

Udder and Teat Affections in Female Dromedary camels: Frequency, Risk Factors, Clinical Findings and Treatment Outcomes

Madeh Sadan

Qassim University

El-Sayed EL-Shafaey

Mansoura University

Fahd AL-Sobayil

Qassim University

Moufida Atigui

Arid Regions Institute

Fahad A. Alshanbari

shnbry@qu.edu.sa

Qassim University

Gamal Alloush

Qassim University

Walid Refaai

University Veterinary Hospital, Qassim University

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Abstract

Udder and teat lesions are among the most important health problems affecting milk production, welfare, and economy in camel's industry. However, comprehensive epidemiological data describing their frequency, risk factors, diagnosis, and treatment outcomes remain limited. This study aimed to determine the frequency, risk factors, diagnosis, and treatment outcomes of udder and teat lesions in dromedary camels. A total of 191 female camels with udder and teat lesions were included in this study based on the clinical and ultrasonographic evaluation. Lesions were classified according to anatomical site, type, age, breed, etiology, treatment approach, and outcome. Udder lesions were more frequent (78.53%, odds ratios (OR): 13.38; confidence intervals (CI) 99%: 8.13-21.94; $p < 0.0001$) than teat lesions (21.47%). Mastitis was the most frequent udder disorder (29.84 %), followed by fibrosis and wounds. Hyperkeratosis and teat wounds were the most common teat lesions. Lesions were most frequently observed in camels aged 5–10 years (OR: 3.6; CI 99%: 2.3-5.5; $p < 0.001$), and the majority were acquired in origin (98.96%). The Wadeh breed showed the highest proportion of udder and teat lesions (53.40%, OR: 2.6; CI 95%: 1.7 to 4.0; $p < 0.001$), followed by Sofor (30.37%) and Mejhém (16.23%). Ultrasonography successfully differentiated between lesions based on echotexture. Overall, treatment was successful in 171 cases (89.53%, OR: 73.1; CI 95%: 38.6 – 134.3; $p = 0.0001$) with complete clinical recovery. In conclusion: Early clinical and ultrasonographic examinations provide accurate diagnosis and prognosis of udder and teat lesions in dromedary camels. Surgical interventions serve as effective curative options for treating udder and teat lesions that do not respond to medicinal treatment.

Introduction

The dromedary camel (*Camelus dromedarius*) is an indispensable livestock species across arid and semi-arid regions of Africa, the Middle East, and Asia, where it plays a pivotal role in food security, rural livelihoods, and socio-economic stability. In many pastoral and agro-pastoral systems, camels contribute up to 30–80% of household income through milk production alone, with lactating females representing the primary economic unit of camel herds. Survey-based studies from North Africa and the Arabian Peninsula have reported that camel milk accounts for 50–70% of total livestock-derived revenue in nomadic and semi-nomadic systems, particularly during prolonged drought periods when other livestock species underperform [6, 9, 15]. The economic sustainability of camel herds is therefore intrinsically linked to optimal reproductive performance and unimpeded lactation output, both of which are critically dependent on the health of the mammary gland [6, 7].

Udder and teat-associated diseases constitute one of the most economically detrimental health problems in dairy camels. Field surveys indicate that clinical and subclinical mammary affections can reduce individual milk yield by 15–40% per lactation, while severe or chronic cases may lead to complete cessation of milk production from affected quarters. Herd-level investigations further suggest that mastitis and teat injuries are responsible for 20–35% of premature culling of breeding females, resulting in substantial indirect losses related to replacement costs, reproductive inefficiency, and genetic dilution. Additionally, treatment expenses, milk withdrawal, and labor costs related to prolonged wound management or surgical intervention further exacerbate economic burdens on camel owners [8–10]. Conditions such as mastitis, abscesses, wounds, and teat disorders directly cause substantial reductions in milk yield and quality, increase culling rates, and incur significant treatment costs [11–15]. In dairy cattle, the etiology, epidemiology, and management of mammary pathologies are extensively documented [16, 17]. In contrast, similar research in dromedary camels remains relatively scarce and fragmented [18]. Existing studies often focus on isolated conditions, particularly subclinical mastitis via somatic cell counts, with comprehensive clinical surveys detailing the full spectrum of gross lesions, their demographic risk factors, and subsequent treatment outcomes being notably lacking [8, 10].

Diagnosis of udder and teat lesions is mainly based on clinical examination. Using advanced noninvasive diagnostic techniques, such as radiography, ultrasonography, and hematological and biochemical examinations, can improve diagnostic accuracy and guide treatment decisions [19, 20]. Treatment of udder and teat lesions can involve a variety of modalities both medicinal and surgical techniques. Surgical intervention is often required in chronic or complicated cases [21–24]. Although udder and teat disorders in dromedary camels have been previously reported, existing studies are largely fragmented and predominantly focused on isolated conditions, particularly subclinical mastitis, bacteriological findings, or abattoir-based observations rather than comprehensive clinical characterization in live animals [8–12, 18]. Integrated clinical cohort studies that simultaneously document the full spectrum of gross lesions, their anatomical distribution, associated demographic risk factors, and treatment outcomes remain scarce. Moreover, the use of advanced noninvasive diagnostic modalities to support clinical decision-making in camel mammary disorders has been inconsistently reported. Accordingly, the present study does not claim to be the first to describe udder and teat lesions in camels but represents one of the few clinical cohort investigations providing an integrated assessment of lesion frequency, morphology, risk factors (age, breed, and location), and therapeutic outcomes under field conditions. While limited by its reliance on clinically presented cases and the absence of longitudinal milk production data, this study addresses an important gap between descriptive pathology and practical clinical management of camel udder and teat affections.

Materials and methods

Study Design and Animals

A prospective clinical study (2018 – 2025) was conducted at the University Veterinary Hospital, Faculty of Veterinary Medicine, Qassim University, Saudi Arabia. The study cohort comprised 191 female dromedary camels (*Camelus dromedarius*) admitted to the University Veterinary Hospital from various owners and farms across different regions of the Kingdom of Saudi Arabia, presenting with various udder and teat disorders. The animals had a mean ($\pm$ SD) age of 97 ± 23 months (range: 12–140 months) and a mean weight of 550 ± 100 kg (range: 250–700 kg). The breed distribution was as follows: Wadeh (n=102), Asfar (Sofor) (n=58), and Mejhém (n=31).

Inclusion Criteria

Camels were included based on clinical and subsequent ultrasonographic confirmation of one or more affections of the udder or teats. Cases were classified according to anatomical site, type, age, breed, etiology, treatment approach, and outcome.

Ethical Approval

The Committee of Animal Welfare and Ethics at Qassim University, in accordance with the Laboratory Animal Control Guidelines (No. 367), approved the study protocol.

Clinical Examination

A comprehensive clinical examination was performed on each animal upon admission. This included a systematic clinical examination of the udder and teats to determine the location, extent, and characteristics of the lesions (size, pain, discharge, chronicity). Signalment data (breed, age, body weight) and clinical history were recorded for all camels.

Ultrasonographic Examination

Ultrasonographic (US) evaluation was performed using a 3.5–7.5 MHz linear array transducer (SSD-500, Aloka, Tokyo, Japan) to characterize all lesions. To minimize stress, ensure animal welfare, and obtain accurate diagnostic images, camels were placed in lateral recumbency under light sedation induced by intravenous administration of xylazine HCl, 0.2 mg/kg. Sedation was considered necessary to reduce struggling, pain-associated reactions, and sudden movements that could compromise image quality, prolong handling time, or increase the risk of injury to both the animal and the operator. The low-dose protocol was selected to provide adequate restraint while minimizing potential physiological alterations that could affect ultrasonographic findings. Transmission gel was applied to the examination area. The US assessment focused on lesion echogenicity, dimensions, margins, and internal contents (e.g., fluid, gas, and tissue). When indicated, ultrasonographically guided fine-needle aspiration was performed for diagnostic purposes [19]. All examinations were conducted by a single investigator to ensure procedural consistency and reduce inter-observer variability.

Treatment Strategies and Decision Criteria (Decision Criteria for Treatment Selection)

The choice between medical and surgical management was based on clinical examination, ultrasonographic findings, lesion chronicity, tissue viability, and the presence or absence of structural destruction. Medical treatment was indicated for acute inflammatory conditions without irreversible tissue damage, including edema, early mastitis, superficial abscessation, and non-complicated lesions without fistulation or necrosis. Surgical intervention was selected for chronic, non-responsive, or structurally destructive conditions such as chronic abscessation, gangrene, extensive fibrosis, deep fistulas, or severe tissue necrosis where conservative therapy was unlikely to achieve resolution. The decision was further supported by the animal's general health status and hematobiochemical profile to ensure surgical fitness.

1. Medical treatment

69 cases with primarily inflammatory or non-surgical conditions received medicinal therapy. The protocol included: Systemic Antibiotics: Amoxicillin and Clavulanic Acid (Synulox RTU, Zoetis, UK) at 1 mL/20 kg body weight, IM, daily for 5-7 days. Systemic Anti-inflammatories: Meloxicam (Rheumocam, Eurovet) at 0.5 mg/kg, IV, daily for 5 days. Topical Therapy: This involved cold hydrotherapy massage and the application of antimicrobial (Mastjet Forte, MSD) or anti-inflammatory (Montazone, Montajat) ointments, tailored to the specific lesion.

2. Surgical treatment

2.1 Preoperative preparation and anesthesia

122 cases with conditions such as chronic abscessation, gangrene, fibrosis, or fistulas were managed surgically. For female camels undergoing surgery, routine clinical and hematological evaluations including, body temperature and vital signs as well as, total and differential leukocyte count and biochemical examination were performed; all the values were within the reference range according to Sadan et al., 2023 [3], allowing the patient to undergo surgery. Food and water were withheld for 12 hours. Preoperative medication included antibiotics and anti-inflammatories as described above. General sedation was achieved with xylazine HCl (0.3 mg/kg IV), followed by epidural anesthesia at the first intercoccygeal space using 10 mL of 2% lidocaine HCl.

2.2 Surgical Procedures:

Mastectomy: Performed for advanced conditions like purulent mastitis, gangrene, or severe fibrosis. An elliptical incision was made around the affected gland(s), followed by careful dissection, ligation of major vessels (using polyglactin 910), and layered closure of subcutaneous tissue and skin [21, 22].
Fistula Repair: After debridement of the fistula tract, the teat canal was repaired in two layers (mucosa/submucosa and muscular/connective tissue) using polyglactin 910. A sterile teat plug was inserted in lactating animals, with daily milking and plug replacement. Intramammary antibiotics were infused post-repair when indicated [23].

2.3 Postoperative Care and Follow-up

Postoperative antibiotic and anti-inflammatory therapies were continued for 10 and 5 days, respectively. Animals were confined for 4 weeks to minimize wound tension and prevent dehiscence. Skin sutures were removed 14 days postoperatively. Long-term outcomes were evaluated over a 6-month follow-up period through scheduled field visits and structured owner interviews. Treatment outcomes were categorized using predefined clinical criteria to avoid oversimplification and to capture partial or delayed failures: Complete recovery: Full wound healing without complications, absence of swelling, discharge, or pain, and restoration of normal udder/teat function (including milk flow in lactating animals). Partial recovery: Clinical improvement with residual functional or structural abnormalities (e.g., reduced milk yield, mild fibrosis, or minor teat canal narrowing) not requiring immediate re-intervention. Not recovered (treatment failure): Persistence of primary clinical signs, wound breakdown, or failure to restore functional integrity requiring additional medical or surgical

management. Recurrence: Reappearance of the same lesion or development of a similar pathological condition at the same site after initial clinical resolution during the follow-up period.

Data and Statistical Analysis

Lesions were categorized by type, location (forequarter, hindquarter, bilateral), age group (<5, 5-10, >10 years), breed, and treatment outcome (Recovered / Recovered with Complications). Statistical analysis was performed using IBM SPSS Statistics (Version 21). Frequencies rates were calculated. Associations between lesion types and potential risk factors (age, site, breed, etiology) were analyzed using Chi-square or Fisher's exact tests, with odds ratios (OR) and 95% confidence intervals (CI) reported. Treatment outcomes were similarly compared. A p -value of < 0.05 was considered statistically significant.

Results

Overall frequency of udder and teat lesions

Out of 191 examined camels, udder lesions (Figs. 1-5) affected 150 animals (78.53%), while 41 animals (21.47%) showed teat lesions (Figs. 6-8). Udder disorders were therefore significantly more frequent (Fig. 9, Table. 1, 2) than teat disorders (Fig. 10, Table. 1, 3) (OR: 13.38; CI 99%: 8.13-21.94; $p < 0.0001$). Mastitis was the most frequently diagnosed udder lesion, accounting for 57 cases (38.0% of udder lesions), followed by fibrosis (23 cases; 15.33%), wounds (19 cases; 12.67%), and abscesses (17 cases; 11.33%). This underscores mastitis as the principal threat to udder health and milk production. The frequency of chronic mastitis was significantly higher than acute (27 vs 13, $p < 0.01$), suppurative (27 vs 10, $p < 0.001$), and gangrenous mastitis (27 vs 7, $p < 0.001$). Less frequently recorded conditions included edema (2.67%), necrosis (2.0%), and gangrene (4.0%). Among teat disorders, hyperkeratosis (17.07%) and teat wounds (17.07%) were the most common findings, followed by dilated teat cistern (14.64%), Thelitis (12.19%), and teat gangrene (12.19%). Blocked teat was rarely encountered (2.44%).

Udder and teat lesions distribution, and epidemiological associations

Most udder lesions were localized to the hindquarters (OR: 3.12; CI 95%: 1.38-3.2; $p < 0.01$), particularly mastitis, fibrosis, and abscesses. Lesions affecting both fore and hindquarters were more common in pendulous udders and chronic mastitis cases, suggesting long-standing pathology. However, wounds were found more frequently in fore quarters than rear ones (11 vs 7). Teat lesions were predominantly unilateral, with a higher frequency in hindquarters compared with forequarters.

Udder and teat lesions were most frequently observed in camels aged 5–10 years (OR: 3.6; CI 99%: 2.3-5.5; $p < 0.001$), accounting for 62.83% of total cases, whereas animals younger than 5 years represented only 5.24% of affected cases. This pattern indicates a strong association between lesion occurrence and productive age. However, fibrosis and pendulous udder were more common older camels (> 10 years).

The Wadeh breed showed the highest proportion of udder and teat lesions (53.40%, OR: 2.6; CI 95%: 1.7 to 4.0; $p < 0.001$), followed by Sofor (30.37%) and Mejhém (16.23%). Breed-related variation was more pronounced for mastitis and fibrosis.

The vast majority of lesions were acquired (98.96%, OR: 4.83; CI 95%: 3.12 - 7.5; $p = 0.0001$), while congenital lesions represented only 1.04%. Infectious causes predominated in mastitis, abscesses, and Thelitis, whereas traumatic and non-infectious causes were mainly associated with wounds, hematomas, and teat stenosis.

Clinical findings

She-camels affected with acute purulent mastitis exhibited anorexia, fever, general depression, and marked udder swelling with pus discharge (Fig. 1A and 1C), accompanied by severe inflammation and pain. In chronic cases, the udder was firm, swollen, and non-painful, showing fibrous consistency with nodular indurations and atrophy of one or more quarters (Fig. 1B). In she-camels with gangrenous mastitis, the udder appeared bluish and edematous, felt cold to the touch, and exhibited blackened, corrugated skin with signs of putrefaction (Fig. 1D). Six she-camels with a history of trauma were diagnosed with hematomas. The appearance of the contents differed according to severity and duration. A case with recent hematoma showed hot, painful, inflammatory swelling of the udder. Clinical examination of the five cases with organized hematomas revealed circumscribed non-painful cold firm swelling of the udder. Exploratory puncture of these hematomas under strict aseptic preparation revealed pure blood and haemoserous fluids (blood-tinged fluid) in recent and organized hematoma respectively (Fig. 2C). Udder fibrosis was observed in 23 cases (15.33%) (Fig. 2E) and was attributed to chronic inflammation or injury. The condition was characterized by induration of one or more quarters, leading to firmness and hardening of the affected udder tissue along with a history of pain or discomfort during milking and a decline in milk yield. Udder edema was documented in 4 animals (2.67%) (Fig. 3A) in the present study. On clinical examination, the udder exhibited soft, diffuse enlargement with pitting upon palpation. The overlying skin appeared stretched, and the swollen region was cooler to the touch compared to adjacent tissues. Affected animals also demonstrated discomfort or pain during milking.

In this study, nine she-camels (6%) exhibited pendulous udders (Fig. 3). The udder was observed to hang lower than normal and swing markedly during movement, leading to noticeable changes in the animals' gait. Neoplastic lesions were identified in six cases (4%), including papillomas, granulomas, and adenocarcinomas (Fig. 4). Udder wounds were observed in 19 cases (12.67%) in this study, including lacerations in 5 animals (3.33%) (Fig. 5A) and fistulas in 14 animals (9.34%) (Fig. 5B and C), with variation depending on the severity and extent of the damage. Fistulas were identified by abnormal external openings on the udder, resulting in continuous or intermittent leakage of milk, or serous fluid. Affected she-camels frequently displayed localized swelling, inflammation, and pain, particularly during milking. In chronic cases, skin irritation, crust formation around the fistulous tract, and fibrosis of surrounding tissues were commonly observed. Udder necrosis was observed in 3 cases (2%) of the affected female camels. The condition involved one or more quarters and was characterized by skin discoloration (darkening or blackening) (Fig. 5D), a cold and corrugated surface, and in severe cases, sloughing of the tissue

or complete loss (amputation) of the affected quarter. Udder gangrene was detected in six female camels (4%) (Fig. 5E and F). In the acute stage, the udder appeared hard, hot, and painful, whereas in chronic cases it became cold and firm, with dark red to black skin discoloration. The surface of the udder developed a corrugated texture, accompanied by a foul odor due to necrotic tissue.

Clinical symptoms of teats injuries varied according to severity and extent of injury. Teat laceration was diagnosed in 2 cases (4.88%). The condition presented as a distinct cut or tear on the teat skin, which could be either superficial—affecting only the skin—or deep, extending into the teat canal or cistern. Affected teats showed swelling around the injured area, with active bleeding in recent cases and scab formation in older ones. Teat fistulas were observed in 5 cases (12.19%) (Fig. 6A and B), characterized by abnormal external small or large orifice on the teat that caused continuous or intermittent dribbling of milk. Affected she-camels often showed localized swelling, inflammation, and pain, especially during milking. In chronic cases, skin irritation, crust formation around the fistulous opening, and fibrosis of the surrounding tissues were frequently noted.

Thelitis was observed in five female camels (12.19%), and it was characterized by teat swelling, tenderness upon palpation, thickening and hardening of the teat skin, as well as the presence of crusts, scabs, or ulcerative lesions (Fig. 7A). Teat hyperkeratosis was detected in 7 female camels (17.07%), presenting as a rough, thickened, hardened, or scaly teat surface, accompanied by brown crust formation and constriction of the teat opening (Fig. 7B). Teat necrosis was identified in three she camels (7.32%), characterized by a cold, dry teat surface accompanied by discoloration and loss of sensation (Fig. 7C). Gangrene of the teat was detected in five she-camels (12.19%). The affected teats were swollen, cold, and moist, emitting a foul odor, with dark brown to black skin discoloration and a clear demarcation line distinguishing viable from necrotic tissue (Fig. 7D).

Dilated teat cistern was detected in six she-camels (14.64%). The condition was characterized by teat enlargement, particularly at the base, with a soft and fluctuating consistency on palpation, absence of pain or heat, and failure to discharge milk through a visibly narrowed orifice (Fig. 8A). Dilated teat orifice (free milker) was observed in two she-camels (4.88%). There was enlarged and widened teat opening, accompanied by continuous or intermittent milk dripping and moistness around the teat end, occasionally with crusts of dried milk. In chronic cases, thickening of the skin around the teat orifice was evident (Fig. 8B). Teat stenosis (hard milker) was recorded in three she-camels (7.32%). Clinically, the teat orifice appeared firm, narrowed, or pin-point, with hardness on palpation particularly near the orifice and slight swelling at the distal end of the teat. In chronic cases, palpable fibrous thickening was noted around the orifice or teat canal (Fig. 8D). Blocked teat was identified in one she-camel (2.44%). The affected teat was firm, swollen, and fluctuated on palpation, eliciting pain when pressed or during milking, and showed complete or markedly reduced milk flow (Fig. 8E). Two cases of teat papilloma (4.88%) were identified in the present study.

Ultrasonographic findings

The sonogram of acute mastitis typically reveals non-homogenous echogenicity and less visualized alveoli. Conversely, chronic mastitis presents with hyper echogenicity of the udder parenchyma (Fig. 1 B and D). The ultrasonographic appearance of udder abscesses varied from hypoechoic to hyperechoic contents, respectively bounded by echogenic capsules containing varying amounts of pus, debris, or homogenous material (Fig. 2 B). Ultrasound scanning of a recent udder hematoma demonstrated anechoic to hypoechoic fluid contents with an echogenic wall. Sonograms of organized hematomas displayed hyperechoic contents surrounded by an echogenic wall, notably exhibiting a decrease in anechoic fluid content and an increase in content echogenicity when compared to recent hematomas (Fig. 2D). Ultrasonographic examination of the fibrosed udder showed a homogeneous or heterogeneous hyperechoic pattern, corresponding to areas of thickened connective or scar tissue in mild and severe cases, respectively. In certain instances, where fibrosis was associated with abscess formation, the hyperechoic regions were interspersed with hypoechoic areas (Fig. 2F). Neoplastic lesions were identified in six cases, including papillomas, granulomas, and adenocarcinomas (Fig. 4 E). Ultrasonographic evaluation revealed masses ranging from isoechoic to hyperechoic in appearance. Finally, ultrasonography of the dilated teat cistern in the same female camel showed a widened, largely anechoic cavity (cistern) and, at times, increased echogenicity of the milk within the cistern (Fig. 8 B).

Treatment and outcomes

Medical treatment was applied in acute cases, while chronic, traumatic, and neoplastic conditions required surgical intervention. Combined medical–surgical management was employed in selected cases with complications. Overall, treatment was successful in 171 cases (89.53%, OR: 73.1; CI 95%: 38.6 – 134.3; $p = 0.0001$) with complete clinical recovery, while routine postoperative complications were recorded in 20 cases (10.47%), which were most commonly associated with mastitis, fibrosis, and teat wounds.

Discussion

The growing demand for dromedary camel milk, driven by its nutritional, functional, and perceived therapeutic benefits, has accelerated the expansion of camel dairy systems in arid and semi-arid regions. Several epidemiological investigations across the Arabian Peninsula and North Africa have similarly emphasized that udder health remains a cornerstone of sustainable camel milk production, directly influencing milk yield, hygienic quality, and market value [1–3]. Studies from Saudi Arabia, Sudan, and Ethiopia have reported that compromised udder integrity significantly increases somatic cell counts and bacterial contamination, thereby reducing both shelf life and commercial acceptability [9–13]. Udder and teat affections can compromise milk yield, alter physicochemical and sensory properties, and increase the risk of microbial contamination [8, 10, 13]. The present study provides a comprehensive epidemiological overview of udder and teat disorders in camels, highlighting their frequency, distribution, etiological factors, and treatment outcomes. The high overall frequency of udder lesions (78.53%) compared with teat lesions (21.47%) indicates that the udder remains the primary anatomical site affected by pathological conditions in camels, likely due to its greater exposure to infectious agents, mechanical trauma, and physiological stress during lactation.

Mastitis emerged as the most frequent udder disorder, accounting for nearly one-third of all examined camels. This finding is consistent with previous reports [1, 4, 6, 7, 10, 12] describing mastitis as the most economically significant mammary gland disorder in camels, particularly in intensive and semi-

intensive management systems. The predominance of chronic and suppurative forms observed in the present study suggests delayed diagnosis or inadequate early treatment, poor milking hygiene, and inadequate dry-period management, which may contribute to reduced milk yield and increased recurrence rates. often linked to delayed intervention,

Fibrosis (15.33%) and abscess (11.33%) formation was also frequently recorded, often as sequelae of chronic inflammatory processes. Previous ultrasonographic case reports have demonstrated that chronic mastitis produces heterogeneous echotexture and hyperechoic fibrotic strands, patterns that correspond closely with our imaging findings [8, 14, 18]. Abscess formation (11.33%) has also been documented in earlier case reports, particularly in animals subjected to penetrating injuries or secondary bacterial invasion following untreated mastitis. Reports describing surgical drainage and systemic antimicrobial therapy in such cases have indicated favorable outcomes when intervention is performed promptly, supporting the high recovery rates recorded in this study [21–24]. The strong association between these lesions and older age groups further supports the role of cumulative tissue damage and repeated inflammatory insults over successive lactation cycles [25, 26]. Similarly, Traumatic lesions, including wounds (12.67%) and hematomas (4%), have been repeatedly described in pastoral and semi-intensive systems, where environmental hazards, thorn injuries, or aggressive calf behavior contribute to mammary damage [1, 2, 7]. Field observations from desert-based production systems similarly note a higher incidence of traumatic lesions in poorly sheltered housing conditions, reinforcing the importance of environmental management. Teat disorders, although less frequent, were clinically significant.

Teat lesions, although less frequent, represented clinically important conditions that directly interfere with milk flow and milking efficiency. Hyperkeratosis and teat wounds (17.07%) were the most common teat disorders identified, which may be linked to repetitive mechanical irritation, improper milking practices, or excessive negative pressure during machine milking. Comparable case descriptions in camel dairies have linked hyperkeratotic changes with chronic teat canal inflammation and secondary stenosis. The relatively high frequency of dilated teat cisterns (14.64%) and stenosis (7.32%) indicates long-standing functional alterations, likely secondary to inflammation or fibrosis [6, 8–11], frequently necessitating surgical correction to restore milk flow.

Age was a significant determinant of lesion occurrence, with the highest frequency observed in camels aged 5–10 years (120 cases, 62.83%). This age group corresponds to peak productive and reproductive activity, during which animals are exposed to maximal physiological demands and management-related stressors. While A significant proportion were in the >10 years group (61 cases, 31.94%), suggesting cumulative effects of age, repeated lactations, and chronic conditions. In contrast, the low prevalence recorded in camels younger than 5 years (10 cases, 5.24%) may reflect limited exposure time and lower milking pressure. The sustained frequency in animals older than 10 years further supports the cumulative tissue-degeneration hypothesis. Similar findings were reported by [2, 6, 14].

In terms of breed distribution, udder and teat disorders were most commonly observed in Wadeh camels (102 cases, 53.40%), followed by Sofor camels (58 cases, 30.37%) and Mejhem camels (31 cases, 16.23%). Some authors have suggested management-related rather than genetic factors as primary determinants, others have observed higher lesion frequencies in high-yielding or more commercially valuable breeds. The higher frequency in Wadeh camels may be attributed to their larger population and breed distribution in Saudi Arabia, as well as their superior productivity, reproductive value, and economic value, as reported by [15].

Regarding the anatomical distribution of the udder and teat lesions, the hind quarters (HQs 48.69%) were most frequently affected, followed by the fore quarters (FQs, 30.89%). Several ultrasonographic and clinical case series have reported similar distribution patterns [7, 10, 12], reinforcing the functional and anatomical rationale for this finding. The overwhelming predominance of acquired lesions (98.96%) confirms earlier conclusions that environmental, infectious, and management-related factors play decisive roles in disease pathogenesis. Comparable economic analyses have quantified substantial financial losses due to reduced yield, discarded milk during antimicrobial withdrawal periods, and premature culling [2, 4, 23]. These consistent findings across studies underscore the preventable nature of most udder and teat disorders. This is clinically logical, as HQs are larger, produce more milk, and are more prone to trauma and contamination. [7, 10, 12].

The predominance of acquired lesions (98.96%) underscores the major role of environmental, infectious, and management-related factors in the pathogenesis of udder and teat disorders. This suggests infections are often persistent or inadequately treated, becoming chronic. These conditions also result in significant economic losses due to reduced milk yield, milk being discarded during antibiotic treatment, and the potential loss of one or more quarters when drying off becomes necessary, all of which diminish the overall value of dairy camels [3, 5, 6]. These findings highlight the potential for effective preventive strategies through improved hygiene, early detection, and proper milking practices.

Diagnostic integration of clinical examination with ultrasonography has been increasingly advocated in camel medicine. Previous case reports and controlled studies have demonstrated that ultrasonography enhances early detection of intraparenchymal abscesses, fibrosis, ductal obstruction, and cisternal abnormalities [8, 14, 18]. The imaging patterns documented in this study closely mirror those reported in earlier diagnostic investigations, supporting the reliability and reproducibility of ultrasonographic assessment in field conditions. Therapeutically, the high overall recovery rate (89.53%) observed here is comparable to previously published surgical case outcomes for chronic mastitis, abscesses, teat fistulae, and stenosis [21–24]. Earlier reports emphasize that prognosis improves significantly with early surgical decision-making and strict postoperative care protocols. The relatively low complication rate in this study further reinforces the safety and practicality of surgical management in appropriately selected cases. A wide range of clinical signs associated with udder and teat disorders was observed in this study, varying with the nature and severity of the lesion. Clinical examination, combined with advanced non-invasive diagnostic tools, particularly ultrasonography, enables accurate diagnosis of udder and teat disorders in camels. The ultrasonographic appearance of udder and teat abnormalities varied with the type of lesion, underlying cause, duration, severity, and extent of tissue involvement. Observed patterns included homogeneous and heterogeneous echotextures, as well as anechoic, hypoechoic, or hyperechoic areas. These observations were consistent with those reported by [8, 14, 18].

Management of udder and teat lesions involved both medical therapies and various surgical interventions depending on the specific teat or udder pathology. Treatment outcomes were generally favorable, with an overall recovery rate of 89.53%. Medical management was mainly reserved for early and

uncomplicated lesions. Surgical intervention proved effective in the majority of cases, particularly in chronic, complicated, or irreversible conditions. Postoperative complications were relatively low (10.47%) but were more commonly observed in chronic mastitis, fibrosis, and teat wounds, emphasizing the importance of timely intervention and appropriate follow-up [3, 8, 11, 13].

Despite these strengths, several limitations remain. Broader multicenter studies across diverse ecological zones would enhance generalizability. Future investigations should integrate bacteriological culture, antimicrobial sensitivity testing, and histopathological confirmation to refine etiological classification. Additionally, detailed evaluation of herd-level management practices, milking systems, hygiene protocols, and housing design would facilitate development of targeted preventive strategies. Collectively, by contextualizing the present findings within existing epidemiological surveys, ultrasonographic case series, and surgical outcome reports, this discussion provides a clearer and more comprehensive understanding of udder and teat pathology in dromedary camels and reinforces the clinical and economic importance of early diagnosis and evidence-based intervention.

Conclusion

This study demonstrates that the early integration of systematic clinical examination with targeted ultrasonographic assessment markedly improves the accuracy of diagnosis, prognostic evaluation, and therapeutic decision-making in udder and teat lesions of dromedary camels. Prompt identification of lesion type and severity allows timely intervention, reducing disease progression, preventing secondary complications such as mastitis, and minimizing production losses. The findings confirm that well-planned surgical interventions represent safe, practical, and highly effective curative options for lesions unresponsive to medical therapy. When combined with appropriate perioperative care, hygiene management, and follow-up protocols, these procedures significantly enhance recovery rates, preserve mammary functionality, and improve animal welfare. For camel farmers and the broader camel dairy industry, implementing early diagnostic screening protocols, routine ultrasonographic evaluation of suspicious cases, and rapid referral for surgical correction when indicated can substantially reduce culling rates, protect milk yield and quality, and limit economic losses. Adopting these evidence-based clinical protocols strengthens herd health management programs and contributes directly to sustainable camel production systems. Overall, this work provides a comprehensive clinical framework that supports veterinary practitioners in evidence-based field practice while offering actionable recommendations that safeguard udder health, enhance productivity, and sustain the livelihoods of communities dependent on camel farming.

Declarations

Authors' contributions

MS, EE: Conceptualization and data curation, MS, EE, FA, MA, FSH, GA, and WR: Formal analysis, funding acquisition, and investigation, all Authors: Writing - review and editing of the manuscript.

Ethics approval and consent to participate:

All experimental procedures were conducted in accordance with the Laboratory Animal Control Guidelines of Qassim University, which adhere to the principles outlined in the Guide for the Care and Use of Laboratory Animals of the U.S. National Institutes of Health (NIH Publication No. 86–23, revised 1996). Animals included in this study were privately owned by owners and farms across different regions of the Kingdom of Saudi Arabia and informed consent from the owners were obtained from them to use their animals in the study. The study protocol (Approval No. 370) was reviewed and approved by the Committee for Animal Welfare and Ethics, Qassim University, Saudi Arabia.

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Data availability:

The relevant information, including raw data, has been included in the manuscript.

Consent to Publish Declaration

Not applicable.

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Data Availability Statement:

All data presented in this study are available on request from the corresponding authors.

Competing interests

The authors declare no competing interests.

Author details

¹Department of Clinical Sciences, College of Veterinary Medicine, Qassim University, P.O. Box 6622, Buraydah, 51452, Saudi Arabia. m.sadan@qu.edu.sa.

²Department of Surgery, Anesthesiology, and Radiology, Faculty of Veterinary Medicine, Mansoura University, Mansoura City, Dakahlia 35516, Egypt. eelshafay@mans.edu.eg

³Department of Veterinary Surgery, Salam Veterinary Group, Buraydah- City 51452, PO Box 6622, Qassim, Saudi Arabia.

⁴Arid Regions Institute, Livestock and Wildlife Laboratory, 4119, Medenine, Tunisia.

⁵Departement of Medical Biosciences, College of Veterinary Medicine, Qassim University, P.O. Box 6622, Buraydah, 51452, Saudi Arabia.

⁶Department of Surgery, Anesthesiology and Radiology, University Veterinary Hospital, Qassim University, P.O. Box 6622, Buraydah, 51452, Saudi Arabia.

⁷Department of Surgery, Anesthesiology, and Radiology, Faculty of Veterinary Medicine, Zagazig University, Zagazig City, El Sharkia 44519, Egypt.

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Tables

Table 1
Frequency rate (%) of the udder and teat lesions in 191 camels' cohort.

Anatomical site	Lesion	Number of cases	frequency (%)
Udder (n = 150)	Mastitis	57	38.00
	Abscess	17	11.33
	Hematoma	6	4.00
	Fibrosis	23	15.33
	Edema	4	2.67
	Pendulous udder	9	6.00
	Neoplasia	6	4.00
	Wounds	19	12.67
	Necrosis	3	2.00
	Gangrene	6	4.00
Teat (n = 41)	Thelitis	5	12.19
	Hyperkeratosis	7	17.07
	Teat necrosis	3	7.32
	Gangrene	5	12.19
	Wounds	7	17.07
	Dilated teat cistern	6	14.64
	Dilated teat orifice	2	4.88
	Teat stenosis	3	7.32
	Blocked teat	1	2.44
	Neoplasia	2	4.88

Table 2

Distribution of the udder lesions in camels' cohort according to location, age, breed, and treatment outcomes.

Lesion	Location			Age (Year)			Breed			Causes				Treatment	
	FQ	HQ	Both	< 5	5–10	> 10	Wadeh	Sofor	Mejhem	Congenital	Acquired			Medicinal	Surg
											Traumatic	Infectious	Non-infectious		
Mastitis (n = 57)	18	27	12	3	39	15	31	17	9	0	1	53	3	45	12
Abscess (n = 17)	5	9	3	1	10	6	9	5	3	0	3	13	1	4	13
Hematoma (n = 6)	2	4	0	0	4	2	4	1	1	0	6	0	0	0	6
Fibrosis (n = 23)	7	11	5	0	9	14	11	8	4	0	2	20	1	3	20
Edema (n = 4)	2	1	1	1	3	0	1	2	1	0	0	3	1	4	0
Pendulous (n = 9)	1	2	6	0	3	6	4	3	2	2	1	6	0	2	7
Neoplasia (n = 6)	1	3	2	0	4	2	4	2	0	0	1	1	4	0	6
Wounds (n = 19)	11	7	1	2	12	5	8	6	5	0	19	0	0	0	19
Necrosis (n = 3)	0	3	0	0	2	1	2	1	0	0	0	2	1	1	2
Gangrene (n = 6)	2	3	1	0	5	1	4	2	0	0	0	6	0	0	6
Total (150)	49	70	31	7	91	52	78	47	25	2	33	104	11	59	91

Table 3

Distribution of the teat lesions in camels' cohort according to location, age, breed, and treatment outcomes.

Lesion	Location			Age (Year)			Breed			Causes				Treatment	
	FQ	HQ	Both	< 5	5–10	> 10	Wadeh	Sofor	Mejhem	Congenital	Acquired			Medicinal	Surg
											Traumatic	Infectious	Non-infectious		
Thelitis (n = 5)	1	3	1	1	4	0	4	1	0	0	1	3	1	5	0
Hyperkeratosis (n = 7)	1	4	2	0	5	2	4	3	0	0	1	0	6	2	5
Teat necrosis (n = 3)	1	2	0	0	3	0	2	0	1	0	0	3	0	2	1
Gangrene (n = 5)	1	3	1	0	4	1	3	1	1	0	0	5	0	1	4
Wounds (n = 7)	2	5	0	1	4	2	3	2	2	0	7	0	0	0	7
Dilated teat cistern (n = 6)	1	1	4	0	4	2	3	2	1	0	4	2	0	0	6
Dilated teat orifice (n = 2)	1	1	0	0	1	1	1	0	1	0	2	0	0	0	2
Teat stenosis (n = 3)	1	2	0	1	2	0	2	1	0	0	1	2	0	0	3
Blocked teat (n = 1)	0	1	0	0	1	0	1	0	0	0	1	0	0	0	1
Neoplasia (n = 2)	1	1	0	0	1	1	1	1	0	0	0	1	1	0	2
Total (41)	10	23	8	3	29	9	24	11	6	0	17	16	8	10	3

Figures



Figure 1

A: Acute mastitis in Wadheh she camel. B: Chronic mastitis in Asfar she camel. C: Purulent mastitis in Asfar she-camel, please note the discharging of a small amount of pus from the teat (white arrow). D: Gangrenous mastitis in Wadheh she-camel, please note blackening and corrugation of udder skin.

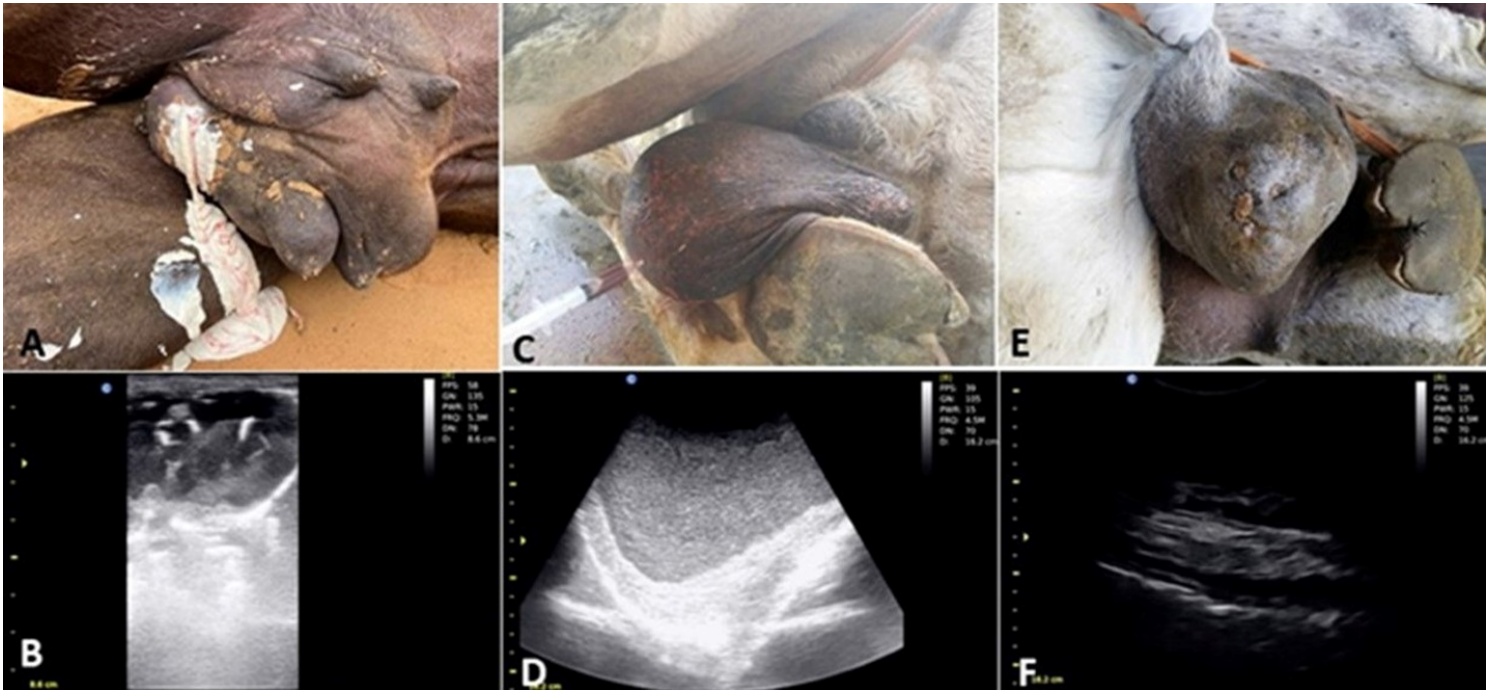


Figure 2

A. Udder abscess in Asfar she-camel. B. Ultrasonography of the udder abscess revealed anechoic to hypoechoic contents bounded by echogenic capsules. Udder hematoma in Wadeh she-camel and its ultrasonographic examination (d) revealed hyperechoic contents surrounded by echogenic wall, additionally decreased of anechoic fluid contents, and increased echogenicity of the contents was noted in comparison to recent one. E. Udder fibrosis in Wadeh she-camel and its ultrasonography (F) revealed homogeneous or heterogeneous hyperechoic pattern, corresponding to areas of thickened connective or scar tissue in mild and severe cases.

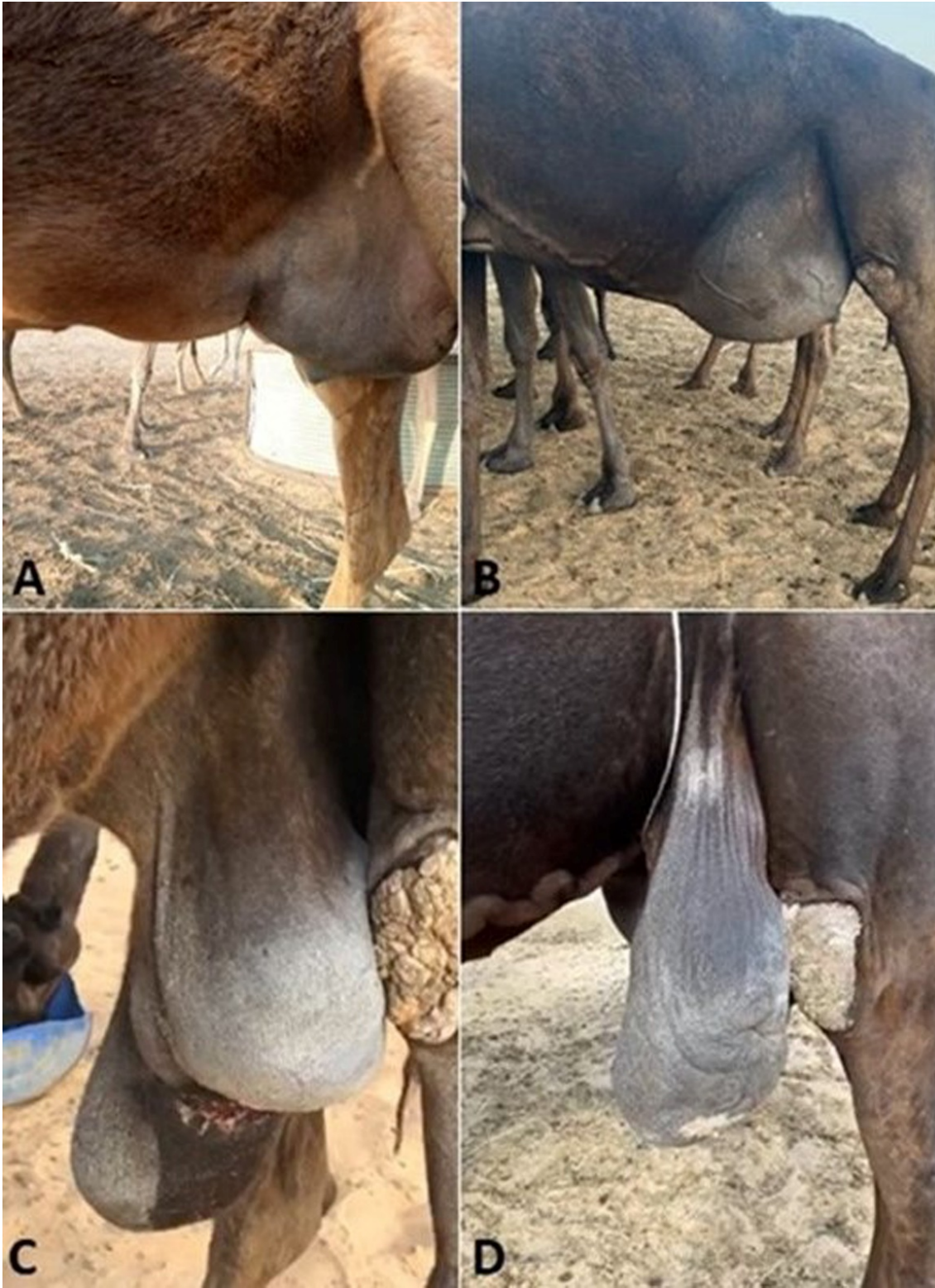


Figure 3

A. Udder edema in Asfar she-camel. B. Different forms of pendulous udder either physiological (A) or pathological (C& D) in Mejhem she camels.

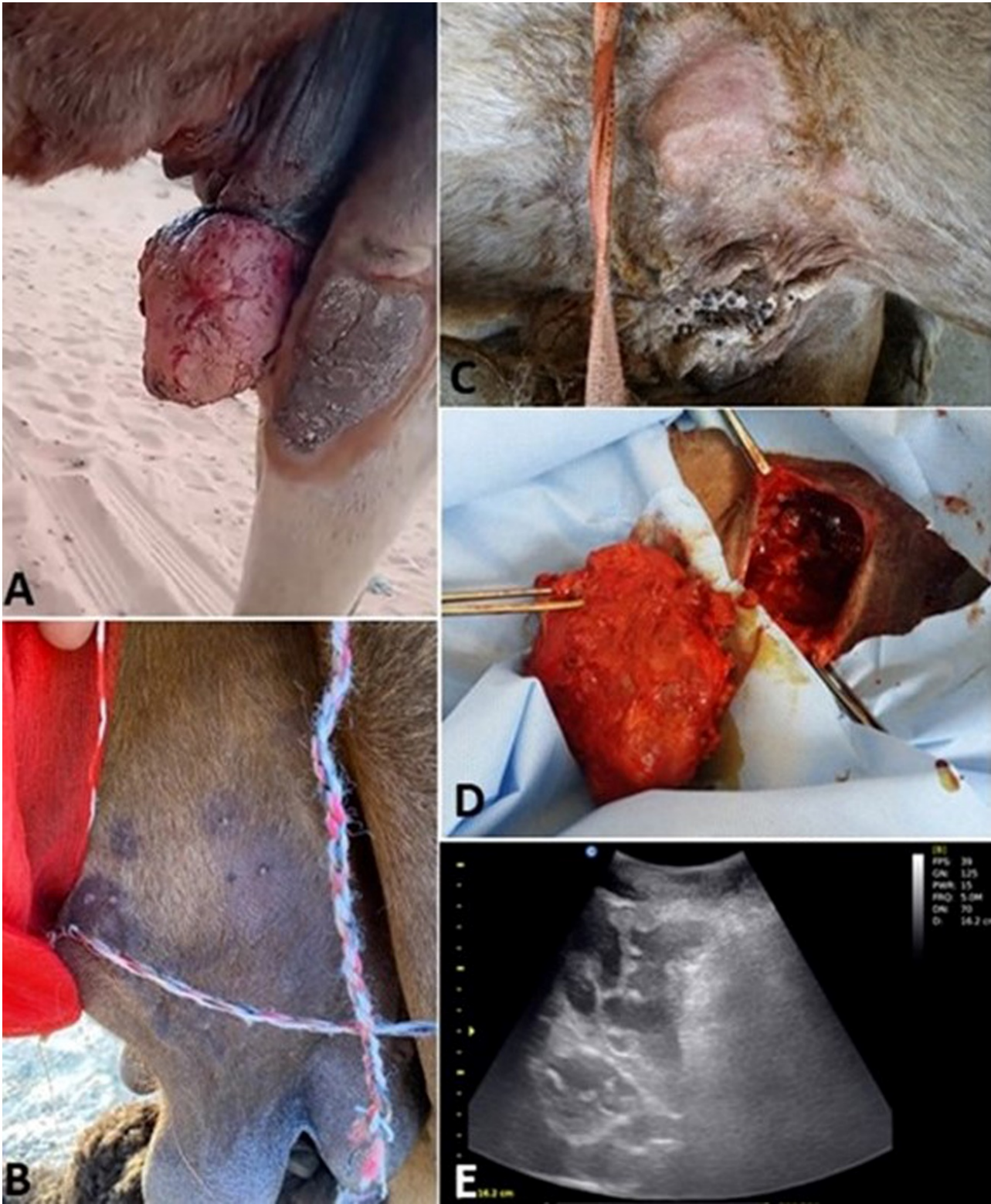


Figure 4

A. Udder granuloma in Asfar she camel. B. Udder and teat papilloma in Asfar she camel. C. Udder adenocarcinoma in Wadeh she-camel. D. Surgical resection of adenocarcinoma in a she camel. Ultrasonography of adenocarcinoma (E) revealed isoechoic to hyperechoic in appearance.

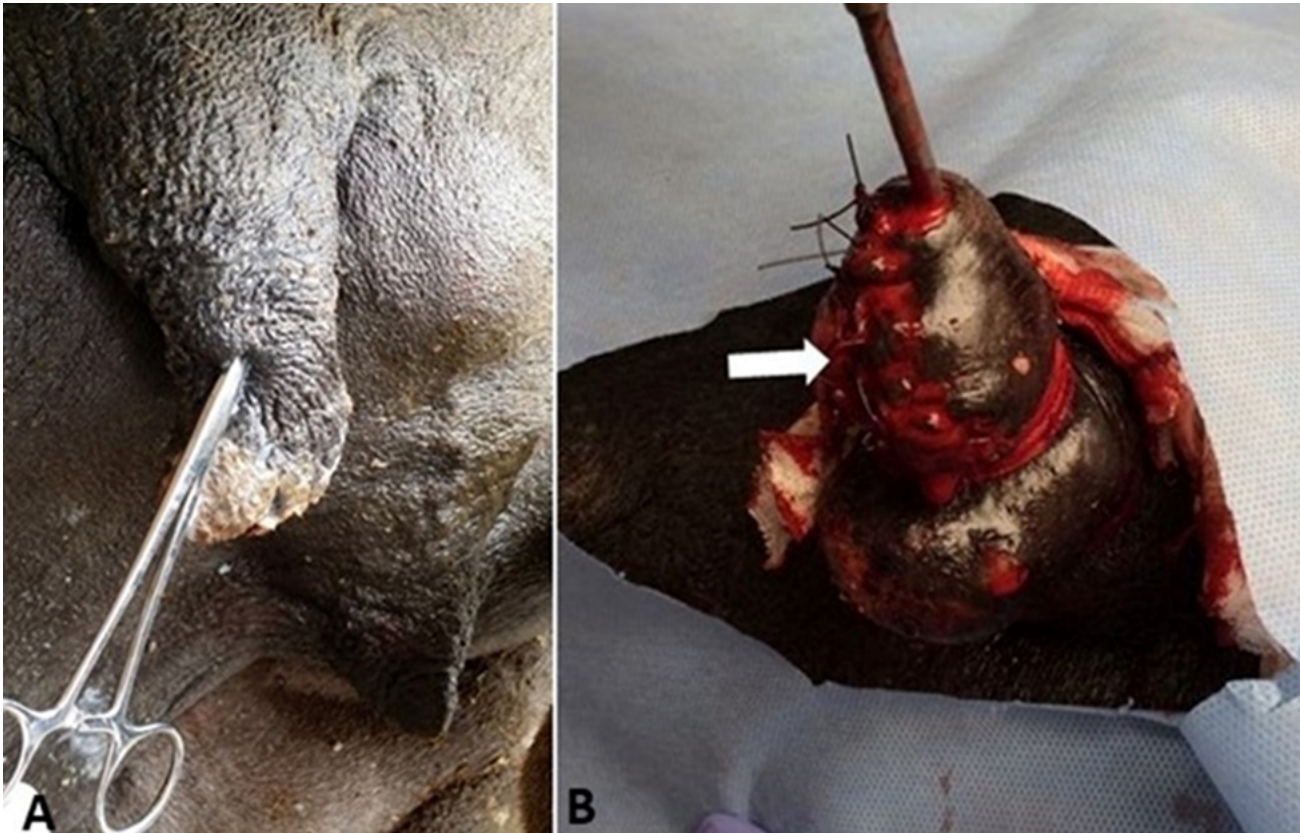


Figure 5

A. Udder laceration in Asfar she camel. B. Udder fistula and its surgical treatment (C) in Mejhem she camel. D. Udder necrosis in Wadeh she camel. E. Udder gangrene in Asfar she camel. F: Mastectomy for treatment of udder fibrosis in Asfar she camel.



Figure 6

A: Teat fistula in Mejhem she camel. B: Surgical repair in the same case in A, please note the refreshment of the fistula with suturing of submucosal and muscular layer with simple continuous sutures using braided coated polyglactin 910 No. 2 (United medical industries Co., Ltd., Riyadh) swaged on atraumatic needle, and the skin was then sutured by silk No. 2 (United medical industries Co. Ltd. Riyadh, Kingdom of Saudi Arabia) and simple interrupted stitches.



Figure 7

A. Thelitis in Wadeh she camel. B. Teat hyperkeratosis in Wadeh she camel. C. Teat black spot in Wadeh she camel. D. Teat gangrene in Wadeh she camel.



Figure 8

A. Dilated teat cistern with stenosed teat in Asfar she-camel. B. Dilated teat orifice in Mejhém she-camel. C. Teat orifice necrosis in Asfar she-camel. D. Teat stenosis in Asfar she-camel, E. Teat blockage and its surgical treatment in Wadeh she-camel.

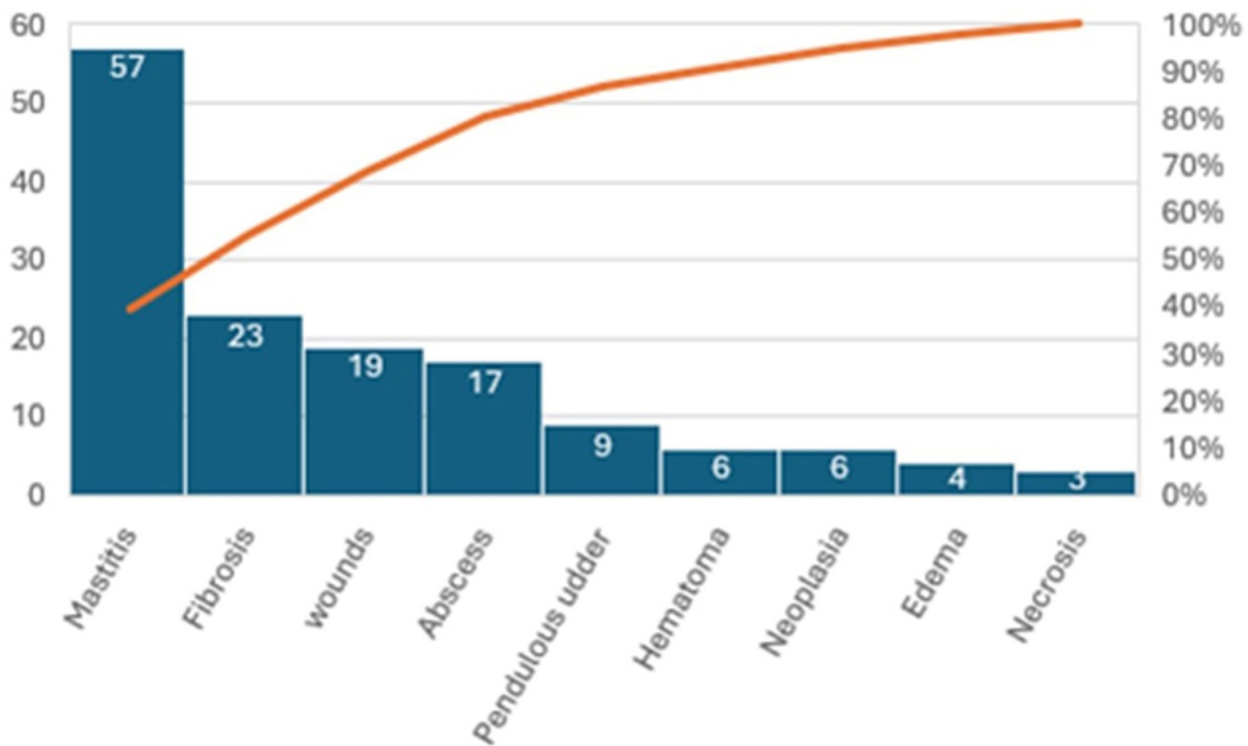


Figure 9

Distribution of udder affections in dromedary she-camels.

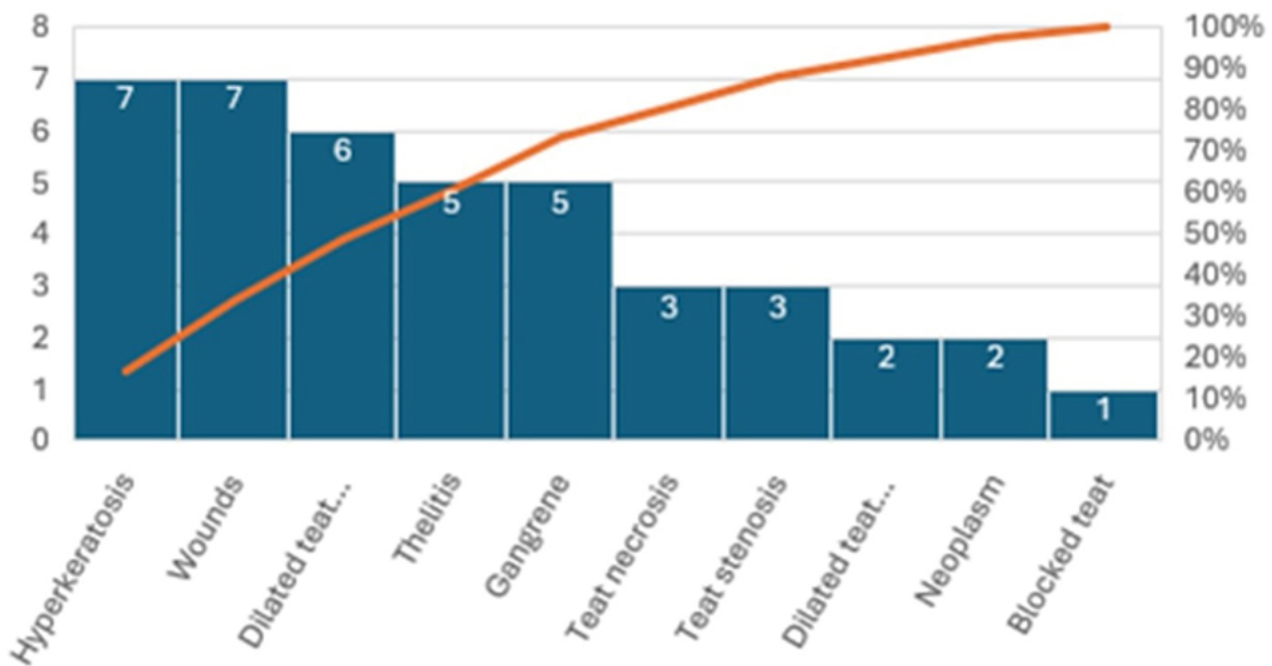


Figure 10

Distribution of teat affections in dromedary she-camels.