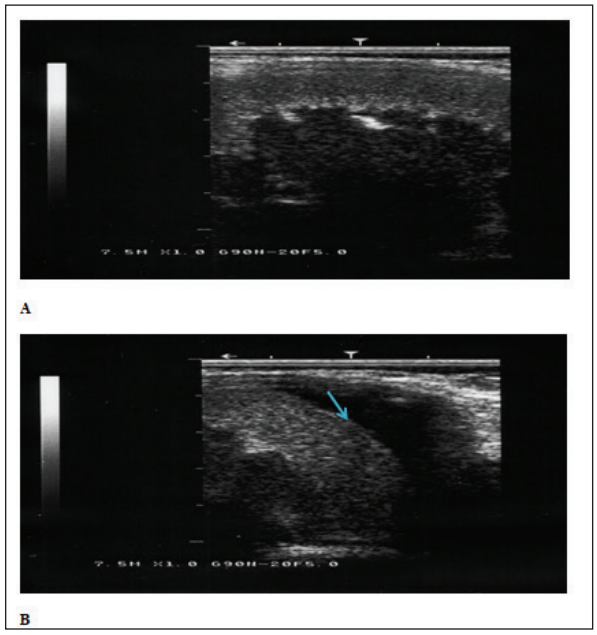

Fig. 4. Renal ultrasonography in a female camel with hematuria. In image (**A**), hyperechoic urine is imaged within the renal pelvis of the right kidney. The cortex and medulla are echogenic and therefore could not be differentiated (star). In image (**B**), a hypoechoic fluid was detected around the left kidney (arrow).

in equines due to traumatic muscular necrosis, immune-mediated myopathy, exertional rhabdomyolysis, polysaccharide storage myopathy, toxic drugs such as monensin, toxic plants such as coffee senna and white snakeroot and idiopathic causes such as atypical myopathy (Schumacher, 2007). In sheep and goats, urine discoloration due to hemoglobinuria is also found due to toxicity by copper (Bozynski *et al*., 2009; Borobia *et al*., 2022).

In this study, all the examined diseased camels with red discoloration of urine had hematuria and none of them had pigmenturia in either hemoglobinuria or myoglobinuria. Similarly, searching the veterinary literature revealed no published reports describing pigmenturia in the dromedary camel. Only reports documented in the camel and describing red urine syndrome also revealed hematuria. They attributed the condition to a concurrent infection of *Salmonella enterica* and *Theileria* (Abdelwahab *et al*., 2019), bilateral renal abscessation and pyelonephritis due to *E. coli* infection (Tharwat *et al*., 2018), nephrolithiasis (Tharwat, 2020a), renal neoplasia (Tharwat, 2017), and undetermined etiology (Bhandare, 2009).

Explanations as to why hemoglobinuria was not found in the present investigation may be due to the unique features of red blood cells in camels. Generally, camels' red cells rarely contain intracellular organelles, except for a few mitochondria. Mammalian microtubule marginal bands are also visible. This microstructure may be connected to erythrocytes' resilience to significant plasma osmotic shifts after heavy drinking and dehydration (Abdo *et al*. 1990; Faye and Bengoumi, 2018).

The fact that camels can consume a large amount of water in a short period is widely recognized. Yagil *et al*. (1974a) described a 600-kg dromedary camel losing 200 kg after 14 days of water restriction. To recover the lost fluids, the camel consumed a total of 200 l in 3 minutes. This physiological accomplishment entails a certain resilience of red blood cells. This resistance may be associated with the nature of the exterior membrane of red blood cells. There is a notable difference in the lipid composition of the erythrocyte membranes between camels and, desert goats and sheep, which have no differences. The levels of phosphatidylcholine, sphingomyelin, cholesterol, and proteins in the erythrocyte membranes of camels are significantly higher compared to the other two species of small ruminants (Al-Qarawi and Mousa, 2004).

Additionally, compared to other mammals, the RBCs of camels have a strong resistance to hypotonicity. This enables camels to undergo significant and sudden dilution of blood tissue during periods of extensive drinking. A water supply of 50 l per min does not destroy red blood cells, known as hemolysis. The red blood cells of camels can achieve a threshold mass before hemolysis in hypotonic solutions 2.3 times their

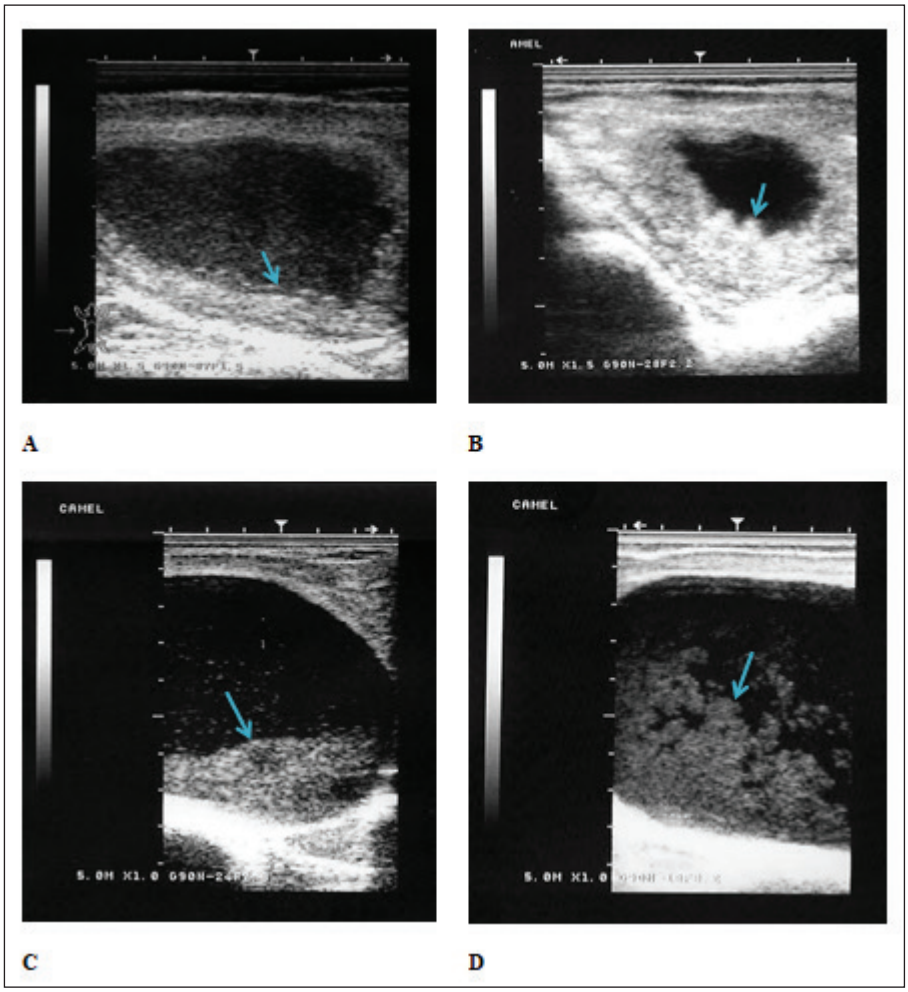

Fig. 5. Ultrasonography of the urinary bladder in camels with hematuria. Images **A** and **B** show, respectively, a moderate and severe corrugated bladder mucosa (arrows). Images **C** and **D** show, respectively, moderate and massive urinary sediments in 2 female camels with hematuria (arrows).

initial volume. This is substantially larger than what is reported in humans (Yagil *et al*., 1974c).

Furthermore, the camel's red blood cells exhibit exceptional resilience when exposed to hypertonic conditions. In 10% hypertonic solutions, the cells maintain their usual shape, while their volume drops slightly. However, in 20% of solutions, the cells largely exhibit abnormal forms (Yagil *et al*., 1974b). In contrast, human red blood cells cannot resist a tonicity greater than 1.5%. Overall, camels have hematological attributes that allow them to tolerate extreme dehydration circumstances without affecting the functionality of their blood cells (Faye and Bengoumi, 2018).

In dromedary camels, sonography has been implemented as a safe and very beneficial method for early prediction and verification of several disorders affecting the cardiopulmonary, hepatobiliary, digestive, and urinary systems. Routine use of ultrasonography for all camels presented with various disorders helped our research group detect numerous diseases and therefore improved the prognostication of diseased animals (Tharwat and Al-Sobayil, 2016; Tharwat, 2019; Tharwat and Al-Sobayil, 2020; Tharwat and Al-Hawas, 2021; Tharwat *et al*., 2023; Tharwat and Al-Hawas, 2024; Tharwat *et al*., 2024a,b,c,d,e,f; Tharwat and Tsuka, 2024).

Sonographic imaging of the urinary system in dromedary camels was reported to be a very useful modality for scanning the renal tissue and the verification, determining outcomes, and for treatment follow-up in cases with either focal or urinary disorders (Tharwat, 2020a). The ultrasound-guided biopsy of a renal specimen can be easily carried out in camels and is a safe and accurate methodology for diagnosing renal pathology (Tharwat *et al*., 2012). In this study,

Table 3. Hematobiochemical parameters in 26 camels with red urine versus healthy ones.

Parameters	Camels with red urine (*n*=26)	Healthy camels (*n*=15)	*P* value
White blood cells ($\times10^9$/l)	31.5 ± 19.2	16.8 ± 3.9	0.002
Lymphocytes ($\times10^9$/l)	2.5 ± 3.39	6.2 ± 2.9	0.006
Neutrophils ($\times10^9$/l)	25.1 ± 20.7	9.7 ± 3.0	0.0003
Red blood cells ($\times10^{12}$/l)	7.9 ± 1.9	11.3 ± 1.4	<0.0001
Hemoglobin (g/dl)	12.5 ± 3.5	16.4 ± 2.8	0.002
Packed cell volume (%)	19.6 ± 5.5	28.9 ± 2.7	<0.0001
MCV (fl)	24.4 ± 2.1	25.5 ± 1.5	0.1
MCH (pg)	15.7 ± 1.5	14.7 ± 2.4	0.2
MCHC (g/dl)	64.4 ± 11.0	57.6 ± 9.0	0.06
Total protein (G/l)	37.4 ± 40.7	67.3 ± 4.3	0.006
Albumin (G/l)	13.9 ± 13.8	60.39 ± 3.0	<0.0001
Globulin (G/l)	23.5 ± 27.0	7.0 ± 3.8	0.02
ALP (U/l)	111.4 ± 67.7	6.6 ± 2.8	<0.0001
Aspartate aminotransferase (U/l)	73.3 ± 19.6	79.5 ± 16.5	0.5
Calcium (mmol/l)	2.0 ± 0.3	2.4 ± 0.2	0.9
BUN (mmol/l)	6.2 ± 3.8	1.1 ± 0.2	0.03
Creatinine (µmol/l)	151.5 ± 62.5	115 ± 44	0.02
Magnesium (mmol/l)	1.4 ± 2.5	0.3 ± 1.0	0.07
Glucose (mmol/l)	253.7 ± 108.6	95.7 ± 0.6	0.001

Fig. 6. Postmortem findings in a male camel with chronic hematuria. The urinary bladder wall is thickened, severely congested, and hemorrhagic.

sonography of the urinary system was very helpful in verifying the disease and determining the prognosis and treatment options. By ultrasound, renal parenchyma was performed andrenal parenchyma was assessed, nephrolithiasis, hydronephrosis, pyelonephritis, and renal abscessation were diagnosed, and neoplasia was suspected. The urinary bladder was also assessed ultrasonographically in the diseased camels; the thickness and corrugation of its wall, the echogenicity of the bladder contents, and distension were easily evaluated. Moreover, whether the bladder wall was intact or perforated was determined. In addition, a collapsed and ruptured wall was diagnosed. Free abdominal fluid within the peritoneal cavity where viscera were floating was also diagnosed. Ultrasound-guided biopsy was also useful for getting of neoplastic tissue sample.

Unfortunately, only four of the diseased camels with grave prognosis were necropsied (cases number 3, 9, 11, and 21). Unfortunately, no histopathological examinations were performed on the male camels' number 3 and 11. The 3 cases examined by histopathology were published as case reports (cases numbers 9, 21, and 26). The case number 9 had bilateral pyelonephritis and renal abscessation (Tharwat *et al*., 2018a). In the female camel number 21, a final histological diagnosis of renal cell carcinoma was made (Tharwat *et al*., 2017). In the female case number 26, a histopathological diagnosis of leiomyoma was made (Sadan *et al*., 2024).

Conclusion

The syndrome of red urine in camels in this study resulted only from hematuria. All the Thirty-one examined camels had hematuria and none had either hemoglobinuria or myoglobinuria. The primary owner's complaint was the voiding of deep or

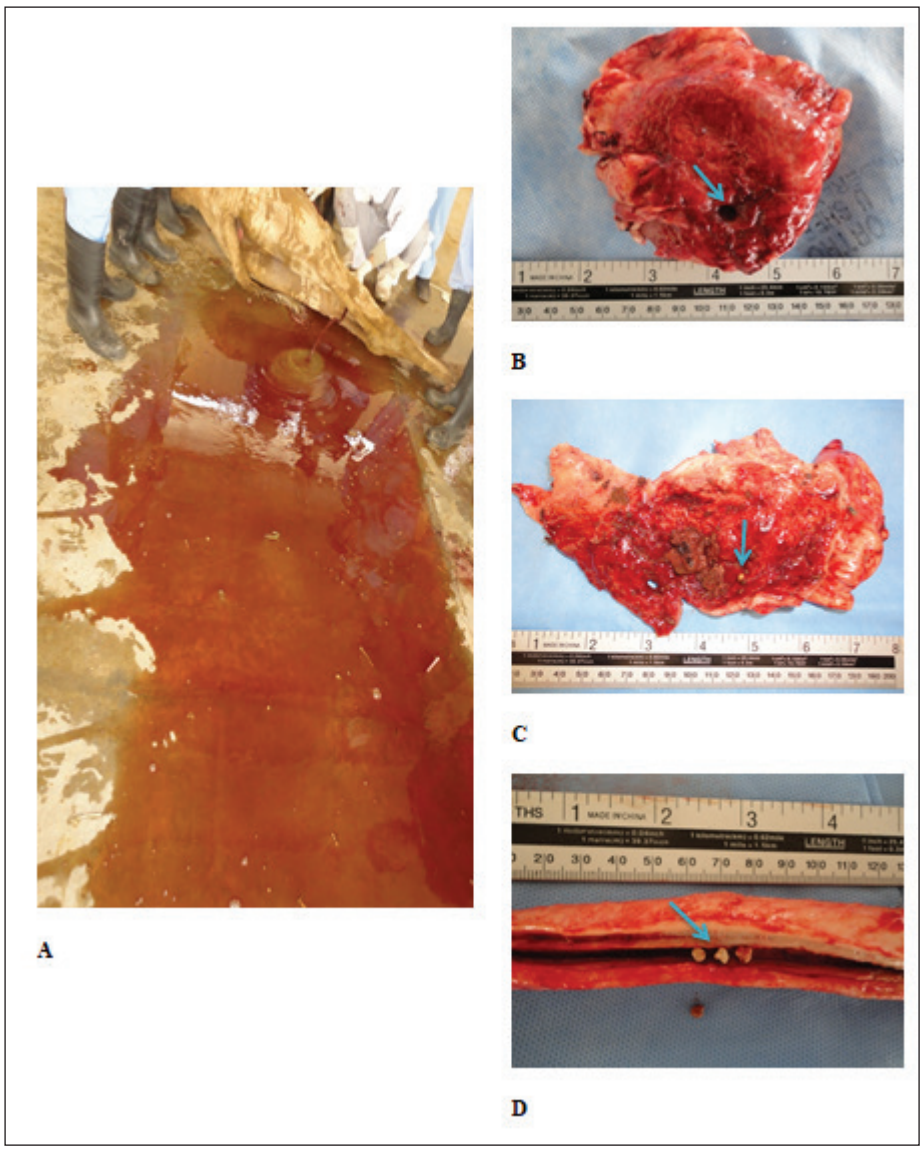

Fig. 7. Postmortem findings in a male camel with urolithiasis. Image **A** shows massive amounts of blood-stained uroperitoneum evacuated by catheterization ante-mortem. Image **B** shows a perforated urinary bladder (arrow). Image **C** shows clotted blood with a calculus (arrow) within the bladder lumen. Image **D** shows four calculi within the penile body (arrow).

moderate red-colored urine. The existing etiologies were nephrolithiasis, cystitis, pyelonephritis, peri-renal and renal abscessation, and renal neoplasia. Neutrophilic leukocytosis with lymphopenia was the characteristic hematological finding. Hypoproteinemia, hypoalbuminemia, hyperglobulinemia, increased BUN and creatinine concentration, and hyperglycemia were the characteristic biochemical findings. Finally, ultrasonography was superior in assessing the renal parenchyma and urinary bladder for the verification of existing nephrolithiasis, hydronephrosis, pyelonephritis, peri-renal and renal abscessation, cystitis, and ruptured or perforated bladder. Moreover, renal neoplasia was suspected by ultrasound and the tumor mass was sampled with the aid of ultrasound guidance.

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Authors' contributions
MT: conceptualization, practical work, writing of manuscript draft, and preparing the figures and tables. HE: practical work and revision of the manuscript draft. AS: review and editing of the manuscript draft. TA: analyzed the hematological and biochemical parameters. All authors approved the final manuscript for publication.

Conflict of interest
The authors declare that there is no conflict of interest.

Data availability
All data supporting the findings of this study are available within the manuscript and no additional data sources are required.

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