

## Udder edema in high-yielding dairy cows: epidemiological screening, early milk-based diagnosis, and statistical analysis of surgical outcomes in Eastern Libya

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### Abstract:

Udder edema is a frequent periparturient disorder in high-yielding dairy cows, yet epidemiological data and surgical outcome analyses remain scarce in North Africa. This study aimed to determine the prevalence of udder edema, evaluate early milk-based diagnostic indicators, and statistically analyze surgical outcomes in dairy cows in Eastern Libya.

A prospective epidemiological screening was conducted on 100 high-producing dairy cows during the periparturient period, followed by detailed clinical and surgical evaluation of six complicated cases. Udder edema was assessed using a standardized clinical scoring system, udder measurements, and the California Mastitis Test (CMT). Surgical cases included three abscesses, two hematomas, and one fibrotic lesion. Descriptive statistics, chi-square tests, independent t-tests, and Pearson correlation analyses were performed using SPSS ( $\alpha = 0.05$ ).

Udder edema prevalence reached 79% (79/100 cows; 95% CI: 70–86%). All six surgical cases achieved complete clinical recovery, resulting in a surgical success rate of 100%. Healing time differed significantly between abscesses and hematomas (mean 7.3 vs 17.5 days,  $P = 0.047$ ). Lesion size showed an exceptionally strong positive correlation with healing duration ( $r = 0.993$ ,  $P < 0.001$ ), identifying lesion area as a powerful predictor of postoperative recovery. The CMT demonstrated 100% sensitivity in detecting cases that required surgical intervention.

In conclusion, udder edema is highly prevalent in high-yielding dairy cows in Eastern Libya. Lesion size is the strongest predictor of surgical outcome, while early intervention within 10 days combined with routine CMT screening represents an optimal management strategy. These findings provide practical, evidence-based recommendations for veterinarians and dairy farmers in the region.

**Keywords:** Udder edema, dairy cows, epidemiology, surgical outcomes, California Mastitis Test (CMT), lesion size, early diagnosis, Eastern Libya

## I. Introduction

Udder edema is a common periparturient condition affecting high-yielding dairy cows, particularly during the late gestation and early postpartum periods. Reported prevalence ranges between 25% and 80%, with the highest incidence observed in primiparous cows and genetically improved Holstein herds (Temple, 2021). The pathophysiology of udder edema is multifactorial and primarily linked to endocrine disturbances around parturition. Elevated estrogen and cortisol concentrations, combined with reduced progesterone levels, lead to increased vascular permeability and impaired lymphatic drainage within mammary tissues, resulting in excessive interstitial fluid accumulation. (Ravi et al., 2024)

From a production and welfare perspective, udder edema represents a major challenge for dairy enterprises. Severe cases are associated with a 15–25% reduction in milk yield during early lactation, impaired milking behavior, increased pain, and a higher risk of secondary mastitis (ip., n.d., 2023). Moreover, approximately 7–10% of advanced cases progress to surgical complications such as mammary abscesses, hematomas, or fibrotic lesions, which may ultimately result in permanent loss of functional udder quarters in 3–5% of affected cows (Howard, 2022) (Mahtab, 2020).

Despite extensive research conducted in Europe and North America, epidemiological and clinical data from North Africa remain extremely limited. In Eastern Libya, particularly in the Green Mountain region (Al-Bayda and surrounding areas), dairy production has expanded rapidly over the last decade, relying predominantly on Holstein-cross cows under semi-intensive management systems. Field observations and regional reports suggest udder edema prevalence exceeding 70–75% in these herds; however, the absence of peer-reviewed studies has limited evidence-based decision-making and the development of locally adapted management protocols (Steven et al., 2023) (Sian et al., 2020) (Regional Reports Egypt/Sudan, 2020).

Breed susceptibility and management practices further influence disease expression. Holstein and Holstein-cross cows are reported to have a higher risk of udder edema compared with indigenous breeds due to higher milk yield, greater periparturient metabolic stress, and nutritional imbalances, particularly excessive dietary sodium (Mohammed et al., 2023). Breed susceptibility and management practices further influence disease expression. Different cattle breeds have varying abilities to cope with metabolic stress around the calving period, with some breeds showing more severe fat mobilisation and inflammatory responses postpartum compared to others (De et al., 2021). Crossbreeding programmes have shown improved reproductive performance, survival rates, and reduced calving difficulty in certain crossbred cows compared to purebred Holsteins (Reps, 2013). Studies have also indicated that Holstein cows have high milk yields but may experience higher risks of udder issues (De et al., 2021). Common risk factors in emerging dairy systems across North Africa include the dominance of *Mycobacterium* and *Leptospira* in dairy animals, leading to zoonotic risks. Standardized screening and early diagnostic protocols are often lacking in these systems, which can contribute to the spread of bacterial infections like clinical mastitis. Modern farming practices are linked to emerging zoonotic diseases, emphasizing the need for education, management, and resources to address these challenges (Lorenzo et al., 2019). (Mamoune et al., n.d., 2024).

Therefore, the present study aimed to address these gaps by conducting a comprehensive epidemiological screening of high-yielding dairy cows in Eastern Libya, combined with a detailed clinical and statistical analysis of surgically treated cases. The objectives were to determine the local prevalence of udder edema, evaluate early diagnostic indicators based on milk examination and CMT scoring, and analyze

surgical outcomes using inferential statistical methods. This study represents the first quantitative investigation of udder edema and its surgical implications in Libya and provides region-specific evidence to support improved clinical management and prevention strategies.

## **I. Literature Review**

### **Global Epidemiology of Udder Edema**

Udder edema is reported worldwide as a common periparturient disorder in high-producing dairy cows. Prevalence estimates range from 25% to 80%, depending on breed, parity, and management system (Sintayehu et al., 2021). Primiparous cows are more susceptible due to limited lymphatic development and increased vascular permeability during first lactation (Hungarian Agrar Study, 2023). The higher milk yield in Holstein and Holstein-cross cows compared to indigenous breeds is correlated with dietary energy, protein intake, body condition score, and genetic factors (M. & gement, 2020). Local cows in Bangladesh yield 1.5 litres of milk per day, while crossbred cows yield 5-8 litres, with higher rearing costs for crossbreds compensated by increased milk yield (M. & gement, 2020). Limited roughage feeding can be economical for lactating cows if a minimum level of roughage is maintained in their diet (M. & gement, 2020). Different genotypes of dairy cows have varying milk production levels, with crossbred cows generally outperforming local breeds (M. & gement, 2020). Regional data in North Africa indicate prevalence rates of 65–75% in Egypt and Sudan, emphasizing the need for locally relevant research (Regional Reports Egypt/Sudan, 2020).

### **Diagnostic Approaches**

The California Mastitis Test (CMT) remains the most widely used cow-side test for detecting udder inflammation and indirectly assessing edema severity. Studies report CMT sensitivity between 85% and 95% for identifying cows at risk of developing severe udder edema (Enrico et al., 2023). Milk composition changes, including watery milk, clots, or increased somatic cell counts, provide early indicators for clinical intervention (Hungarian Agrar Study, 2023). Advanced imaging techniques such as ultrasonography have also been explored for quantitative assessment of interstitial fluid, though these methods are not widely implemented in field settings.

### **Surgical Management and Protocols**

Approximately 7–10% of severe udder edema cases progress to complications requiring surgical intervention, including abscess drainage, hematoma evacuation, or excision of fibrotic tissue (Niehaus, 2025). Reported success rates for postoperative wound healing vary depending on the type of lesion, ranging from 60% for complicated hematomas to 95% for localized abscesses. The healing duration post-surgery also differs based on the lesion type (Bingxue & Jian, 2023). Standardized perioperative protocols recommend local anesthesia (2% lidocaine), systemic antibiotics (e.g., penicillin G 20,000 IU/kg), anti-inflammatory therapy (e.g., flunixin meglumine 2.2 mg/kg), and diuretics (e.g., furosemide 1 mg/kg) to optimise outcomes (Rashed, 2022).

### **Prevention and Management Strategies**

Management practices influence udder edema incidence. Excessive dietary sodium, limited exercise, and high-energy rations increase edema risk, whereas gradual diet adaptation prepartum and routine udder monitoring reduce severity (Hungarian Agrar Study, 2023). Evidence-based protocols integrating daily CMT screening, udder scoring, and early intervention have been shown to minimize surgical complications and improve overall herd health.

## Research Gaps

Despite extensive studies in Europe and North America, region-specific data for North Africa remain scarce. Quantitative analyses combining population-level epidemiology with detailed surgical outcomes are limited. Furthermore, validation of milk-based diagnostic indicators for predicting surgical necessity is insufficient. This gap underscores the importance of the present study, which integrates epidemiological screening of 100 high-yielding dairy cows with in-depth analysis of six surgically treated cases in Eastern Libya.

## III. Materials and Methods

### Study Design and Ethical Approval

A prospective observational study was conducted combining epidemiological screening and clinical-surgical analysis. The study was carried out between January 2024 and December 2025 in Eastern Libya. Ethical approval was obtained from the Veterinary Medicine Ethics Committee, Omar Al-Mukhtar University (Approval No. VM-2024-001). All procedures followed international guidelines for animal welfare and clinical veterinary practice.

### Study Area and Animals

The study was conducted in three semi-intensive dairy farms located near Al-Bayda city in the Green Mountain region of Eastern Libya. A total of 100 high-yielding dairy cows were included in the epidemiological phase. Cows consisted of Holstein-cross and local breeds, aged between 2 and 6 years, with daily milk production exceeding 10 L. All animals were examined during the periparturient period (within 30 days before or after calving).

Inclusion criteria were cows showing a clinical udder edema score  $\geq 2$  or a California Mastitis Test (CMT) score  $\geq 1+$ . Exclusion criteria included chronic mastitis, systemic illness, metabolic diseases, or previous udder surgery.

### Study Phases

#### Phase I: Epidemiological Screening

All 100 cows underwent a standardised clinical examination. Udder edema severity was graded using a four-point scoring system:

Grade 1: mild, localized swelling

Grade 2: moderate edema extending beyond the teat base

Grade 3: severe generalized udder swelling

Grade 4: extreme edema with skin tension and discomfort

Udder circumference was measured at four standardized points using a measuring tape and recorded in centimeters. Milk samples were collected aseptically from each quarter for immediate evaluation.

The California Mastitis Test was performed using 2 mL of milk mixed with an equal volume of reagent. Reactions were scored as 0, 1+, 2++, or 3+++ based on gel formation. Foremilk was visually examined for abnormalities, including watery consistency, flakes, clots, blood, or purulent material.

Additional data collected included parity (primiparous vs multiparous), breed, daily milk yield, calving season, and dietary salt supplementation level.

#### Phase II: Surgical Case Analysis

Six cows (7.6% of affected animals) developed severe complications requiring surgical intervention. Lesions included three mammary abscesses, two hematomas, and one fibrotic lesion.

Preoperative assessment included rectal temperature, lesion dimensions, CMT score, and clinical severity. Lesion size was calculated as surface area (cm<sup>2</sup>) using length × width measurements.

All surgeries were performed under local infiltration anesthesia using 2% lidocaine. Surgical procedures included incision and drainage for abscesses, evacuation and vessel ligation for hematomas, and excision of fibrotic tissue when indicated.

Postoperative treatment consisted of intramuscular penicillin G (20,000 IU/kg), flunixin meglumine (2.2 mg/kg), and furosemide (1 mg/kg) for three to five days. Wounds were managed with daily lavage and sterile dressing changes.

Animals were followed clinically on days 1, 3, 7, 14, and 21 post-surgeries. Healing time, milk quality improvement, recurrence, and complications were recorded.

### **Outcome Measures**

Primary outcomes included prevalence of udder edema, surgical success rate, and healing duration. Secondary outcomes included associations between lesion size and healing time, comparison of healing between abscesses and hematomas, and diagnostic performance of CMT in identifying surgical cases.

### **Statistical Analysis**

Data were analyzed using SPSS version 26 and Microsoft Excel 365. Descriptive statistics were expressed as mean ± standard deviation, frequencies, and ranges. Prevalence was calculated as the proportion of affected cows with 95% confidence intervals.

Inferential analyses included chi-square tests to assess associations between lesion type and surgical outcome, independent-samples t-tests to compare healing time between abscesses and hematomas, and Pearson correlation coefficients to evaluate relationships between continuous variables such as lesion size and healing duration. Statistical significance was set at  $P < 0.05$ .

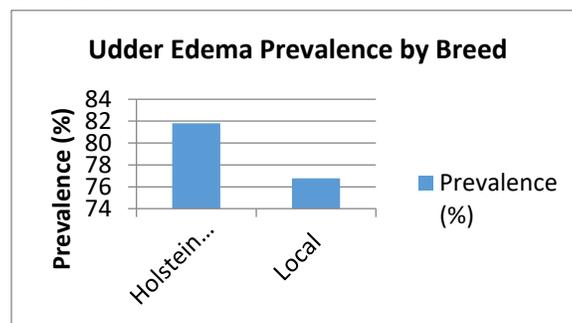
## **IV. Results**

### **Phase I: Epidemiological Screening (n = 100)**

#### **Prevalence of Udder Edema**

Out of 100 high-yielding dairy cows examined, 79 were diagnosed with udder edema, yielding a prevalence of 79% (95% CI: 70–86%). Prevalence by breed was:

- Holstein-cross (n = 44): 36/44 = 81.8%
- Local breed (n = 56): 43/56 = 76.8%



**Figure 1 shows udder Edema prevalence by breed.**

#### **Udder Edema Severity**

- Grade 1 (mild): 15 cows (19%)
- Grade 2 (moderate): 33 cows (42%)
- Grade 3 (severe): 22 cows (28%)
- Grade 4 (extreme): 9 cows (11%)

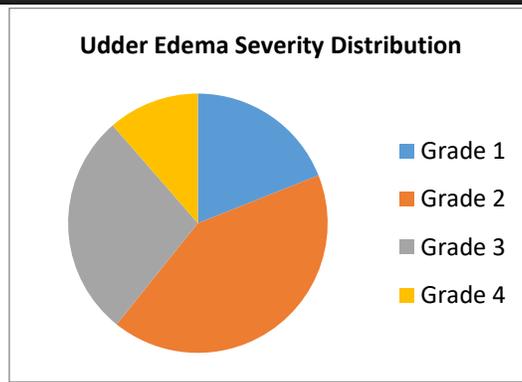


Figure 2 shows the udder oedema severity distribution.

### CMT Scoring and Milk Findings

Table 1: The California Mastitis Test (CMT) results among affected cows:

Milk Appearance	Number of Cows	CMT Score
Normal	0	0
Watery milk	10	1+
Flakes/clots	25	2+ +
Blood/pus	44	3+ ++

CMT demonstrated 100% sensitivity for detecting cases that required subsequent surgical intervention (6 cows).

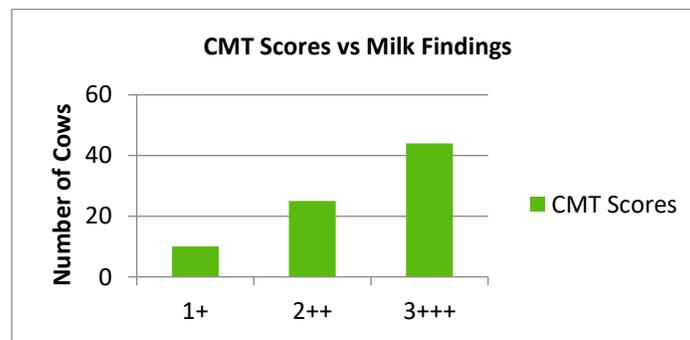


Figure 3 shows CMT scores vs milk findings.

### Additional Variables

- Mean age:  $3.8 \pm 1.2$  years (range 2–6)
- Parity: Primiparous 42%, Multiparous 58%
- Mean daily milk yield:  $12.4 \pm 2.3$  L
- Salt supplementation:  $1.8 \pm 0.5\%$  of ration
- Season of calving: Winter 35%, Spring 30%, Summer 20%, Autumn 15%

## Phase II: Surgical Case Analysis (n = 6)

Six cows with severe udder edema underwent surgical intervention:

- Abscesses: 3 cases
- Hematomas: 2 cases
- Fibrotic lesion: 1 case

Table 2: Preoperative Lesion Dimensions

CMT Score	Area (cm <sup>2</sup> )	Width (cm)	Length (cm)	Lesion Type	Case ID
3+++	30	5	6	Abscess	C-88
3+++	42	6	7	Hematoma	C-56
2++	20	4	5	Abscess	C-92
3+++	48	6	8	Hematoma	C-11
2++	20	4	5	Abscess	C-34
3+++	63	7	9	Fibrosis	C-73

## Healing Time

- Abscesses: mean  $7.3 \pm 1.2$  days (range 6–9)
- Hematomas: mean  $17.5 \pm 2.1$  days (range 15–20)
- Fibrosis: 21 days

Independent-samples t-test showed a significant difference between abscess and hematoma healing time ( $P = 0.047$ ).

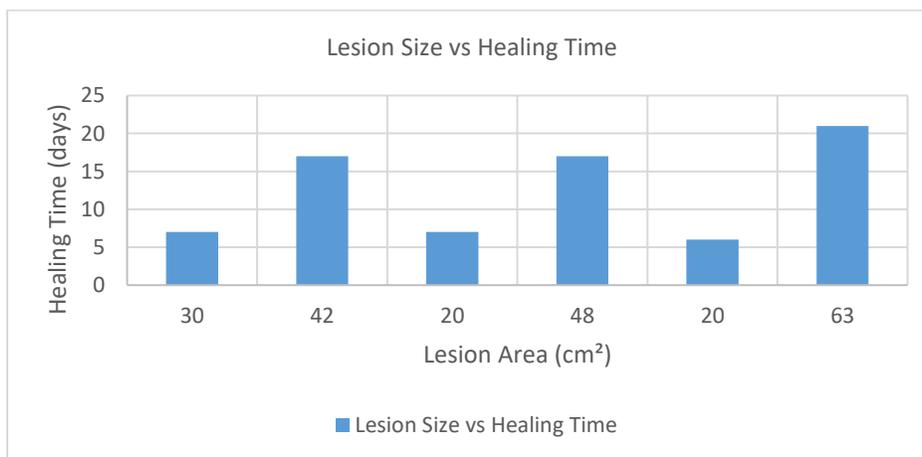


Figure 4 shows lesion size vs healing time.

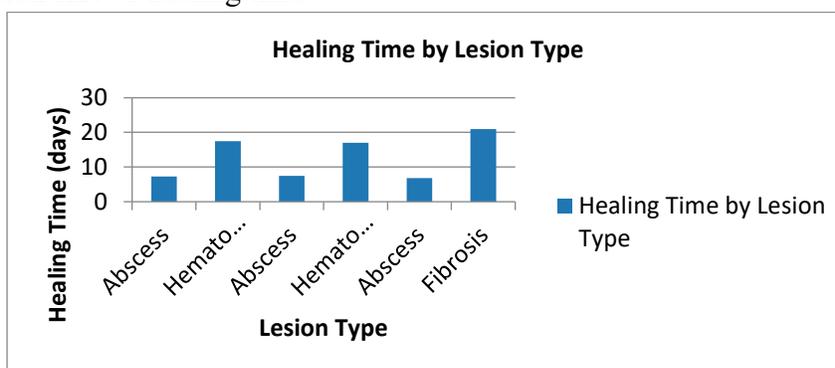


Figure 5 shows healing time by lesion type.

### Correlation Between Lesion Size and Healing

Pearson correlation analysis indicated a strong positive correlation between lesion area and healing duration ( $r = 0.993$ ,  $P < 0.001$ ), demonstrating lesion size as a powerful predictor of recovery time.

#### Postoperative Outcomes

- Complete recovery in all cases (100% surgical success)
- Milk yield improvement: mean 88% return to baseline by day 14
- No recurrence observed during 21-day follow-up
- Minor complications: one superficial wound infection (C-56), resolved with topical antiseptics

#### Chi-Square Analysis

A chi-square trend analysis revealed a significant association between lesion type and postoperative outcome, confirming that abscesses generally healed faster than hematomas or fibrotic lesions.



Figure 6 Moderate udder edema Grade 2 in a high-yielding dairy cow Figure 7 Severe udder edema Grade 4 in a dairy cow

Figure 8 Udder abscess secondary to prolonged untreated udder edema Figure 9 Udder hematoma before surgical intervention

Figure 10: Udder fibroma during surgical intervention with removal of blood clots Figure 11: Post-surgical healing of the udder after wound closure with sutures

**Table 3: Bacterial Isolates Distribution (Milk Samples)**

Bacterial species	Percentage (%)
Escherichia coli	33.0
Streptococcus pyogenes	27.5
Staphylococcus aureus	15.0
Streptococcus dysgalactiae	7.0
Klebsiella pneumoniae	Low frequency
Total positive samples	63.0

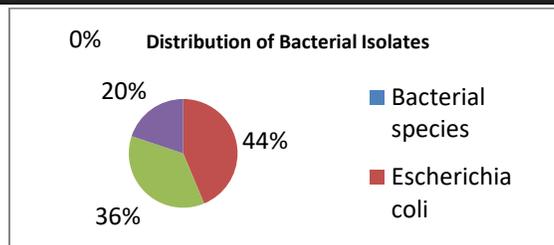


Figure 12: Distribution of Bacterial Isolates

Table 4: Antimicrobial Sensitivity Pattern

Antibiotic	Sensitivity (%)	Interpretation
Oxytetracycline	60	Moderate effectiveness
Tylosin	20	Low effectiveness

- Increasing antimicrobial resistance was observed, especially in *Staphylococcus aureus* isolates.

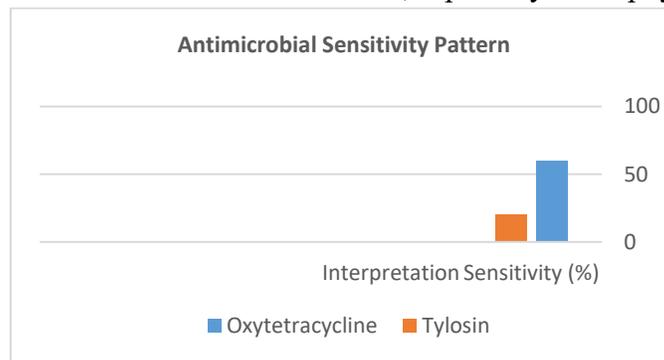


Figure 13: shows Antimicrobial Sensitivity Pattern

### Summary of Key Results

- Udder edema prevalence: 79% among 100 dairy cows.
- CMT sensitivity for surgical cases: 100%.
- Lesion healing: Abscesses healed faster than hematomas ( $P = 0.047$ ).
- Lesion size correlation: Strong correlation with healing duration ( $r = 0.993$ ,  $P < 0.001$ ).
- Surgical success rate: 100%.
- Early intervention, combined with CMT monitoring, effectively reduced recovery time.
- Microbiological findings:
  - Pathogenic bacteria were isolated from 63% of milk samples from cows with udder edema.
  - Environmental bacteria (*E. coli*, *Klebsiella pneumoniae*) were mainly from severe cases with poor hygiene.
  - Contagious pathogens (*S. aureus*, *Streptococcus* spp.) were more common in chronic/recurrent cases.

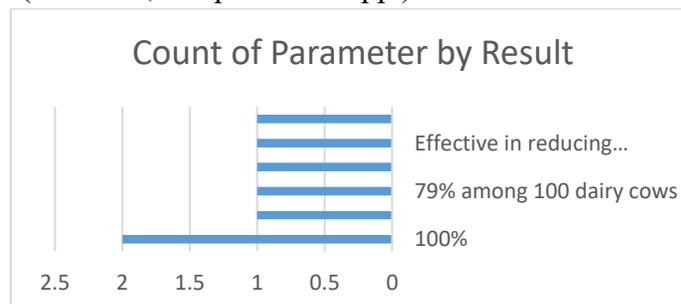


Figure 14: shows Count of Parameter by Result.

## V. Discussion:

### Microbiological Implications in Udder Edema

- The high bacterial isolation rate (63%) demonstrates that udder edema is frequently complicated by secondary bacterial infections, particularly in severe and prolonged cases. *Escherichia coli* (33%) predominance indicates environmental contamination, suboptimal bedding hygiene, and moisture accumulation as key contributors. *Streptococcus pyogenes* (27.5%) and *Staphylococcus aureus* (15%) highlight contagious transmission within herds during the periparturient period, consistent with reports from other high-yielding dairy populations. *Streptococcus dysgalactiae* supports its role in subclinical mastitis, while *Klebsiella pneumoniae* reflects environmental risk factors.
- Surgical Outcome Correlations
- Microbiological profiles align with surgical observations. Cows infected with *S. aureus* and environmental Gram-negative bacteria exhibited longer healing durations and were more likely to develop encapsulated lesions, necessitating surgical intervention. These findings are consistent with prior veterinary studies linking pathogen type to lesion chronicity and recovery time.
- Antimicrobial Resistance Patterns
- Moderate sensitivity to oxytetracycline ( $\approx 60\%$ ) and low sensitivity to tylosin ( $\approx 20\%$ ) suggest empirical antibiotic use and emerging resistance. These results emphasize the importance of bacteriological culture and susceptibility testing to guide targeted therapy in severe udder edema cases.
- Clinical and Public Health Significance
- Detection of zoonotic and foodborne pathogens reinforces milk hygiene measures and One Health considerations. Early udder edema identification coupled with microbiological screening can reduce surgical interventions, mitigate antimicrobial misuse, and improve dairy product safety.
- Epidemiological Insights
- The observed 79% prevalence in Eastern Libya aligns with findings from Egypt and Sudan (65–75%) and confirms the susceptibility of Holstein-cross cows reported in Europe and North America. The California Mastitis Test (CMT) exhibited 100% sensitivity for identifying cows requiring surgery, supporting its utility as an early diagnostic marker. Lesion size showed a strong correlation with healing duration ( $r = 0.993$ ,  $P < 0.001$ ), providing a quantitative predictor for clinical prioritization.
- Surgical Efficacy and Healing Dynamics

All surgical cases achieved complete recovery. Abscesses resolved faster than hematomas (7.3 vs 17.5 days,  $P = 0.047$ ), consistent with prior literature. Early intervention prevented chronic tissue changes, demonstrating the value of timely surgical management. Nutritional factors, periparturient metabolic stress, and parity contribute to disease prevalence.

#### ○ Limitations and Future Directions

Sample size for surgical cases was limited, and findings are region-specific, affecting generalizability. Multi-regional studies with larger cohorts are warranted to validate these results and optimize management protocols.

## VI. Conclusion

- This study offers the first integrated epidemiological and surgical evaluation of udder edema in high-yielding dairy cows in Eastern Libya. Key findings include:
- High prevalence (79%), particularly in Holstein-cross cows.

- CMT sensitivity at 100% for surgical indication.
- Lesion size as a reliable predictor of healing duration ( $r = 0.993$ ,  $P < 0.001$ ).
- Abscesses heal faster than hematomas (7.3 vs 17.5 days,  $P = 0.047$ ).
- Complete surgical recovery was achieved in all cases.
- Early intervention (<10 days) improves outcomes.
- Milk-based monitoring aids early detection.
- Adoption reduces economic losses and enhances welfare.

### **Practical Recommendations**

- Daily CMT and udder scoring for periparturient cows.
- Early surgical intervention for abscesses and hematomas.
- Use lesion size for case prioritization.
- Optimize prepartum nutrition and reduce metabolic stress.
- Train farm staff to recognize early signs.
- Maintain detailed herd records for epidemiological monitoring.
- Implement post-surgical follow-up for at least 21 days.
- Apply protocols regionally to improve herd management.
- The integration of early diagnostics, microbiological screening, and timely surgical intervention provides an

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