A 2.5-year-old Lamancha doe (goat 1) that was 80 DIM was evaluated at the University of California-Davis William R. Pritchard Veterinary Medical Teaching Hospital because of a history of fever, inappetance, and a warm and firm left udder half with milk that contained garget. On the day before, the owner had completely milked out the udder and instituted intramammary antimicrobial treatment with cephaepirin sodium; this treatment was repeated on the morning of initial evaluation. No other goats from the herd were known to be sick. On physical examination, the doe had a body condition score of 3.5 of 5, was lethargic, and was estimated to be 10% dehydrated. The doe was hypothermic (38.06°C; reference range, 38.61° to 40°C [101.5° to 104°F]), and tachypneic (120 breaths/min; reference range, 38.61° to 40°C [101.5° to 104°F]), and tachycardic (132 beats/min; reference range, 70 to 90 beats/min). Moderate bilateral scleral injection was present. On palpation, the left udder half was cooler, more firm, and approximately 3 times larger than the right. A demarcation was observed between normal skin color on the proximal half of the udder and darker reddish-brown skin discoloration of the distal discolored distal portions with sharp demarcations from grossly normal tissue proximally. Udder secretions from the affected sides were serosanguineous in all cases. A Bacillus sp was isolated in pure cultures in all cases. In 1 case, the Bacillus sp was identified as Bacillus cereus.

**Clinical Findings**—Goats were considered to have endotoxemia on the basis of physical examination and clinicopathologic findings. The affected udder halves had gangrenous discolored distal portions with sharp demarcations from grossly normal tissue proximally. Udder secretions from the affected sides were serosanguineous in all cases. A Bacillus sp was isolated in pure cultures in all cases. In 1 case, the Bacillus sp was identified as Bacillus cereus.

**Treatment and Outcome**—Goats were treated for mastitis and endotoxemia with polyionic IV fluid therapy, systemic and intramammary antimicrobial administration, anti-inflammatory drug administration, and other supportive treatment. All goats survived to discharge. All except 1 goat had follow-up information available. The affected udder halves sloughed in 1 to 2 months following discharge. In subsequent lactations after the mastitis episodes, milk production in 2 of 5 goats was above the mean, as determined on the basis of Dairy Herd Improvement records, and 3 of 5 goats were voluntarily withdrawn from lactation. All 5 goats had successful kiddings after the Bacillus mastitis episode.

**Conclusions and Clinical Relevance**—Bacillus sp should be considered as a causative agent in goats with gangrenous mastitis, especially when the Bacillus sp is isolated in a pure culture. Antimicrobial sensitivity testing is recommended for selection of an appropriate antimicrobial for treatment. Prognosis for survival appears to be good, although milk production may be decreased. (J Am Vet Med Assoc 2013;242:836–843)

**Abbreviation**

<table>
<thead>
<tr>
<th>Dim</th>
<th>Days in milk</th>
</tr>
</thead>
</table>

---

From the William R. Pritchard Veterinary Medical Teaching Hospital (Mavangira, Samitz) and the Departments of Veterinary Medicine and Epidemiology (Angelos), Population Health and Reproduction (Rowe), and Pathology, Microbiology and Immunology (Byrne), School of Veterinary Medicine, University of California-Davis, Davis, CA 95616. Dr. Mavangira’s present address is Department of Large Animal Clinical Sciences, College of Veterinary Medicine, Michigan State University, East Lansing, MI 48824.

Address correspondence to Dr. Mavangira (mavangira@msu.edu).
An aseptically collected sample of the secretion from the left udder half was submitted for aerobic and anaerobic bacterial culture and antimicrobial susceptibility testing. The sample was inoculated onto 3% dehydrated sheep blood agar and MacConkey agar and incubated at 35°C in 5% CO₂ for aerobic culture and also inoculated on prereduced Brucella blood agar and incubated at 35°C under anaerobic conditions. The overnight milk culture yielded small numbers of aerobic bacterial growths that appeared as large matte gray colonies that were strongly hemolytic on sheep blood agar. There was no obligate anaerobic growth. A Gram stain revealed large gram-positive rods with central and subterminal ellipsoidal spores, which did not swell the sporangium. A presumptive identification of Bacillus sp was made on the basis of the colony morphology, hemolysis, and Gram staining characteristics. The Bacillus sp grew at 25°C and 42°C. This isolate was positive for arginine dehydrolase and gelatinase as determined with an identification strip and produced acid from salicin. A isolate was motile in Gillies medium at 25°C and 35°C. Partial sequencing of the 16S rRNA gene demonstrated 99% identity to Bacillus cereus and Bacillus thuringiensis in the forward and reverse directions. A final identification as B cereus was made on the basis of the absence of parasporal crystals on a Wirth spore stain.

Antimicrobial susceptibility testing was performed with microdilution on the basis of methodology from the Clinical Laboratories Standards Institute. Briefly, 2 to 3 isolated colonies were inoculated into 2 mL of brain-heart infusion broth and incubated at 35°C without carbon dioxide for approximately 4 hours. The broth culture was then added dropwise to saline (0.9% NaCl) solution to a McFarland standard of 0.5 as determined with a nephelometer; 10 µL of this suspension was then added to cation-adjusted Mueller-Hinton broth with N-Tris (hydroxymethyl) methyl-2-aminoethane sulfonic acid, and 50 µL of broth was used to inoculate each well of an incubating plate. The plates were incubated at 35°C without carbon dioxide overnight, and a minimum inhibitory concentration was determined for each antimicrobial drug. As no standards for interpretation of minimum inhibitory concentrations exist for Bacillus sp in goats, interpretations were determined with those available for bovine mastitis when possible. When interpretations differed on the basis of the organism tested, standards for Staphylococcus aureus were used except in the case of ampicillin, where Enterobacteriaceae standards were used.

Over the next 24 hours, the doe's attitude and activity level improved. Approximately 14 hours following this improvement, the doe began to have grunting respirations and the udder secretion became more hemorrhagic. Parenteral and intramammary ceftriaxone treatments were discontinued, and florfenicol (20 mg/kg [9.1 mg/lb], SC, once) was administered systemically. Intravenous fluid therapy supplemented with electrolytes (calcium and potassium) and flunixin meglumine treatment was continued.

The B cereus isolate from this goat was resistant to β-lactam antimicrobials, including ceftriaxone. At this time, 2 days following admission, antimicrobial treatment with oxytetracycline (10 mg/kg [4.5 mg/lb], IV, q 24 h) was initiated. In addition, the affected udder half was infused with pirlimycin hydrochloride once daily. The frequency of udder stripping was reduced to twice daily, and pirlimycin was infused into each udder half after stripping. Within 24 hours after changing antimicrobials to oxytetracycline and pirlimycin, the doe's clinical condition improved; however, the serosanguineous left udder half secretion persisted. From admission to day 6, the goat was maintained on IV fluid therapy and electrolytes that were tailored to meet the patient's needs as assessed by periodic electrolyte analyses. Six days after admission, the goat's condition had improved, and it was discharged with instructions for the owner to continue supportive care consisting of oxytetracycline (20 mg/kg, SC, q 48 h), twice-daily intramammary treatments, and oral pirlimycin. The udder half began to improve, and it was discharged with instructions for the owner to continue supportive care consisting of oxytetracycline (20 mg/kg, SC, q 48 h), twice-daily intramammary treatments, and oral pirlimycin. The udder half began to improve, and it was discharged with instructions for the owner to continue supportive care consisting of oxytetracycline (20 mg/kg, SC, q 48 h), twice-daily intramammary treatments, and oral pirlimycin. The udder half began to improve, and it was discharged with instructions for the owner to continue supportive care consisting of oxytetracycline (20 mg/kg, SC, q 48 h), twice-daily intramammary treatments, and oral pirlimycin. The udder half began to improve, and it was discharged with instructions for the owner to continue supportive care consisting of oxytetracycline (20 mg/kg, SC, q 48 h), twice-daily intramammary treatments, and oral pirlimycin.

### Table 1—Minimum inhibitory concentration (µg/mL) values and interpretations for Bacillus sp isolates obtained from a 2.5-year-old Lamancha doe (goat 1), 3-year-old Toggenburg doe (goat 2), 2-year-old Oberhasli doe (goat 3), 1.5-year-old Toggenburg doe (goat 4), and 2-year-old Toggenburg doe (goat 6) with acute mastitis. Antimicrobial susceptibility information was not available for goat 5, a 4-year-old Lamancha doe.

<table>
<thead>
<tr>
<th>Antimicrobial</th>
<th>Goat 1</th>
<th>Goat 2</th>
<th>Goat 3</th>
<th>Goat 4</th>
<th>Goat 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ampicillin*</td>
<td>R &gt; 0.00</td>
<td>R &gt; 0.00</td>
<td>S = 0.00</td>
<td>R &gt; 0.00</td>
<td>S = 0.00</td>
</tr>
<tr>
<td>Ceftriaxone*</td>
<td>R &gt; 0.00</td>
<td>R = 0.00</td>
<td>R &gt; 0.00</td>
<td>R &gt; 0.00</td>
<td>S = 0.00</td>
</tr>
<tr>
<td>Oxacillin*</td>
<td>R &gt; 0.00</td>
<td>R &gt; 0.00</td>
<td>S ≤ 0.00</td>
<td>R &gt; 0.00</td>
<td>R = 0.00</td>
</tr>
<tr>
<td>Pencillin/Novobiocin*</td>
<td>S ≤ 0.00</td>
<td>S = 0.00</td>
<td>S ≤ 0.00</td>
<td>R = 0.00</td>
<td>R = 0.00</td>
</tr>
<tr>
<td>Pefillin*</td>
<td>R = 0.00</td>
<td>R = 0.00</td>
<td>S = 0.00</td>
<td>S = 0.00</td>
<td>S = 0.00</td>
</tr>
<tr>
<td>Pirlimycin*</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.50</td>
<td>S = 0.50</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>S ≤ 0.00</td>
<td>R &gt; 16.00</td>
<td>S ≤ 0.00</td>
<td>S ≤ 0.00</td>
<td>S = 0.00</td>
</tr>
<tr>
<td>Sulfamethoxazole</td>
<td>No Int P ≤ 0.50</td>
<td>S ≤ 0.12</td>
<td>S ≤ 0.25</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.25</td>
</tr>
<tr>
<td>Enrofloxacin*</td>
<td>S ≤ 0.50</td>
<td>S &lt; 0.01</td>
<td>S &lt; 0.01</td>
<td>S &lt; 0.50</td>
<td>S &lt; 0.01</td>
</tr>
<tr>
<td>Florfenicol*</td>
<td>S &lt; 0.50</td>
<td>S ≤ 0.01</td>
<td>S ≤ 0.01</td>
<td>S &lt; 0.50</td>
<td>S &lt; 0.01</td>
</tr>
<tr>
<td>Gentamicin*</td>
<td>S ≤ 0.50</td>
<td>S = 0.50</td>
<td>S ≤ 0.01</td>
<td>S ≤ 0.50</td>
<td>S = 0.50</td>
</tr>
<tr>
<td>Spectinomycin*</td>
<td>I = 0.01</td>
<td>I = 0.01</td>
<td>S ≤ 0.01</td>
<td>S ≤ 0.50</td>
<td>S = 0.01</td>
</tr>
<tr>
<td>Tilmicosin*</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.50</td>
<td>S ≤ 0.50</td>
</tr>
<tr>
<td>Tidamycin*</td>
<td>S = 0.50</td>
<td>S = 0.50</td>
<td>S = 0.50</td>
<td>S = 0.50</td>
<td>S = 0.50</td>
</tr>
</tbody>
</table>

1 = Intermediate. No Int P = No interpretation. R = Resistant. S = Susceptible.

*Interpretation based on breakpoints for Enterobacteriaceae. **Interpretation based on breakpoints for Staphylococcus aureus. †Interpretation based on breakpoints for bovine mastitis. Interpretation based on breakpoints for cattle respiratory disease. Interpretation based on breakpoints for swine respiratory disease.
stripping, and intramammary infusion (after each stripping) of the left udder half with pirlimycin for another 48 hours.

A follow-up examination was performed at the veterinary medical teaching hospital 7 days after discharge. General physical examination was unremarkable except for the left udder half that was cold on palpation and approximately twice the size of the right half. A line of demarcation remained between normal udder skin proximally and a dark gangrenous distal portion. A serosanguineous secretion was observed dripping from the left teat. All treatments were discontinued, and the owner was instructed to closely monitor the goat for clinical signs of relapse and fly strike as well as for evidence of abscess formation or sloughing of the left udder half. Eighteen months after the initial evaluation, the affected gland had sloughed and the wound was completely healed with normal haired skin covering the affected half.

A 3-year-old Toggenburg doe (goat 2) that was 100 DIM was evaluated because of an acute onset of anorexia, lethargy, and a swollen and warm left udder half with a serosanguineous secretion that was noted at the morning milking. The owner initiated treatment with a single intramammary infusion of cephaloridine sodium into the left udder half. On physical examination, the goat was normothermic (102.2°F [39.0°C]) and tachycardic (132 beats/min). The respiratory rate could not be accurately determined because the goat was vocalizing. Mucous membranes were pale pink with a prolonged capillary refill time (4 seconds). The ears and distal portions of the limbs were cool. The left teat and left udder half were enlarged, moderately firm, and cool on palpation. A purple discoloration that involved the left udder skin and teat distally with a demarcation from grossly normal udder tissue proximally was observed. A serosanguineous secretion was expressed from the left teat. The right half of the udder palpated normally and had normal-appearing milk when the teat was expressed.

The initial diagnostic plan included a CBC and serum chemistry panel. The CBC revealed leukopenia (2,800 leukocytes/µL) with a degenerative left shift (neutropenia [304 neutrophils/µL; reference range, 700 to 7,600 neutrophils/µL] and band neutrophilia [728 band neutrophils/µL]; reference range, 2,500 to 12,000 lymphocytes/µL] with toxic changes), lymphopenia (1,484 lymphocytes/µL; reference range, 2,500 to 12,000 lymphocytes/µL), and monocytopenia (56 monocytes/µL; reference range, 70 to 370 monocytes/µL). The fibrinogen concentration was normal (400 mg/dL; reference range, 100 to 400 mg/dL). Serum biochemical abnormalities included hypocalcemia (<8 mg/dL; reference range, 8.9 to 11.2 mg/dL); low total CO₂ concentration (18 mmol/L; reference range, 22 to 28 mmol/L); elevations in concentrations of creatinine (1.2 mg/dL), BUN (37 mg/dL), and total bilirubin (0.3 mg/dL; reference range, 0.0 to 0.1 mg/dL); and increased activities of aspartate transaminase (757 U/L; reference range, 58 to 196 U/L), creatine kinase (246 U/L; reference range, 104 to 219 U/L), alkaline phosphatase (1,123 U/L; reference range, 27 to 210 U/L), and γ-glutamyl transferase (71 U/L; reference range, 34 to 65 U/L). Gangrenous mastitis and secondary endotoxemia were diagnosed. A sample of the serosanguineous udder secretion was submitted for aerobic bacterial and Mycoplasma culture and antimicrobial susceptibility testing. The initial treatment for goat 2 included IV fluid therapy with lactated Ringer’s solution, oxytetracycline (10 mg/kg, IV, q 24 h), flunixin meglumine (0.25 mg/kg [0.11 mg/lb], IV, q 8 h), and hourly udder stripping with intramammary infusion of sodium cloxacillin® (q 6 h) following udder stripping. The initial choice for systemic oxytetracycline treatment was made on the basis of the antimicrobial susceptibility results of a Bacillus sp isolate in a clinical mastitis case from the herd of origin 12 months prior; however, a change to florfenicol (20 mg/kg, SC, q 48 h) was made 48 hours later when the results of antimicrobial susceptibility testing became available (Table 1). Electrolyte and acid-base disturbances were monitored via blood gas analyses, and treatment was altered to meet patient needs on the basis of the results of serial blood analyses.

The milk cultures revealed moderate numbers of Bacillus sp that were not identified further. A coagulase-negative Staphylococcus sp cultured from the right nonaffected udder half only after enrichment was considered unrelated to the clinical disease. Results of Mycoplasma cultures were negative.

On day 2 of hospitalization, goat 2 continued to be inappetant; thiamine hydrochloride (20 mg/kg, SC, q 24 h) treatment was initiated, and dextrose (5%) was added to the crystalloid IV fluid therapy. That same day, red discolored urine was observed; however, a urinalysis was not performed. A follow-up CBC revealed a severe normocytic anemia (Hct, 12.1% [reference range, 23% to 36%]; mean corpuscular volume, 18.9 fl [reference range, 15 to 23 fl]; hemoglobin concentration, 4.4 g/dL [reference range, 8.2 to 12.4 g/dL]) with moderate anisocytosis, slight polychromasia, slight hemolysis, and hyperfibrinogenemia (1,000 mg/dL). A repeated serum biochemistry panel revealed hypocalcemia (7.9 mg/dL) and hypoalbuminemia (2.7 mg/dL; reference range, 3.8 to 4.5 mg/dL). A blood transfusion was initiated, but it could not be completed because the doe developed a transfusion reaction and had to be treated with epinephrine (0.3 mg/kg [0.14 mg/lb], IV, once) and dexamethasone (0.5 mg/kg [0.23 mg/lb], IV, once).

By day 4, the appetite and activity level of the goat had improved. The right udder half had stopped producing milk, and the skin color of the affected left udder half had turned from red to purple and then black. A follow-up CBC indicated a slightly improved Hct (13.8%) with evidence of regeneration (reticulocyte count, 6,990 reticulocytes/µL). On day 8, the goat was discharged. The affected udder half sloughed approximately 2 months following discharge. At the end of the lactation when the Bacillus mastitis episode occurred, this goat was removed from the herd through a voluntary herd reduction program.

A 5-year-old Oberhasli doe (goat 3) from a herd of 100 healthy dairy goats was evaluated because of anorexia and reluctance to walk or lie down for 3 days. The doe had been dry for 1 week earlier. Five days after dry off, the doe was noted to be ill and the owner had instituted treatment with flunixin meglumine once daily for 2 days. On initial evaluation, the doe was normothermic (38.94°C [102.1°F]), slightly tachypneic (32
eters were within reference limits except for tachypnea (120 breaths/min). There was moderate bilateral scleral injection and slight bilateral mucoid nasal discharge. The doe had a stiff gait that was attributed to a painful udder. The udder was asymmetric with the right half being swollen, darkly discolored, and cold on palpation. The milk expressed from the right teat had pink discoloration. Blood was collected for a CBC and chemistry profile. The CBC was unremarkable except for the presence of slightly toxic band neutrophils (8.9%; 663 band neutrophils/µL) and hyperfibrinogenemia (800 mg/dL). Abnormalities on the chemistry panel included hypoalbuminemia (2.7 mg/dL), increases in BUN (37 mg/dL) and total bilirubin (0.9 mg/dL) concentrations, and increases in creatine kinase (464 U/L) and alkaline phosphatase (1,164 U/L) activities. Gangrenous mastitis and endotoxemia were diagnosed.

An aseptically collected milk sample from the right udder half was submitted for aerobic and anaerobic bacteria and Mycoplasma culture and antimicrobial susceptibility testing. Intravenous fluid therapy with saline solution supplemented with potassium chloride as well as antimicrobial (ampicillin; 22 mg/kg [10 mg/lb], IV, q 8 h) and NSAID (flunixin meglumine; 1.1 mg/kg, IV, q 24 h) treatment were initiated. The unaffected left udder half was milked out twice daily, and the right half was stripped out every 2 hours during the day. Following the last milking in the late evening, the right udder half was treated with an intrammary infusion of cephapirin sodium.

Over the next 24 hours, the condition of the goat stabilized and vital signs remained normal. The right udder half remained cool but became progressively more swollen. The goat’s appetite improved, and fluids were tapered and then discontinued on day 2; ampicillin and flunixin meglumine treatments were continued for 4 days.

Bacteriologic culture of milk revealed large numbers of a Bacillus sp that was not speciated further and was susceptible to multiple antimicrobials (Table 1). This isolate was resistant to cefotiofur, oxacillin, and penicillin G. Results of Mycoplasma cultures were negative. On the basis of these results and the goat’s apparent clinical improvement, the initial antimicrobial treatment regimen was continued. The goat was discharged on day 5 with recommendations for the owner to maintain antimicrobial treatment over the next 14 days with long-acting oxytetracycline (20 mg/kg, SC, q 48 h). The affected distal portion of the right udder half sloughed off in approximately 1.5 months. The doe was dried off for the remainder of the lactation and voluntarily withdrawn from milk production in subsequent lactations. Six years following initial evaluation, goat 3 was still in the herd and had kidded 6 times, with sufficient milk production in the unaffected udder half to raise kids.

A 1.5-year-old Toggenburg doe (goat 4) that was 156 DIM from the same herd as goat 2 was evaluated because of mastitis. The doe was reported to be normal until the morning of initial evaluation when the owner found the goat to be lethargic with a warm udder. This goat had been housed with 4 other goats that were apparently healthy. On physical examination, vital parameters were within reference limits except for tachypnea (48 breaths/min). Severe bilateral scleral injection and hyperemia of the oral mucous membranes were present. The left udder half was swollen, and signs of pain were elicited on palpation, and the left teat was cooler, compared with the right udder half. Milk expressed from the left teat was hemorrhagic. A CBC revealed the presence of band neutrophils (7%; 504 band neutrophils/µL); no clinically relevant abnormalities were noted on a serum biochemistry profile. A diagnosis of gangrenous mastitis with endotoxemia was made. Aseptically collected udder secretions from both glands were submitted for bacterial and Mycoplasma culture and antimicrobial susceptibility testing.

Initial treatments for this goat included cefotiofur (1.1 mg/kg, IV, q 12 h), sodium ampicillin (20 mg/kg, IV, q 6 h), flunixin meglumine (0.5 mg/kg [0.23 mg/lb], IV, q 12 h), and fluid therapy (4 mL/kg/h, IV) with lactated Ringer’s solution supplemented with 23% calcium gluconate (0.3% solution). Both udder halves were stripped every 2 hours, and cephapirin sodium was infused into the left half every 6 hours.

A Gram stain of the secretion expressed from the left teat revealed multiple gram-positive rods consistent with Bacillus sp. After 24 hours, bacterial growth consistent with Bacillus sp was confirmed. Similar to goat 2, a coagulase-negative Staphylococcus sp cultured only after enrichment from the normal-appearing milk from the right udder was considered unrelated to the clinical disease. Results of Mycoplasma cultures were negative. The same treatments were maintained, and the goat became progressively brighter with an improved appetite; during this time, the left udder half became darker and colder and a serosanguineous secretion persisted. On day 3, chemical cauterization of the left udder half was performed by infusing 1 g of oxytetracycline hydrochloride diluted in 50 mL of saline solution into the left teat. Prior to udder infusion, the doe was pretreated with flunixin meglumine (1.1 mg/kg, IV, once). The antimicrobial susceptibility of the Bacillus sp indicated resistance to cefotiofur (Table 1); as such, systemic treatment with cefotiofur was discontinued and treatment with oxytetracycline (10 mg/kg, IV, q 24 h) was begun. The left udder half became more swollen and warm and more signs of pain were elicited on palpation over the next 4 days, and the left teat remained dark purple in color and cool on palpation. The appetite and overall mental status of this doe continued to improve during this time, and the doe was discharged with instructions for the owner to continue 5 more treatments with oxytetracycline (20 mg/kg, SC, q 48 h) and to monitor the goat’s overall condition as well as the left udder half for sloughing. Approximately 1.5 months after discharge, the affected udder half had completely sloughed and skin overlying the area had healed. The goat’s records obtained from the dairy herd improvement program indicated that total milk production during the first lactation in which the Bacillus mastitis episode occurred was 2,540 lb for a total of 305 DIM. Milk production for later lactations was 2,790 lb (lactation 2), 2,130 lb (lactation 3), and 1,610 lb (lactation 4) for a total of 342, 242, and 191 DIM, respectively.

A 4-year-old Lamancha doe (goat 5) that had kid- ded 3 days earlier was evaluated because of possible...
mastitis and 48 hours of decreased appetite. At the morning milking 1 day after kidding, udder secretions were thick and pasty from the left udder half and watery and blood tinged from the right. The owner had initiated treatment with 2 intramammary antimicrobial preparations for cattle: cepahpin sodium in the left half and cepahpin benzathine in the right half. The herd of origin consisted of 20 other goats that were all apparently healthy. One doe had died of acute mastitis 2 years previously; however, the cause of the mastitis was not determined. On physical examination, the goat was normothermic (39.1°C [102.4°F]), tachypneic (40 breaths/min), and tachycardic (130 beats/min). Moderate bilateral scleral injection was present. The right udder half was cold and swollen, and bloody milk was expressed from the right teat. A sample of this secretion was submitted for aerobic bacterial and Mycoplasma culture and antimicrobial susceptibility testing. A CBC revealed a mild anemia (Hct, 20.9%; hemoglobin concentration, 7.7 g/dL), monocytosis with normal WBC count, and hyperfibrinogenemia (800 mg/dL). Serum chemistry revealed decreases in albumin (2.0 g/dL), bicarbonate (19 mmol/L), and calcium (7.7 mg/dL) concentrations. A diagnosis of gangrenous mastitis with endotoxemia was made.

The initial treatment consisted of flunixin meglumine (0.5 mg/kg, IV, followed by 0.25 mg/kg, IV, at 6, 12, and 24 hours after initial treatment), procaine penicillin G (22,000 U/kg [10,000 U/lb], IM, q 12 h); cefotiofur (2.2 mg/kg, IV, q 12 h), IV fluid therapy (lactated Ringer's solution [3 mL/kg/h]), and frequent stripping of the udder halves 5 times daily. Following the final stripping of the day, each gland was infused with cephapirin benzathine.

Over the next 3 days, the goat’s clinical appearance and appetite improved, although the right udder remained swollen and warm proximally and cold and discolored more distally. The milk remained blood tinged. Intravenous fluid therapy was discontinued on day 3; however, other treatments were continued until discharge on day 8. Results of the bacterial cultures revealed small numbers of a Bacillus sp; antimicrobial susceptibility testing was not performed on this isolate. Results of Mycoplasma cultures were negative. Eight days after admission, a follow-up CBC revealed neutrophilia (13,422 neutrophils/µL), fibrinogen concentration had decreased to 600 mg/dL. By this time, the distal half of the right udder was cold, edematous, and dark and the right teat was firm. The goat was discharged with instructions for the owner to continue cefotiofur treatment (2.2 mg/kg, SC, q 24 h) for 10 days. Owners were also instructed to continue stripping the right udder half daily and to gradually reduce the frequency to allow the udder to dry up (cease milk production). No follow-up information was available for this goat.

A sixth case of Bacillus sp gangrenous mastitis that was treated on the farm by one of the authors (JDR) occurred in a 2-year-old Toggenburg doe (goat 6) that was 86 DIM in the first lactation and from the same herd as goats 2 and 4. This goat had an acute onset of signs of depression, fever (41.1°C [106°F]), and firmness of the left udder half 2 days after returning from a dairy goat show. This gland rapidly progressed over 2 hours from warm and firm to cool below a dark line of demarcation of the entire distal portion of the left half. During this time, the left udder secretion changed from pink-tinged milk to a dark serosanguineous secretion. The goat was treated systemically with polyionic IV fluid therapy, flunixin meglumine, and florfenicol, and by intramammary infusion of cephapirin sodium.

The secretion from the left udder half was submitted for aerobic bacterial and Mycoplasma culture and antimicrobial susceptibility testing (Table 1). Results of bacterial culture revealed a pure growth of Bacillus sp. Results of Mycoplasma cultures were negative. Approximately 1 month following the clinical episode, the gangrenous portion of the left half had sloughed. Unlike goats 1, 2, 3, and 4 that completely lost function from the affected udder half during the lactation in which the mastitis episode occurred, this goat had only partial sloughing of the affected left half that did not involve the teat and continued to produce milk from the left half. At the next kidding following the episode of mastitis, scarring of the left gland cistern prevented normal milk production and secretion. The left gland remained small and nonfunctional at all subsequent kiddings. Seven years after the Bacillus mastitis episode, this goat was 9 years old and was still in the milking herd with normal milk production from the right udder half. The goat’s records obtained from the dairy herd improvement program indicated that total milk production during the first lactation in which the Bacillus mastitis episode occurred was 1,600 lb for a total of 229 DIM. Milk production for subsequent lactations was 2,600 lb, 3,030 lb, 2,680 lb, 1,350, and 900 lb for a total of 281, 341, 294, 155, and 136 DIM, respectively.

Discussion

Bacillus cereus has a ubiquitous distribution in the environment and has generally been considered to be a contaminant in clinical specimens from human patients. In cattle, B cereus is considered a common contaminant in milk sample cultures, however, clinical cases of gangrenous mastitis due to this bacterium have been reported but are considered rare. The relatively low occurrence of B cereus mastitis in the face of a fairly wide host and environmental distribution of Bacillus sp has suggested that specific predisposing factors may be required for the development of clinical mastitis due to B cereus. Sources of infection that have been implicated in bovine cases include contaminated intramammary antimicrobial preparations, teat tubes, syringes, and teat dilators. Contamination of intramammary products has been reported for other organisms, most notably Pseudomonas spp. Associations with bedding materials such as chaff and feeds such as brewers grains were suggested to be predisposing causes of bovine B cereus mastitis; however, in 1 report, no specific inciting cause was identified in a pastured dairy cow with B cereus mastitis. In reported Bacillus mastitis cases in cattle associated with intramammary products, the mastitis occurred from a few hours after calving to 3 to 22 weeks after calving. Although fatal outcomes have been reported in bovine mastitis cases, most affected animals survived.

840 Scientific Reports JAVMA, Vol 242, No. 6, March 15, 2013

Unauthenticated | Downloaded 10/29/23 03:52 PM UTC
One report from Nigeria cited that 7.5% of mastitis cases in goats were due to _B. cereus_; however, no description of the clinical progression of disease was reported. Isolation of _B. cereus_ in goats with subclinical mastitis has also been reported. To our knowledge, this report is the first that describes the clinical progression of acute gangrenous mastitis associated with _Bacillus sp_ in dairy goats.

The development of clinical disease following intracisternal introduction of _Bacillus_ spp appears to depend on the infection status of the gland at the time of bacterial entry. In the cattle of 1 report, previously normal lactating glands appeared more vulnerable to the development of clinical _B. cereus_ mastitis, compared with those considered already infected or inflamed as determined by a California mastitis test. Clinical signs of _B. cereus_ mastitis in cattle included acute onset of fever, anorexia, and lethargy, with considerably swollen affected quarters; similar clinical signs were observed in 5 goats of the present report.

In _B. cereus_ mastitis in cattle, affected udders have skin discoloration, enlargement, and necrosis over a short period of time. Udder secretions from affected glands are uniformly hemorrhagic in appearance in naturally occurring cases. In experimental bovine _Bacillus_ mastitis, clinical signs were transient and characterized by an acute febrile response and udder inflammation as well as in an increase in somatic cell count and milk chloride ion content. Milk secretions in these cattle were abnormal (garget and yellowish-green in color) within 5 hours after infection and abnormalities persisted for 3 to 6 weeks. These reported color changes in milk of the experimentally inoculated cattle differ from the bloody secretions described in natural bovine cases as well as the goats of this report. Sometimes necrotic mammary gland tissue is present in the udder secretions, and milk production from nonaffected quarters decreases dramatically in lactating cattle. Over time, affected quarters can slough with a return to milk production in the unaffected quarters; however, production in the current and future lactations is decreased. In the 5 hospitalized goats of the present report, similar clinical progressions were observed, and all 5 were discharged after 5 to 9 days of hospitalization.

A hemorrhagic milk secretion continued for at least 5 days after discharge in goat 1, whereas in _B. cereus_ cases (goats 1, 2, 3, and 4), the gangrenous portions of the udder completely sloughed over 1 to 2 months. Of the 5 goats with follow-up information, goats 1 and 3 were dried off for the remainder of the lactation in which the _Bacillus_ sp mastitis occurred. Goats 2, 4, and 6 continued to lactate from the unaffected udder half for the remainder of the lactation, but the milk was discarded. Goats 1, 2, and 3 were voluntarily withdrawn from subsequent lactations, whereas milk production from goats 4 and 6 was considered above average in subsequent lactations when compared with the 305-day Toggenburg breed average of 2,141 lb (most current available data from 2011). All goats recovered after having systemic signs of disease, suggesting that the prognosis for survival following gangrenous mastitis due to _Bacillus_ sp in goats is favorable when appropriate treatment is initiated early in the course of the disease. In a report of 150 gangrenous mastitis cases in goats due to _S. aureus_ and other bacteria, treatment early in the clinical course of the disease resulted in complete recovery, with a return to lactation without sloughing of the affected udder halves. In that report, the early stage of clinical disease was defined by an onset of signs of intense hyperemia, swelling, and distension that occurred before the appearance of blood-tinged milk. In the goats described in the present report, complete (4/5) or partial (1/5) sloughing of affected halves and losses in that lactation were observed despite early treatment. Eventual sloughing of affected gangrenous portions of the mammary gland followed by skin healing was observed in 5 of 6 goats in this case series without a need for surgical mastectomy.

Systemic clinical pathological changes attributable to _B. cereus_ acute gangrenous mastitis in cattle have been described and include endotoxemia, disseminated intravascular coagulation, hemolysis, and hemoglobinuria with hemoglobinuric nephrosis. Bacteremia was not detected in _Bacillus_ mastitis cases in cattle with systemic signs in 1 report. The systemic signs due to _Bacillus_ infection in the bovine udder have been attributed to the production of a variety of toxins, including hemolysins and phospholipases. The lethality of these _B. cereus_ toxins as tested on mice exceeded that of the lethal factor of _Bacillus anthracis_. In 1 goat (goat 2) of this case series, severe anemia developed that required a blood transfusion. The anemia in this goat could have been associated with _B. cereus_ hemolysins that caused intravascular hemolysis or hemorrhage through the udder; however, there was no clinical pathological evidence of hemoglobinemia to indicate intravascular hemolysis. Hemolysin titers of _B. cereus_ isolates from severe clinical conditions in humans and bovine mastitis cases did not have a clear relationship with increased pathogenicity.

The diagnosis of acute gangrenous _B. cereus_ mastitis should be made in cases where _B. cereus_ is isolated from a properly collected milk sample obtained from an animal with signs of endotoxemia and rapidly developing gangrenous changes in the udder. Because of the ubiquitous environmental distribution of _Bacillus_ sp and the fact that many _Bacillus_ sp are closely related, identification at the species level is difficult and requires biochemical, phenotypic, and molecular methods. Apart from mastitis, _B. cereus_ has been associated with natural cases of abortion in cattle. The ability of _B. cereus_ to induce abortion was demonstrated through IV inoculation in heifers and sheep. In human patients, _B. cereus_ is a cause of gastrointestinal and nongastrointestinal infections. In 1 report, none of the _B. cereus_ serotypes isolated from bovine mastitis cases were similar to those isolated in human cases. In this case series, only 1 _Bacillus_ sp isolate was characterized to the species level. The _Bacillus_ isolates in the other cases most likely belonged to the _B. cereus_ group on the basis of colony morphology, Gram-staining characteristics, and complete hemolysis. Additionally, they were likely either _B. cereus_ or _B. thuringiensis_ on the basis of the presence of complete hemolysis that differentiated them from _B. anthracis_ and _Bacillus mycoides_. Molecular and phenotypic differentiation of members of the _B. cereus_ group can be difficult because only small differences in 16S rRNA sequences may oc-
This was evident in the sequence obtained from the isolate from goat 1, which had 99% identity with both *B. cereus* and *B. thuringiensis*. Our conclusion that the isolate was *B. cereus* relied on failure to detect endosporal crystals.

Dual infections of *Bacillus* sp with other pathogens in cases of bovine mastitis have been reported. A *Bacillus* sp was isolated along with *Clostridium perfringens* in a cow in South Africa, and in a Jersey crossbred cow with a fungal infection. In 2 goats of the present report, a coagulase-negative *Staphylococcus* sp was cultured from normal-appearing milk sampled from the nonaffected udder half. Since the coagulase-negative *Staphylococcus* sp was only isolated after enrichment, it was considered clinically unimportant. Results of all *Mycoplasma* cultures were negative for those cases (5/6) in which they was requested.

Antimicrobial susceptibility testing is recommend when choosing the most appropriate antimicrobial to treat caprine *Bacillus* sp mastitis. β-Lactamase production in 1 *B. cereus* isolate from a goat mastitis case has been reported. The presence of this enzyme would render these isolates resistant to β-lactam antimicrobials such as penicillins and cephalosporins, 2 common empirical antimicrobial choices for treatment of undifferentiated mastitis. In 5 of the *Bacillus* sp isolates from the goats of this case series, resistance to at least 1 β-lactam antimicrobial was observed. Resistance to penicillins and cephalosporins has also been demonstrated for *B. cereus* isolates from human patients.

Although the prognosis for survival from *Bacillus* sp mastitis was favorable in the goats described in this case series, these successful outcomes were affected, at least in part, by the value of these goats and the use of antimicrobials in an extralabel manner. All of the goats of this case series were identified by clients as having high genetic merit and high individual value, and these clients were willing to invest in the treatment of these animals. No drugs are currently labeled for treatment of *Bacillus* sp mastitis in goats, so it was necessary to use drugs in an extralabel manner. Whenever drugs are used in an extralabel manner, it is important to observe the appropriate drug withdrawal intervals established by the Food Animal Residue Avoidance Database.

**References**


From this month’s AJVR

Comparison of efficacy and duration of effect on corneal sensitivity among anesthetic agents following ocular administration in clinically normal horses

Jonathan D. Pucket et al

**Objective**—To compare efficacy and duration of effect on corneal sensitivity of 0.5% proparacaine hydrochloride, 0.5% bupivacaine hydrochloride, 2% lidocaine hydrochloride, and 2% mepivacaine hydrochloride solutions following ocular administration in clinically normal horses.

**Animals**—68 clinically normal horses.

**Procedures**—60 horses were assigned to receive 1 anesthetic agent in 1 eye. For each of another 8 horses, 1 eye was treated with each of the anesthetic agents in random order with a 1-week washout period between treatments. Corneal sensitivity was assessed via corneal touch threshold (CTT) measurements obtained with a Cochet-Bonnet aesthesiometer before and at 1 minute, at 5-minute intervals from 5 to 60 minutes, and at 10-minute intervals from 60 to 90 minutes after application of 0.2 mL of anesthetic agent. General linear mixed models were fitted to the CTT data from each of the 2 experimental groups to assess the effects of the anesthetic agents over time, accounting for repeated observations within individual horses.

**Results**—Corneal sensitivity decreased immediately following topical application of each anesthetic agent; effects persisted for 35 minutes for proparacaine and mepivacaine treatments, 45 minutes for lidocaine treatment, and 60 minutes for bupivacaine treatment. Maximal CTT reduction was achieved following application of bupivacaine or proparacaine solution, whereas mepivacaine solution was least effective.

**Conclusions and Clinical Relevance**—Ocular application of each evaluated anesthetic agent reduced corneal sensitivity in horses, although 0.5% proparacaine or 2% lidocaine solution appeared to induce adequate short-duration corneal anesthesia, use of 0.5% bupivacaine solution may be more appropriate for procedures requiring longer periods of corneal anesthesia. (Am J Vet Res 2013;74:459–464)