

Osseous sequestration in cattle: 110 cases (1987–1997)

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Objective—To determine risk factors for development of sequestra in cattle and identify factors associated with a successful outcome.

Design—Retrospective study.

Animals—110 cattle.

Procedure—Medical records of cattle treated at veterinary teaching hospitals in North America were reviewed. To determine risk factors for osseous sequestration, breed, age, and sex of cattle with osseous sequestration were compared with breed, age, and sex of all other cattle admitted during the study period.

Results—110 cattle were included in the study. Three had 2 sequestra; thus, 113 lesions were identified. Most sequestra were associated with the bones of the extremities, most commonly the third metacarpal or third metatarsal bone. Ninety-two animals were treated surgically (ie, sequestrectomy), 7 were treated medically, 3 were initially treated medically and were then treated surgically, and 8 were not treated. Follow-up information was available for 65 animals treated surgically and 6 animals treated medically. Fifty-one (78%) animals treated surgically and 5 animals treated medically had a successful outcome. Cattle that were 6 months to 2 years old had a significantly increased risk of developing a sequestrum, compared with cattle < 6 months old. Cattle in which sequestrectomy was performed with the aid of local anesthesia were significantly more likely to undergo 2 or more surgical procedures than were cattle in which sequestrectomy was performed with the aid of general anesthesia.

Conclusions and Clinical Relevance—Results suggest that sequestrectomy will result in a successful outcome for most cattle with osseous sequestration. (*J Am Vet Med Assoc* 2000;217:376–383)

Osseous sequestration is a common orthopedic condition in cattle.¹ However, although the incidence and treatment of sequestra in horses has been well-documented,^{1–6} reports describing treatment and out-

come of cattle with sequestra have been limited to small numbers of cases.^{1,7,8} In horses and cattle, most of these lesions develop in the bones of the distal portion of the limbs. Typically, sequestration is associated with trauma that results in localized cortical ischemia and bacterial invasion secondary to loss of adjacent periosteal and soft-tissue integrity and viability. It is speculated that soft tissues covering the bones that make up the distal portions of the limbs fail to provide adequate protection and collateral blood supply to the bone. Less commonly, sequestration may be a result of nontraumatic hematogenous bacterial osteitis or osteomyelitis.

Clinically, animals with osseous sequestration may have wounds that vary from small nonhealing wounds or fistulous tracts (with or without discharge) to large defects with exposure of the underlying bone. Affected animals may not be lame or may have an associated lameness ranging from mild to non-weight-bearing lameness, depending on the neighboring structures that are involved. The diagnosis usually is confirmed radiographically; however, ultrasonography can be used in those areas inaccessible to radiography. Surgical intervention has been the method of choice for sequestra, because few cases in which medical treatment was successful have been described.

The purposes of the study reported here were to determine risk factors for development of sequestra in cattle, to correlate clinical findings with short- and long-term outcome, and to identify factors associated with a successful outcome.

Criteria for Selection of Cases

A computer-assisted search of medical records for all cattle admitted to any 1 of 9 veterinary teaching hospitals between Jan 1, 1987 and Dec 31, 1997 was performed. Records of cattle in which osseous sequestration was diagnosed were reviewed for history and physical examination, clinicopathologic, radiologic, and surgical findings. Cattle were included in the study only if the medical record contained a detailed radiol-

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ogy or ultrasonography report and, if the animal was treated surgically, a detailed surgery report. Outcome was considered successful if clinical abnormalities resolved, and the animal returned to production. Follow-up information was obtained via telephone interviews with owners or herd managers.

To determine possible risk factors for osseous sequestration, records of all cattle with sequestra and all other cattle entered in the **Veterinary Medical Data Base (VMDB)** between Jan 1, 1987 and Dec 31, 1997 were compiled. The VMDB provides information about animals examined at veterinary teaching hospitals throughout North America. Although information in the database is biased against cattle of low perceived economic value (such cattle would not typically be brought to veterinary teaching hospitals for treatment), the VMDB is currently the foremost resource for determining incidences of animal diseases and allows for an overall representation of their occurrences.

Age (< 6 months old, 6 months to 1 year old, 1 to 2 years old, 2 to 4 years old, and > 4 years old), breed (dairy vs beef), and sex (male vs female) were examined as potential risk factors for osseous sequestration.

Procedures

Discrete data were summarized as percentages. Continuous data were summarized as medians and quartiles. The Student *t*-test or the Mann-Whitney *U* test was used to analyze continuous data. The Fisher exact test or χ^2 tests were used to analyze categorical data such as breed, age, and sex. Risk factors were evaluated by calculating, for each factor, the crude **odds ratio (OR)**. Odds ratios were adjusted for confounding effects of other study variables by the use of the Mantel-Haenszel method.⁹ Ninety-five percent **confidence intervals (CI)** were computed for the OR. A commercial statistical program^a was used for data analyses. For all statistical tests, a value of $P < 0.05$ was considered significant.

Results

Cattle—The initial search of medical records identified 184 cattle with osseous sequestration examined during the study period. Records for 174 of these 184 cattle were retrieved and reviewed; 10 records were not available for review. Of the 174 cases reviewed, 64 were excluded because of a lack of complete records or because radiography was not performed. The remaining 110 records were examined for pertinent data. Three animals each had 2 sequestra; thus, 113 lesions were identified in the 110 animals included in the study. Ninety-two animals were treated surgically (ie, sequestrectomy), 7 were treated medically, 3 were initially treated medically and were then treated surgically, and 8 were not treated.

Signalment—Median age of the cattle was 1.8 years (range, 0.1 to 11 years). Of the 110 cattle included in the study, 53 were beef cattle, and 57 were dairy cattle. Angus ($n = 12$) was the most common beef breed; other beef breeds represented were Beefmaster (2), Blonde d'Aquitaine (1), Brangus (2), Charolais (2), Chianina (3), Gelbveih (1), Hereford (3), Limousin

(4), Longhorn (1), Maine Anjou (1), Red Devon (1), Red Poll (1), Salers (1), Shorthorn (4), and Simmental (10). The remaining 4 beef cattle were crossbreeds. Holstein ($n = 52$) was the most common dairy breed, followed by Ayrshire (3), Brown Swiss (1), and Gurnsey (1). Beef cattle included 27 sexually intact males, 22 sexually intact females, and 4 castrated males. Dairy cattle included 3 sexually intact males and 54 sexually intact females. The proportion of Holsteins among cattle with sequestra (52/110; 47.3%) was significantly ($P = 0.003$) greater than the proportion of Holsteins among the control cattle (13,683/40,532; 33.8%). Among cattle with sequestra, the proportion of dairy cattle that were male (3/57; 5.3%) was significantly ($P = 0.001$) less than the proportion of beef cattle that were male (31/53; 58%).

History—Duration of the injury or time since the owner first became aware of a problem prior to admission of the animal to the veterinary teaching hospital ranged from 1 day to 1 year (median, 25.5 days). Duration or awareness of the injury was not significantly associated with anatomic location of the sequestrum.

Lesions reported by owners or referring veterinarians consisted of lacerations ($n = 34$), contusions with abrasions (16), and puncture wounds (11). In 48 cattle, osseous sequestration was known or presumed to be a result of an injury. In these cattle, injuries consisted of entanglement in wire fencing ($n = 10$); entrapment of a limb in a feed trough or manger (7), tie stall or neck chain (5), cattle chute (2), stanchion pipe (1), metal gate (1), sewer grate (1), or farm equipment (1); laceration from sheet metal (5); puncture wound from a nail (5); transporting accident (5); dog attack (2); halter trauma (1); falling (1); and impalement on a metal fence post (1).

The owner or referring veterinarian reported some degree of lameness for 59 (53.6%) animals. Severity of lameness was not significantly associated with the bone affected. However, lameness was described as most severe when sequestration was associated with a fracture or involved an articular structure.

Sixty-nine (63%) cattle were treated by the owner or referring veterinarian prior to admission to the veterinary teaching hospital. Parenteral administration of an antimicrobial ($n = 53$) was the most common treatment. Procaine penicillin G ($n = 34$) was used most frequently, followed by oxytetracycline hydrochloride (10), ceftiofur sodium (1), ampicillin (1), trimethoprim-sulfonamide (1), terramycin (1), dihydrostreptomycin (1), and sulfamethazine (1). Duration of treatment with antimicrobials ranged from 1 to 180 days (median, 7 days), with many animals receiving treatment intermittently and in a manner inconsistent with label recommendations or standard protocols. Other treatments administered included administration of nonsteroidal anti-inflammatory drugs, bandaging, topical administration of various medications, and hydrotherapy. In 15 (13.6%) animals, radiography of the affected limb was performed prior to admission.

Physical examination findings—Seventy-seven (70.0%) cattle were reported by the attending clinician

to be lame at the time of admission to the veterinary teaching hospital. Lameness was detected only in cattle with sequestration involving a long bone or the distal phalanx of the appendicular skeleton. Of 86 cattle with sequestration involving a long bone or the distal phalanx of the appendicular skeleton, 77 (89.5%) were lame at the time of admission.

Draining wounds associated with sequestration were reported for 32 (29%) cattle. Three animals had draining tracts in 2 limbs, and each tract was associated with a sequestrum.

A concomitant musculoskeletal or systemic abnormality was identified in 13 (11.8%) cattle. Conditions identified included pneumonia ($n = 4$), weight loss (4), multiple slowly healing wounds (2), dehydration (1), generalized weakness (1), and injection site abscess (1). Most ($n = 9$) of these animals were reported to be lame by the attending clinician. Four of the 16 cattle with sequestration of the distal phalanx had problems identified in other claws. These problems included Rusterholz ulcers ($n = 2$), interdigital dermatitis (1), and subsolar abscess (1).

Radiologic findings—Radiographic examinations were performed on 111 sites in 108 animals (in 3 animals, 2 sites were radiographed). For 2 animals (each with sequestration of a rib), sequestra were not identified radiographically but were identified ultrasonographically. Radiographs revealed the presence of a sequestrum for 105 of the 111 (94.6%) sites. For 6 sites (distal phalanx, $n = 4$; third metacarpal bone, 1; rib, 1), sequestra were not identified radiographically but were identified at surgery.

Most sequestra were associated with the bones of the extremities (Fig 1), most commonly the third metacarpal or third metatarsal bone. Seven sequestra involved the distal phalanx of the forelimb (left lateral digit, 1; right medial digit, 4; right lateral digit, 2), and 9 involved the distal phalanx of the hind limb (left lateral digit, 5; right lateral digit, 4).

A fracture was identified radiographically in association with the sequestrum in 10 of the 113 (8.8%) lesions. Fractures involved the third metatarsal bone ($n = 3$), third metacarpal bone (2), tibia (2), distal phalanx (2), and sternebra (1). The term osteomyelitis was used to describe severe infection of the cortical bone and medullary cavity in 15 (13.2%) of the 113 lesions identified; these lesions involved the third metatarsal bone ($n = 8$), third metacarpal bone (2), tibia (2), middle phalanx (1), tuber coxae (1), and sternebra (1). Three animals had sequestra involving a physis (distal physis of the tibia, distal physis of the third metacarpal bone, proximal physis of the proximal phalanx). These animals were 10, 9, and 3 months old, respectively. Radiographs of the tibial and metacarpal lesions did not reveal a fracture; however, radiographic evidence of osteomyelitis was detected. Sequestration involving an articulation was identified in 7 cattle. One of these animals had bone fragments within the margins of the metacarpophalangeal joint, and 1 had fragments within the distal interphalangeal joint. Four cattle were reported as having developed osteoarthritis of the tarsometatarsal joint as a result of encroachment of

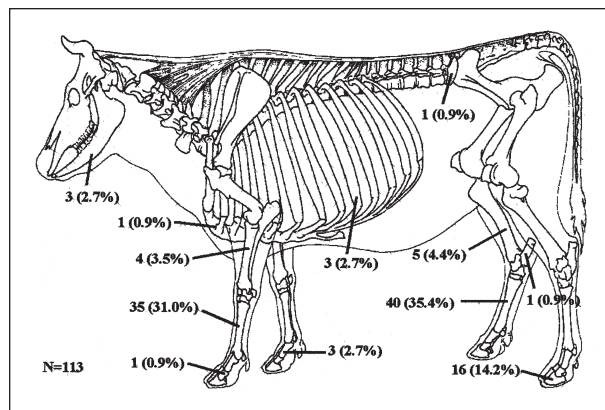


Figure 1—Location of sequestra in 110 cattle; 3 animals had 2 sequestra each.

periosteal new bone resulting from sequestration of the proximal end of the third metatarsal bone. One 9-month-old Holstein heifer had a metatarsal fracture with sequestration of the diaphysis and extension of periosteal new bone to the margin of the metatarsophalangeal joint.

Clinicopathologic findings—A CBC and serum biochemical testing were performed on 38 cattle during hospitalization. Results for all serum biochemical tests were within reference limits. Results of CBC were within reference limits for 25 (66%) animals. For these 25 cattle, median fibrinogen concentration was 600 mg/dl (range, 200 to 1,700 mg/dl; reference range, 300 to 700 mg/dl). White blood cell count was high in 13 (34%) cattle (median, 14,500 cells/ μ l; range, 12,200 to 42,400 cells/ μ l; reference range, 4,000 to 12,000 cells/ μ l). For these 13 cattle, median neutrophil count was 9,731 cells/ μ l (range, 1,456 to 33,900 cells/ μ l; reference range, 1,000 to 5,000 cells/ μ l), and median lymphocyte count was 4,278 cells/ μ l (range, 2,536 to 14,560 cells/ μ l; reference range, 2,500 to 7,500 cells/ μ l). Nine cattle had a reversal of the neutrophil-to-lymphocyte ratio. Median fibrinogen concentration for the 13 cattle was 550 mg/dl (range, 300 to 900 mg/dl). A 2-month-old Holstein heifer with sequestration of the distal part of the tibia and severe mycoplasma pneumonia had an initial WBC count of 42,400 cells/ μ l, with a neutrophil count of 33,900 cells/ μ l and a band neutrophil count of 2,120 cells/ μ l. It was suggested, but not confirmed, that the calf had bovine leukocyte adhesion deficiency. Only 2 cattle had a follow-up CBC performed. Lymphocyte count of 1 animal decreased from 14,560 to 9,590 cells/ μ l, and the neutrophil count increased from 1,456 to 3,014 cells/ μ l during a period of 3 days. There was no mention of any abnormal cellular morphology in the clinical pathology report nor was any testing performed to rule out bovine lymphoma. The second animal had a stress leukogram that returned to normal within 1 day after admission.

Results of bacterial culture—Forty-five samples were collected at the time of surgery or during physical examination and submitted for bacterial culture and susceptibility testing. A total of 61 aerobic and 23

anaerobic isolates were cultured. More than 1 organism was isolated from 19 (42%) samples. Organisms were not isolated from 5 (11%) samples. Aerobic isolates included *Actinomyces pyogenes* (n = 24), *Escherichia coli* (11), *Streptococcus* spp (5), *Proteus* spp (5), *Pasteurella* spp (3), *Staphylococcus* spp (4), *Prevotella* spp (3), *Klebsiella* spp (1), *Citrobacter* spp (1), *Eubacterium* spp (1), *Enterococcus* spp (1), *Bacillus* spp (1), and *Peptococcus* spp (1). Anaerobic isolates included *Fusobacterium necrophorum* (n = 8), *Fusobacterium* spp (4), *Bacteroides* spp (6), *Clostridium* spp (4), and an unidentified coccobacillus (1). All isolates were susceptible to more than one antimicrobial agent.

Medical treatment—Seven of the 110 cattle were treated medically, and an additional 3 were treated medically initially but were subsequently treated surgically. Nine of the 10 animals had extensive soft-tissue trauma to the affected limb. Only 2 had radiographic evidence of sequestration on initial examination at the veterinary teaching hospital. Sequestra subsequently developed in 3 animals after they were released from the hospital and in 5 animals while they were still in the hospital.

Medical treatment consisted of wound lavage and debridement (n = 10), parenteral administration of antimicrobial (10) and anti-inflammatory (2) drugs, and external coaptation with a compression bandage (8) or fiberglass cast (2). Lesions involved the third metacarpal bone (n = 4), tibia (2), third metatarsal bone (2), radius (1), and proximal phalanx (1). Three cattle with sequestra of the proximal phalanx, third metatarsal bone, and third metacarpal bone underwent surgery after medical treatment failed. All 3 of these animals had persistent lameness, signs of inflammation, drainage from the wound, and delayed wound healing.

Size of the sequestrum was reported for only 3 cattle treated medically. One was a 2-month-old Holstein calf that had been attacked by dogs 30 days earlier and had 2 tibial sequestra approximately 1 cm² each. The second was a 4-year-old Holstein cow that had swelling of the antebrachium of 7 days' duration and had 2 radial sequestra approximately 2 and 1 cm². The third was a 2-year-old Hereford bull with a 1.2 cm² sequestrum of the dorsal aspect of the distal portion of the third metatarsal bone.

Median duration of antimicrobial administration for the 7 cattle that did not require sequestrectomy was 19 days (range, 7 to 28 days). Antimicrobials used included ampicillin (n = 3), ampicillin in combination with ceftiofur sodium (2), lincomycin in combination with ceftiofur sodium (1), and procaine penicillin G (1). Median duration of hospitalization for these 7 cattle was 27 days (range, 11 to 60 days).

Surgical treatment—Ninety-two cattle (95 lesions) underwent surgery; an additional 3 cattle (3 lesions) underwent surgery after medical treatment failed. In all 95 cattle, surgery consisted of sequestrectomy with debridement and curettage. Nine (9.5%) of these cattle had a fracture, 2 (2.0%) had joint involvement, and 3 (3.2%) had involvement of a physis. General anesthesia was used for surgical treatment of

sequestra involving the third metacarpal bone (n = 24), third metatarsal bone (23), mandible (3), radius (3), tibia (2), proximal phalanx (2), middle phalanx (1), and rib (1). Perineural, local regional, or intravenous regional anesthesia was used for sequestra involving the third metatarsal bone (n = 11), third metacarpal bone (5), distal phalanx (8), rib (2), proximal phalanx (1), tibia (1), tuber coxae (1), and sternebra (1). Seven sequestra involving the distal phalanx were removed without anesthesia.

For 16 (16.3%) of the 98 lesions, a second surgery was required because of failure to identify or completely remove sequestered bone fragments. These lesions were located in the distal phalanx (n = 5), third metatarsal bone (4), third metacarpal bone (4), tibia (1), mandible (1), and rib (1). A second surgery was performed to amputate the digit of an 11-year-old Angus cow after postoperative radiographs revealed complete sequestration of the distal phalanx. Five of the 16 lesions required a third surgical procedure, including 1 lesion associated with a tibial stress fracture. One lesion required a fourth surgical procedure before a sequestrum involving the distal phalanx could be completely removed. Cattle in which sequestrectomy was performed with the aid of local anesthesia were significantly ($P = 0.008$) more likely to undergo 2 or more surgical procedures than were cattle in which sequestrectomy was performed with the aid of general anesthesia (OR, 6.0; 95% CI, 1.8 to 19.7). Cattle in which sequestrectomy was performed without anesthesia were also significantly ($P = 0.02$) more likely to undergo 2 or more surgical procedures (OR, 10.0; 95% CI, 2.0 to 48.4). Because of the small number of cases, we did not detect a significant association between anatomic location of the lesion and the need for more than 1 surgical procedure.

Forty-seven (48%) of the 98 surgical sites were completely closed, 6 (6%) were partially closed, and 44 (45%) were left to heal by second intention (for 1 surgical site, details of closure were not given). Surgical sites involving the third metatarsal bone (n = 21), third metacarpal bone (15), radius (3), mandible (2), rib (2), proximal phalanx (2), middle phalanx (1), and tibia (1) were completely closed. Surgical sites involving the third metatarsal bone (n = 4), third metacarpal bone (1), and tuber coxae (1) were partially closed. Surgical sites allowed to heal by second intention included those created in the hoof wall and sole to remove sequestra involving the distal phalanx (n = 16) and sites involving the third metacarpal bone (13), third metatarsal bone (9), tibia (2), rib (1), proximal phalanx (1), mandible (1), and sternebra (1). Wounds dehiscid in 2 cattle in which the wound had been completely closed and in 5 cattle in which the wound had been partially closed. All 7 dehiscid wounds were allowed to heal by second intention.

Size of the sequestrum was recorded for 46 lesions involving the third metatarsal bone (n = 22), third metacarpal bone (14), distal phalanx (4), rib (3), radius (1), tibia (1), and proximal phalanx (1). Median size of the sequestrum was 5.5 cm² (range, 2.0 to 27.0 cm²) for lesions involving the third metatarsal bone, 3.5 cm² (range, 0.3 to 15.0 cm²) for lesions involving

the third metacarpal bone, 1.5 cm² (range, 1.0 to 3.0 cm²) for lesions involving the distal phalanx, and 18.0 cm² (range, 1.0 to 120 cm²) for lesions involving the rib. Sequestra involving the radius and tibia measured 3.0 and 4.0 cm², respectively. Size of the sequestrum was not significantly correlated with the need for more than 1 surgical procedure or with outcome.

Postsurgical treatment consisted of external coaptation, parenteral and oral administration of antimicrobials and nonsteroidal anti-inflammatory agents, topical wound treatment, and hydrotherapy in most cattle. External coaptation consisted of a compression bandage (n = 41), fiberglass cast (16), splint (8), wooden block with compression bandage (14), or stent bandage (1). Fiberglass casts were used most often to provide rigid support in the face of large osseous defects (n = 15) rather than a fracture (1). A wooden block fastened to the sound claw with polymethyl methacrylate in combination with a compression bandage was used exclusively after sequestrectomy involving the distal phalanx. A stent bandage was used to support a closed wound following removal of a rib sequestrum. Overall, compression bandages were used for a median of 8 days (range, 1 to 39 days), fiberglass casts for a median of 10 days (range, 1 to 30 days), splints for a median of 8.5 days (range, 3 to 30 days), and wooden blocks with compression bandages for a median of 13.5 days (range, 1 to 51 days).

Antimicrobials were administered to 83 (87.4%) of the 95 cattle treated surgically. Median duration of antimicrobial treatment was 8 days (range, 1 to 101 days). A 12-year-old Holstein cow was treated for 101 days because of severe pleuropneumonia that developed as a result of trauma and extension of the septic process involved with a rib sequestrum. Antimicrobials used included procaine penicillin G (n = 60), ceftiofur sodium (14), oxytetracycline hydrochloride (11), dihydrostreptomycin (10), ampicillin (6), gentamicin (6), lincomycin (5), chloramphenicol (3), trimethoprim-sulfonamide (2), amoxicillin (2), tilmicosin (1), rifampin (1), and isoniazid (1). Cattle treated surgically were administered antimicrobials for a significantly shorter time than cattle treated medically.

Nonsteroidal anti-inflammatory agents were administered to 34 (35.8%) of the 95 cattle treated surgically. Drugs used included phenylbutazone (n = 29), flunixin meglumine (6), and aspirin (2). Median duration of nonsteroidal anti-inflammatory drug administration was 4 days (range, 1 to 30 days).

Fifty-one (53.6%) cattle were lame after surgery; 10 of these had not been lame prior to surgery. Some animals did improve over time; however, 33 (34.7%) cattle were lame when discharged from the hospital. Other postoperative complications included left displacement of the abomasum 18 days after sequestrectomy in 1 animal and dystocia requiring cesarean section 5 days after sequestrectomy in another.

Duration of hospitalization was significantly ($P = 0.01$) shorter for cattle that were treated surgically than for cattle that were treated medically. Median duration of hospitalization for cattle treated surgically was 10 days (range, 1 to 111 days). Median duration of hospi-

talization for cattle with sequestra involving the appendicular skeleton was 11 days (range, 1 to 64 days), whereas median duration of hospitalization for cattle with sequestra involving other locations was 4.5 days (range, 1 to 111 days). Median duration of hospitalization for the 16 cattle with sequestra involving the distal phalanx was 7.5 days (range, 1 to 51 days); 8 of these animals were treated on an outpatient basis.

Follow-up evaluation—Follow-up information was obtained for 65 of the animals treated surgically, 6 animals treated medically, and 4 animals that were not treated. Median time from surgery to follow-up interview was 7 years (range, 1 to 11 years). Fifty-one of the 65 (78%) animals treated surgically had a successful outcome, 11 (17%) were culled because of moderate or severe lameness, and 3 (5%) died within 3 weeks after discharge from the hospital. The 14 cattle with unsuccessful outcomes had 15 lesions involving the third metatarsal bone (n = 8), distal phalanx (3), third metacarpal bone (1), tibia (1), mandible (1), and rib (1). Eight of the 14 cattle were reported to be lame when discharged from the hospital. A 5-month-old Charolais bull that underwent surgery (3 procedures) because of sequestration of the right third metatarsal bone and right tibia was sold 180 days after discharge from the hospital because of chronic lameness that was severe enough to preclude him from being used as a breeding animal. A 3-year-old Holstein bull died 3 weeks after discharge of peritonitis associated with a perforating abomasal ulcer. An 8-year-old Hereford bull treated for sequestration of the distal phalanx died 14 days after discharge as a result of prolonged recumbency secondary to severe lameness. A 4-year-old Simmental bull died 10 days after discharge of severe pleuropneumonia associated with sequestration of a rib. A 19-month-old Hereford cow that was surgically treated for sequestration of the third metatarsal bone was retired from the show circuit and became a brood cow because of a cosmetic defect that developed at the surgical site.

Five of the 6 cattle that were treated medically had a successful outcome; the remaining animal, a 4-year-old Holstein cow with sequestration of the radius, was culled 165 days after discharge from the hospital because of persistent lameness, failure to return to milk production, and a chronic nonhealing wound that was not responsive to antimicrobial treatment administered by the owner.

Of the 4 cattle that were not treated at the veterinary teaching hospital, 3 were culled for economic reasons soon after diagnosis, and 1, a 4-year-old Holstein cow, was treated at home by the owner and survived for 1,200 days.

Evaluation of risk factors—Review of the VMDB records between 1987 and 1997 identified 184 cattle with osseous sequestration (including the 110 cattle described in the present report); 83,612 cattle were treated at veterinary teaching hospitals during the corresponding time period. Therefore, the 10-year period prevalence of osseous sequestration was 2.2/1,000 cattle admissions. Cattle that were 6 months to 1 year old or that were 1 to 2 years old had a significantly

Table 1—Risk factors for osseous sequestration among cattle examined at veterinary teaching hospitals

Variable	No. of cases	No. of controls	OR	95% CI	P value
Breed					
Beef	53	24,214	1	Reference	NA
Dairy	57	16,318	1.6	1.1–2.3	0.014
Sex					
Female	76	12,688	1	Reference	NA
Male	30	12,712	0.8	0.5–1.3	0.41
Castrated male	4	2,036	0.7	0.3–2.0	0.48
Age					
< 6 months	17	8,058	1	Reference	NA
6 months to 1 year	21	3,467	2.6	1.5–5.3	0.001
1 to 2 years	31	5,595	2.6	1.5–4.6	0.001
2 to 4 years	26	9,075	1.4	0.7–2.5	0.32
> 4 years	15	12,462	0.60	0.3–1.1	0.11

OR = Mantel-Haenszel adjusted odds ratio. CI = Confidence interval. NA = Not applicable.

increased risk of developing a sequestrum, compared with cattle < 6 months old (Table 1). Dairy cattle had a significantly increased risk, compared with beef cattle, but the effects of 1 referral institution that contributed a large number of cases involving dairy cattle could possibly explain this increased risk. Sex was not associated with risk of developing a sequestrum.

Discussion

Results of the present study suggest that dairy cattle had a higher risk of developing sequestra than did beef cattle. However, this difference may have been a result of regional differences in the type of cattle admitted to veterinary teaching hospitals. Furthermore, dairy cattle are generally monitored more closely and are more likely to receive medical treatment than are beef cattle. Cattle between 6 months and 2 years old had a higher risk of developing sequestra, compared with cattle < 6 months old. This finding was consistent with reports concerning osseous sequestration in horses.^{2,5} Adolescent cattle, like adolescent horses, are more likely to be involved in traumatic incidents that result in sequestra formation. It has been theorized that periosteal trauma may have a more severe outcome in young animals, because the periosteum plays a greater role in cortical circulation in young animals than in adults.²

In the present study, 61 of the 110 (55.4%) cattle had osseous sequestration that accompanied physical evidence (lacerations, contusions, abrasions, or puncture wounds) of a previous traumatic event. For 48 of these animals, the actual cause of the injury was known or presumed. However, the true percentage of cattle in which osseous sequestration was a result of injury was likely much higher, because the cause of osseous sequestration was not always known by the owner or recorded in the medical record. In particular, it was impossible to determine the number of cattle that developed sequestra as a consequence of blunt trauma without visible damage to the skin.

It has been suggested that blunt trauma alone can result in osseous sequestration, and sequestration in these instances is a result of soft-tissue damage that allows bacterial invasion through the skin or hematogenously.^{1,2} Hematogenous bacterial invasion may play a greater role in development of osseous infections in mature cattle than in mature horses.⁷ In the present

study, 10 animals had sequestra that were not obviously associated with an open wound, and 9 of these 10 had a stress fracture involving the affected bone. Most sequestra in this study involved the third metatarsal or third metacarpal bone, and it has been well-documented that sequestra are more likely to develop in locations with little soft-tissue covering.^{2,5,10-12}

Intermittent lameness or lameness that increases in severity over time is a common clinical finding in horses and cattle with osseous sequestration involving a long bone.^{1,2} In the present study, 77 (70%) animals were lame at the time of admission to the veterinary teaching hospital. However, it was not possible to determine whether lameness was attributable to the initial injury or developed as a result of osseous sequestration. Lameness was a consistent finding in animals with sequestration of the distal phalanx. A concomitant musculoskeletal or systemic abnormality was identified in 13 (11.8%) cattle, which was not surprising in that cattle often develop secondary illnesses as a consequence of painful musculoskeletal conditions, especially those that result in lameness or recumbency.

Unlike previous studies, a large percentage of sequestra in the present study involved the distal phalanx. Sequestration of the distal phalanx may still have been underrepresented, because such cattle are often treated during a physical examination, and a surgery report is not filed in the medical record. Nine of the 16 distal phalanx sequestra involved the lateral claws of the hind limb. This is the most common site for any lesion associated with lameness in cattle,^{13,14} and distal phalanx sequestra were often found in association with other pathologic conditions such as sole ulceration, white line disease, toe ulceration, double sole, and sole trauma associated with foreign body penetration. Osseous sequestration resulting from pedal osteitis or osteitis of the third phalanx in cattle has not been well described.

Ineffective or temporary improvement in clinical signs following conservative medical treatment with antimicrobial agents was a common historical finding. Most of these animals were treated in the field without knowledge of the presence of a sequestrum. This was reflected by the small number of animals for which radiographs of the affected area were obtained prior to admission and stresses the need for radiographic evaluation of draining nonhealing wounds in cattle.

Radiography can be used to confirm a diagnosis of osseous sequestration. In the present study, radiography accurately identified sequestra in all anatomic locations, except the distal phalanx. Although the digital portion of the limb is the most frequently radiographed area in cattle, many factors can adversely affect imaging of the bovine digit and, thus, make radiographic interpretation difficult. Artifacts created by dirt, debris, topically applied medications, and hoof defects associated with trimming, gas densities, vascular channels, and overlapping of bones and joints can complicate diagnosis of distal phalangeal sequestration. Thorough cleaning of the hoof wall and sole as well as filling in solar defects with a material of soft-tissue radiographic opacity will help eliminate radiographic artifacts. Results of the present study suggest that multiple projections should be obtained to detect sequestra of the distal phalanx in animals in which sequestration is suspected but not evident on routine survey radiographs.

Results of bacterial culture in the present study yielded an overall impression of the types of bacteria involved in osseous sequestration in cattle. However, these results should not be overinterpreted, because consistent bacterial culture techniques were not used. Nevertheless, bacterial culture yielded 13 species of aerobic bacteria and 3 species of anaerobic bacteria. In general, bacteria were representative of bacteria in the environment of cattle. Anaerobic isolates were always cultured together with aerobic isolates, and mixed populations of bacteria are commonly cultured from sequestra.^{2,10} *Actinomyces pyogenes* was the most common isolate in this study and in a previous study of cattle with hematogenous osteomyelitis.⁷ In contrast, *Salmonella* spp was not isolated from any of the cattle in the present study.

Successful medical treatment of horses and cattle with small sequestra has been well-documented.^{1,2,7} However, the maximum size of sequestra that can be treated medically has not been determined. In the present study, the largest sequestrum among cattle treated medically that did not respond to treatment was approximately 2 cm². According to a follow-up interview with the owner, this animal was culled after discharge from the hospital because of persistent lameness, decreased milk production, and delayed wound healing. Most animals that were treated medically were treated within 10 days after the inciting injury. This suggests that prompt antimicrobial treatment and wound management is beneficial, because it may help decrease the size of impending sequestra by reducing the extent of soft-tissue compromise and bacterial load. Although medical treatment was considered successful in a few animals in the present study, most of these animals required prolonged antimicrobial treatment and a lengthy hospital stay, compared with animals that were treated surgically.

In previous reports,^{1,2,6,10,15-18} sequestrectomy was suggested to be the treatment of choice for sequestra in horses and ruminants. Perineural, local regional, or intravenous regional anesthesia is more likely to be used in cattle undergoing sequestrectomy because of the ability to provide good restraint and reduce costs

associated with surgery. This technique has been recommended for removal of simple, early, or small sequestra in cattle.¹⁹ In the present study, however, we found that cattle undergoing sequestrectomy with these methods of anesthesia were more likely to require a second surgical procedure, compared with cattle undergoing sequestrectomy with general anesthesia. With perineural, local regional, or intravenous regional anesthesia, surgical exposure can be inadequate, and excessive hemorrhage makes it difficult to identify and retrieve sequestra that are small or deeply embedded in fibrous tissue and periosteal new bone. In particular, extracting sequestra from the distal phalanx can often be an arduous endeavor and may require more aggressive debridement and curettage than extracting sequestra from other anatomic locations.

Another factor that may influence the need for multiple surgical procedures is the lack of radiographic evaluation during surgery. In cattle in which general anesthesia was not used, radiographs of only 4 of 30 (13%) lesions were obtained during surgery. In most instances, it was unclear why clinicians did not have intraoperative radiographs taken; however, economic considerations may have played a role. Placement of radiopaque markers to more precisely determine the location of sequestra is advantageous whenever it appears that surgical removal will be difficult. This will ensure that all fragments are removed and allow for better assessment of the remaining parent bone. Costs may be reduced in the long run by decreasing the need for additional surgical procedures.

In the present study, primary closure of surgically created wounds resulted in few incisional complications, compared with wounds that were partially closed or left to heal by second intention. It could not be determined from the medical records whether primary closure resulted in significantly faster healing times. Wounds that were partially closed had a higher rate of dehiscence than did wounds that were completely closed, which was similar to results of a study of horses treated for osseous sequestration.²

In most animals in the present study, some form of external coaptation was used during the postoperative period. Compression bandages were used more frequently than fiberglass casts, because in most animals, cortical defects were not large enough to compromise the strength of the bone. In the past, use of casts following sequestrectomy has been advocated whenever large cortical defects could result in pathologic fracture.²⁰ In the present study, more casts were applied for this reason than were applied to animals in which a stress fracture of the affected bone was identified. Furthermore, catastrophic failure was not reported as a complication in any animal in this study. It has been theorized that in most instances, periosteal new bone and adjacent sclerotic bone that make up the involucrum behave biomechanically like a callus, providing sufficient strength to resist normal forces encountered in the limb.¹⁹ The use of a wooden foot block was effective in most cases for providing relief from weight bearing by the affected claw.

Follow-up information was available for 65 animals treated surgically and 6 animals treated medically.

Fifty-one (78%) of the animals treated surgically and 5 of the animals treated medically had a successful outcome. Persistent moderate to severe lameness affecting production was the most common reason given by owners and herdsmen for culling animals in which outcome was unsuccessful, suggesting that lameness after sequestrectomy may indicate a poor prognosis for return to production.

^aPROC FREQ, SAS Institute Inc, Cary, NC.

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