Femoral fractures are often catastrophic injuries in large animals. Although sporadic, femoral fractures were reported to be the most common long bone fracture in 32% (68/213) of cattle and 16.5% (19/115) of horses. Clinical findings associated with femoral fracture include swelling, crepitus, and rotational instability but these can be obscured by the large overlying muscle mass of the upper hind limb in horses and cattle, especially in adult patients. In immature animals, capital physeal fractures occur with some frequency but less consistently produce swelling or other localizing clinical signs, and definitive diagnosis in suspect cases requires differentiation from other coxofemoral injuries.

Definitive diagnosis of femoral fractures has traditionally relied on radiography. Radiography of the femur and coxofemoral region in large animals generally requires transportation to a referral hospital equipped with a ceiling mounted system. Acquisition is time and personnel intensive, yielding high radiation exposure and possible fracture displacement during anesthetic recovery. Fractures involving the proximal femur and mid-diaphysis pose additional diagnostic challenges in mature large animals due to the femur’s proximity to the pelvis and extent of regional muscle mass that limits accessibility of radiographic equipment. Ventrodorsal projections with the patient in dorsal recumbency are ideal to visualize the proximal two-thirds of the femur.
the femur and coxofemoral joint in horses and cattle but require general anesthesia or heavy sedation and a high output generator in a hospital setting. Standing oblique radiographic projections of the coxofemoral joint and pelvis have been described in cattle and horses, but did not detect femoral fractures in either study despite use of appropriate radiographic equipment in a hospital environment.

Regardless of fracture location, the vast majority of reported cases are young animals < 1 year of age. Although the capital physeal fractures are most often reported in animals ≤ 1 year of age, often secondary to trauma (kicks, falls, or limb entrapment) in foals, forced extraction during dystocia in calves, or aggressive behaviors in young bulls housed together. Diaphyseal and distal physeal fractures are also more frequently reported in immature horses and cattle, including 1 study in which 20 of 26 affected cattle were < 2 months old and the remaining 6 cattle ranged from 7 to 102 months of age (median, 25 months). Various surgical and conservative treatments have been described in young animals, but euthanasia is generally recommended in horses weighing > 200 kg and cattle weighing > 300 kg. Descriptions of femoral fractures in mature horses and cattle are infrequent and primarily limited to textbooks and case reports, including one 18-year-old Warmblood stallion with a pathologic fracture secondary to hemangiosarcoma.

In contrast to radiography, ultrasonography is widely available to ambulatory and hospital-based veterinarians, yields limited to no exposure risks to personnel, and can be performed in standing and recumbent patients. Ultrasonography has been increasingly used to diagnose equine pelvic fractures and is recommended as the initial imaging modality in suspect equine cases on the basis of reasonable agreement with radiography. Ultrasonography has been used to diagnose fractures of the femoral third trochanter in horses, but its use to detect more catastrophic femoral fractures appears to be limited to 1 horse with an apophyseal fracture of the greater trochanter and 2 horses with femoral neck fractures. In cattle, ultrasonography has been used to diagnose coxofemoral luxations in calves, but reports describing ultrasonographic diagnosis of femoral fractures were not found.

The severity of clinical signs associated with acute upper hind limb injuries often creates a highly charged setting for owners and clinicians alike, made even worse by the relatively poor prognosis associated with many femoral fractures. Because many injuries can create similar clinical signs in the acute phase, fracture localization and differentiation from other less catastrophic injuries are important for prognostication and decision-making. The purpose of this study was to document the use of ultrasonography to provide a definitive diagnosis of femoral fracture in large animals with severe acute upper hind limb lameness.

**Materials and Methods**

Medical records were reviewed of large animal patients that underwent ultrasonographic evaluation of the femoropelvic region by experienced large animal ultrasonographers from the William R Pritchard Veterinary Medical Teaching Hospital at the University of California-Davis School of Veterinary Medicine between January 1, 2000, and December 31, 2019. All animals with ultrasonographic evidence of femoral fracture were considered with the exception of horses with third trochanter fractures, as these have been reported elsewhere. Information collected from the medical record included signalment, historical and clinical features, imaging, outcome, and postmortem findings.

Ultrasonographic examinations were performed with a console or portable ultrasound machine, depending on availability at the time of presentation, equipped with a low frequency (2.5-5.0 MHz) curvilinear transducer. The hair was clipped with No. 40 blades, the skin was washed with soap and water, and ultrasound coupling gel was applied. The pelvis and coxofemoral joint were evaluated by use of previously described techniques. The femur was evaluated transcutaneously from the greater trochanter to the stifle joint, including transverse and longitudinal views (Figure 1). Femurs were consid-
ered fractured if bony incongruities were identified at any location along the femur. Abnormal findings included step defects, evidence of comminution (ultrasonographic visibility of multiple bone fragments) or motion of fractured bone ends during limb manipulation or voluntary weight shifting by the patient. Wherever possible, fracture lines were followed circumferentially from their cranial visible extent(s), along the lateral aspect of the femur, and then caudally and caudomedially as far as anatomically possible. Medial views were performed of the distal femur when tolerated by the patient or deemed safe to perform on the basis of species and individual temperament considerations. Ultrasonographic evidence of hemorrhage or muscle tearing was also recorded.

Results

Over the 20-year study period, 12 large animal patients, including 6 horses, 5 cattle, and 1 adult elephant, showed ultrasonographic evidence of femoral fracture. All cases were identified from 2010 to 2019. Five of 12 cases were ≤ 1 year of age. The remaining 7 cases ranged in age from 2 to 33 years (median, 13 years). In all patients, ultrasonography was the initial imaging modality to identify femoral fracture. Individual case details are summarized (Supplementary Table S1).

Cases were presented to our hospital from 6 hours to 30 days (median, 2 days) after the onset of clinical signs. Eight animals were presented within 48 hours and the remaining 4 cases were presented at 5, 10, 14, and 30 days after the development of clinical signs. All cases were either non–weight-bearing or toe-touching lame on the affected limb at the time of presentation. Two cattle arrived recumbent and were unable to rise. The left hind limb was affected in 9 animals and the right hind limb in 3 animals. Limb swelling was identified in 10 patients, recorded as severe diffuse femoral swelling (3 horses and 1 steer), mild femoral swelling (1 horse), regional stifle swelling (1 horse), distal femoral swelling (1 cow), swelling of the gluteal and thigh region (1 cow), regional swelling (1 elephant), and swelling from the stifle to the tarsus (1 cow). Crepitus was palpated in 3 cases and thought to have originated from the pelvis in one horse, the stifle in another horse, and upper limb in a cow during external and rectal palpation. In the elephant, a subtle variation in limb position during ambulation heightened clinical suspicion for femoral fracture; however, onsite veterinarians had initially suspected stifle injury. No case demonstrated an overtly abnormal limb position or obvious deviation of the bony column to yield a definitive diagnosis of femoral fracture prior to imaging studies.

Horses included 4 adults, ranging from 7 to 22 years (median, 17 years) and weighing 368 to 626 kg (median, 590 kg), and 2 juveniles, an 8-month-old Paint filly (weight, 246 kg) and a 6-month-old Quarter Horse colt (estimated weight, 200 kg). Adult horses included a 22-year-old Quarter Horse mare (general purpose), 21-year-old Thoroughbred gelding (dressage), 7-year-old Pinto mare (use not listed), and 13-year-old Thoroughbred breeding stallion. Three horses had a history of falling, including the filly that got its limb caught in a gate 30 days before presentation, 1 adult that slipped in mud and fell onto its affected side, and the colt that flipped over backward while being trimmed by a farrier. Another horse had been wearing an ipsilateral full limb cast for 30 days as treatment for tarsometatarsal luxation when it showed acute worsening of lameness after a suspected fall. The Quarter Horse mare caught its left hind limb in a fence 14 days prior to presentation. Although the owners reported no significant issues at that time, the horse developed signs interpreted as colic on the day of presentation after it was frightened by fireworks and ran around its pasture. Colic examination at our hospital was unremarkable, after which a left hind limb lameness was noted and deemed to be the source of the horse’s discomfort. The breeding stallion was found acutely lame at pasture without any witnessed incident.

Bovine patients included a 5-year-old Jersey cow at 260 days of lactation that was found lame with regional swelling on the day of presentation. The second bovine was a 2-year-old Shorthorn first-calf heifer unable to rise after its calf was pulled because of dystocia earlier in the day. The third bovine was a 6-month-old Maine Anjou heifer found to be non–weight-bearing lame after it was suspected to have caught the limb in a gate 5 days earlier. The fourth was a yearling Charolais heifer that was found down in mud on the day of presentation. The heifer was able to walk onto the trailer but went down again and was unable to rise on presentation. The fifth bovine was a 10-month-old Angus steer whose limb was accidentally run over by an all-terrain vehicle after the steer escaped from its pasture. Bovine patients weighed from 261 to 557 kg (median, 390 kg).

The elephant was a 33-year-old female Asian elephant that underwent ultrasonographic examination of the femur 10 days after a fall that resulted in regional swelling and severe right hind limb lameness.

Ultrasonographic findings

Ultrasonographic examinations were performed in the patient’s stall or stall-side in all adult horses due to lack of patient mobility and severe pain. In horses with comminuted diaphyseal fractures, examinations were technically challenging due to patient distress, frequent movement, and weight shifting. Ultrasonography was accomplished in 1 horse while it was supported in a sling to assist with standing. The filly and colt with capital physeal fractures were comparatively less painful and could be walked to the ultrasound examination room. Ultrasonographic examinations were performed in recumbency in both cattle that were down upon arrival and in the 6-month-old calf. Ultrasonography was performed in 1 juvenile and 1 adult bovine while they were standing in stocks. In the elephant, ultrasound was performed in the standing position at its normal off-site housing facility.

Ultrasonographic evidence of comminuted diaphyseal fractures was found in 6 patients, including
3 adult horses, 2 cattle, and the elephant. Findings included multiple step defects and hyperechoic bone fragments visible throughout the femoral diaphyseal region (Figure 2). Movement of fragments was detected as the patient shifted its weight between hind limbs or during gentle limb manipulation in the equine and bovine patients. Simultaneous crepitus during ultrasonography was not palpable or audible in any of the cases with comminuted fractures.

Ultrasonographic evidence of greater trochanteric fracture was identified in 1 adult horse and the first calf heifer. In both cases, longitudinal views of the femur facilitated sonographic fracture configuration. The fracture line was visible as a gap or step defect near the greater trochanter which could be followed as the transducer was moved semicircumferentially from the cranial, lateral, caudal, and caudomedial aspects of the femur (Figure 3).

Figure 2—Ultrasonographic image (A) from a 7-year-old Pinto mare showing a large step defect (arrow) distal to the third trochanter with associated hemorrhage (arrowheads). Multiple step defects were visible on other views, consistent with comminuted fracture. Proximal is to the right. Transducer placement (B) used to obtain the longitudinal ultrasonographic image shown in panel A. This image was created from a 3-D model based on the horse’s postmortem specimen (C).

Additional ultrasonographic findings included regional hemorrhage or evidence of muscle tearing in 4 horses and 4 cattle. Hemorrhage was not seen in horses with capital physeal fractures or in the elephant whose skin thickness dramatically compromised soft tissue image quality. The presence of hemorrhage was not recorded in 1 bovine.

Radiographic findings
Upper limb radiography was performed in the standing position in 8 of 12 cases (4 horses, 3 cattle, and 1 elephant). Of these, stifle radiography was performed in 5 cases, including 3 horses and 2 cattle. Two of these horses also underwent attempts at radiography of the proximal/mid femur that was either negative or nondiagnostic. Standing ultrasonographic evidence of capital physeal fracture was found in both juvenile horses during evaluation of the coxofemoral joint. In both cases, the femoral head was visible in its normal location within the acetabulum; however, a large gap could be detected at the capital physis between the femoral head and neck. Additionally, the greater trochanter and femoral neck showed dorsal displacement relative to the acetabulum (Figure 4). Coxofemoral joint effusion and synovitis were visible in both cases.

Figure 3—A—Ultrasonographic image from a 22-year-old Quarter Horse mare with a greater trochanter fracture. A step defect (arrow) and regional hemorrhage (arrowheads) are visible proximal to the third trochanter (not shown in this image). A continuous step defect was visible along the cranial, lateral, and caudal aspects of the femur that aided in antemortem fracture configuration. Proximal is to the right. B—Transducer placement used to obtain the longitudinal ultrasonographic image shown in panel A. This image was created from a 3-D model based on the horse’s postmortem specimen.

Figure 4—Transducer placements (upper left panel) to obtain transverse ultrasonographic images of the cranial (A), craniodorsal (B), and dorsal (C) surfaces of the coxofemoral joint in an 8-month-old Paint filly with a capital physeal fracture. A—Ultrasonographic image of the cranial surfaces obtained with transducer placement A shows the femoral head (FH) within the acetabulum (AC) and a large step defect between the FH and femoral neck (FN). B—Ultrasonographic image of the craniodorsal joint obtained with transducer placement B reveals dorsal displacement of the FN and greater trochanter (GT) relative to the AC. C—Ultrasonographic image of the dorsal joint surfaces obtained with transducer placement C demonstrates dorsal displacement of the GT relative to the AC. The FH is not visible in either panel B or C. IB = ilial body.
Radiography was able to detect evidence of femoral fracture in only 2 of 8 cases, both cattle with distal femoral fractures (Figure 5). These were described as a comminuted Salter-Harris type IV fracture in the yearling Charolais heifer and included medial and lateral femoral condylar fractures in the 5-year-old cow. In both cases, radiography was performed after ultrasonographic detection of femoral fracture in an effort to further characterize fracture configuration. In the remaining cases, standing radiography was unremarkable in the third horse. Radiography was limited to the tibia in 1 cow. Radiography was attempted in the elephant by the referring veterinarian and was reported to be nondiagnostic. The type and number of radiographic projections were highly variable between cases due to many factors, including overall tolerance, pain level, limb stability, patient size, and safety concerns.

Ventrodorsal radiographic projections were only obtained in 1 case, the Quarter Horse colt. Standing radiographic projections had been acquired at the time of presentation but were interpreted as negative. Ultrasonography was performed the following day and showed evidence of capital physeal fracture. Although ultrasonography was considered diagnostic, ventrodorsal radiographic projections under general anesthesia were subsequently performed to further characterize fracture configuration for the purpose of potential surgical repair. These projections confirmed the ultrasonographic diagnosis and revealed additional comminution of the capital physeal fracture than was visible ultrasonographically (Figure 6).

Radiography was not performed in 2 horses (the filly and breeding stallion) and in 2 cattle due to patient size, limited mobility that precluded movement to the radiology suite, or convincing ultrasonographic findings.

**Outcome and postmortem findings**

Treatment was not attempted in any case due to grave prognosis, lack of viable surgical or nonsurgical options, financial limitations, or owner preference. All patients were euthanized with the exception of 1 bovine with a comminuted mid-diaphyseal fracture that was slaughtered after discharge. Ten patients were euthanized within 24 hours of ultrasonographic diagnosis and 1 was euthanized 6 days later. Ten of 11 euthanized animals were subjected to necropsy examination, which confirmed femoral fractures in all cases. In the 5 euthanized cases with comminuted fractures, necropsy revealed the degree of comminution to be greater than that visualized ultrasonographically. In the breeding stallion with a severely comminuted proximal/mid-diaphyseal fracture, necropsy also revealed an oblique spiral fracture of the distal half of the femur. This fracture was suspected to have occurred during euthanasia when a loud crack was heard as the horse went down. No additional findings were found in the filly with the capital physeal fracture or the horse with the greater trochanteric fracture; however, ventrolateral luxation of the coxofemoral joint was noted in the cow with the greater trochanteric fracture despite a normal ultrasonographic appearance of the joint 1 day prior. Necropsy findings in the 2 cattle with distal femoral fractures included a slab fracture of the medial femoral condyle in one bovine in addition to the lateral condylar fracture seen ultrasonographically and, in the other bovine, comminuted supracondylar and intercondylar articular fractures of the distal femur consistent with Salter-Harris type IV and III physeal fractures. Regional hemorrhage and

**Figure 5**—Radiographs showing distal femoral fractures in 2 bovines. A—Caudocranial projection of the distal femur/stifle in a yearling Charolais heifer reveals a comminuted fracture of the distal femoral physis (arrows) consistent with a Salter-Harris type IV fracture. B—Lateromedial projection of the distal femur/stifle in a 5-year-old Jersey cow with a comminuted femoral condylar fracture (arrows). This projection shows some proximodistal obliquity as a result of the patient’s abnormal limb position and non-weight-bearing status.

**Figure 6**—Ventrodorsal radiographic projections of a 6-month-old Quarter Horse colt obtained under general anesthesia to further characterize the capital physeal fracture visualized ultrasonographically. Radiography was able to assess the degree of comminution by use of both frog-leg (A) and extended limb (B) projections. The capital physeal fracture is visible in both views (arrows) but becomes increasingly displaced with extended limb projections. A fragment (arrowhead) is seen cranial to the joint in the frog-leg projection (A).
edema were noted in all cases except the filly with the capital physeal fracture. Radiographic confirmation of the capital physeal fracture in the euthanized colt was deemed sufficient by the owner, and necropsy was subsequently declined.

Postmortem radiography and CT were performed on both ex vivo femurs from the elephant to rule out preexisting disease that may have led to fracture. Bone density was deemed consistent between femurs and also when compared to CT images of the elephant’s left humerus. No evidence of underlying infectious or neoplastic pathology was noted on gross or histopathologic examination of regional tissues that could have contributed to long bone fracture. Postmortem radiography was also performed on both femurs from the Thoroughbred breeding stallion, and no evidence of osteoporosis or other predisposing osseous pathology was identified.

Discussion

Ultrasonography was the lone imaging modality used for antemortem diagnosis of femoral fractures in 75% (9/12) of cases of this report and was the initial imaging modality utilized in 100% (12/12) of cases. Ultrasonographic examinations were requested on the basis of historical and clinical features suggestive of pelvic or proximal hind limb fracture. None of our cases showed obvious femoral deviation for which physical examination could have been considered sufficient for diagnosis. This preferential use of ultrasonography reflects our hospital’s reliance on ultrasound to diagnose upper limb and pelvic injuries in large animal patients with severe acute hind limb lameness. Ultrasonography was not considered in any injections were negative despite the young age of the general anesthesia after standing radiographic procedures. Finally, we should highlight that radiographic confirmation of 1 capital physeal fracture was confirmed by means of stifle radiography in the 2 patients with distal femoral fractures. Both were cattle (1 and 5 years old), and ultrasonographic findings helped to justify the efforts necessary to pursue radiography and better characterize fracture configuration. Radiography was limited to the stifle in 2 of 4 radiographed horses and was negative because no horse sustained a distal femoral fracture. Radiography of the proximal mid femoral regions in 2 adult horses was either negative or nondiagnostic due to poor image quality. Standing radiographic projections (50° cranial and 30° lateral to caudomedial oblique) have been reported to detect third trochanter fractures in horses and may provide limited visualization of the proximal and mid-diaphyseal regions of the femur. While not attempted in our patients, feasibility of this projection remains questionable given the frequent and sometimes continuous movement that our patients exhibited due to limb instability, pain, and distress. It should also be noted that radiographs were often obtained in stalls with portable equipment less likely to yield sufficient penetration. Radiography was not attempted in the 2 remaining bovines due to the convincing nature of ultrasonographic findings and desire to not move the patient to the radiology suite. Finally, we should highlight that radiographic confirmation of 1 capital physeal fracture required ventrodorsal projections under general anesthesia after standing radiographic projections were negative despite the young age of the colt. Nuclear scintigraphy was not considered in any equine due to constant weight shifting or in the cat-
Treatment was not elected in any of our cases due to poor prognosis, patient size, or age. Prognosis for long bone fractures is generally better for immature horses and cattle due to their smaller size and weight, improved bone healing, and open physeal growth plates that can counteract femoral shortening from overriding of fractured ends in cases managed conservatively.\textsuperscript{7,13,14} While 5 of 12 cases were ≤ 1 year of age in our study, these included juvenile horses with capital physeal fractures and 3 bovines with comminuted mid-diaphyseal and distal physeal fractures. Equine studies highlight the poor prognosis that accompanies femoral fractures in horses, even in foals < 1 year of age with capital physeal fractures.\textsuperscript{4} Reports of successfully repaired diaphyseal or physeal fractures are also primarily limited to foals < 1 year of age.\textsuperscript{7,11,16} All 4 adult horses in our study were full-size, and 3 had severely comminuted diaphyseal fractures that were not amenable to repair. In bovine diaphyseal fractures, survival has been associated with preoperative ambulatory status and fracture location.\textsuperscript{12} That study\textsuperscript{12} reported improved survival of cattle with repaired mid-diaphyseal fractures (5/9 survivors) versus those with distal diaphyseal fractures (0/6 survivors). In our 2 cattle with diaphyseal fractures, radiography would have been helpful to differentiate between mid and distal diaphyseal involvement; however, neither case was ambulatory, nor was surgical repair a consideration. While successful conservative management has been reported in 50% of calves (4/8; 1 to 8 months old) with proximal femoral fractures, only 2 of 6 calves treated conservatively for distal femoral fractures in the same study survived.\textsuperscript{16} Conservative management was not considered in our similarly affected bovine patients. Although we had no capital physeal fractures in cattle, prognosis is improved for calves < 12 months with surgically repaired capital physeal fractures compared with older calves.\textsuperscript{5} However, another study\textsuperscript{6} reported 14 of 20 slightly older dairy bulls (11 to 27 months old) to have positive outcomes after surgical repair of capital physeal fractures.

Study limitations include the low number of affected animals despite a 20-year study period. Femoral fractures represented < 1% of femoropelvic ultrasonographic examinations performed during this time. The clustering of cases in the latter half of the study can be explained by the increasing acceptance of ultrasonography to diagnose upper limb fractures in large animals at our hospital. It should be noted that additional large animal patients were diagnosed with femoral fractures during this time frame but did not undergo ultrasonographic examination due to the convincing nature of clinical findings. However, no large animal patient was later diagnosed with femoral fracture after a negative ultrasonographic examination. While ultrasonography was useful to detect evidence of fracture, it was unable to precisely configure comminuted fractures, as would be expected, and underestimated the degree of comminution compared with necropsy findings. This was not surprising given the large number of fragments in these cases that would have similarly complicated radiographic configuration. Regardless, it is doubtful that precise configuration of comminuted fractures in these animals would have significantly altered outcome. Lastly, radiography was not performed in all cases and radiographic projections obtained were variable between patients, resulting in inconsistent and limited evaluation of the femur.

In summary, ultrasonography is useful to diagnose femoral fractures in large animal patients with severe acute lameness, especially when radiography is not feasible or unlikely to produce diagnostic images. Similar to previous reports, femoral fractures had a poor prognosis in our study, emphasizing the need for differentiation between potentially less catastrophic injuries that can produce similar clinical signs in the acute injury phase. As low-frequency curvilinear transducers become more commonplace in large animal practice, ultrasonographic evaluation in suspect cases may reduce the need for transportation to referral hospitals or facilitate prompt referral if surgical repair is a consideration. Image acquisition and interpretation require some experience with ultrasonography of long bones, including knowledge of normal findings and interspecies anatomic variations.

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References


**Supplementary Material**

Supplementary materials are posted online at the journal website: avmajournals.avma.org