A 1-month-old 64-kg (141-lb) mixed-breed bull calf (patient 1) was examined because of a congenital limb deformity. The only remarkable finding during physical examination was a severe varus deformity of the metatarsophalangeal region of the right pelvic limb. The calf walked on the abaxial aspect of the lateral claw of the affected limb. Evaluation of dorsoplantar radiographic images of the affected limb confirmed the presence of a 21° varus deformity of the metatarsophalangeal region that was characterized by medial subluxation of P1 of digits 3 and 4 at the metatarsophalangeal joints. No other radiographic abnormalities were noted.

Owing to the severity of the varus deformity, it was likely that if left untreated the calf would develop severe gait abnormalities and trauma to the affected limb, resulting in poor weight gain and welfare. Surgical correction with a closing wedge ostectomy with transfixation pin–cast stabilization was recommended to and elected by the owner. An appropriately sized wedge needed to be removed from the lateral aspect of the limb to correct the varus deformity. Because the angulation was centered at the distal metatarsal epiphysis and metatarsophalangeal joints, it was decided to remove a wedge proximal to the horizontal plane for the medial metatarsophalangeal joint deviated from that for the lateral metatarsophalangeal joint, the deviation was halved to approximate the mean location of the horizontal plane for both joints. Two additional lines were drawn (one perpendicular to the line representing the horizontal plane of the distal tarsometatarsal joint and the other perpendicular to the line representing the horizontal plane of the metatarsophalangeal joints) along the midsagittal plane of the respective joints. Those 2 lines were extended until they intersected, and the acute angle at that intersection was measured and recorded as the degree of angulation (Figure 1).

Case Description

4 calves were evaluated because of lameness and an angular limb deformity of the metatarsophalangeal region.

Clinical Findings

3 calves (ages, 5 days, 10 days, and 1 month) had a congenital varus deformity of the metatarsophalangeal region characterized by medial subluxation of the first phalanx of digits 3 and 4 at the metatarsophalangeal joints. A 6-month-old heifer had a valgus deformity of the metatarsophalangeal region secondary to a malunion of a Salter-Harris type II fracture. The degree of deformity angulation ranged from 16° to 54° for the 4 patients.

Treatment and Outcome

A closing wedge ostectomy with transfixation pin–cast application was performed on the affected limb of all 4 patients. The ostectomy healed with only minor complications (disuse osteopenia distal to the transfixation pins [n = 4] and cast sores [1]) that were easily resolved with no long-term adverse effects. Duration of follow-up for the 4 patients ranged from 6 to 17 months, and the owners reported satisfactory ambulation with no (n = 2) or only mild (2) residual lameness in the affected limb.

Clinical Relevance

Results suggested that a closing wedge ostectomy with transfixation pin–cast stabilization is an alternative for management of angular limb deformities of the metatarsophalangeal region in cattle. Such treatment improved the quality of life for all 4 patients. However, 2 of the 4 patients had congenital deformities confirmed to be heritable. There are ethical concerns associated with treating animals with heritable disorders, and exhibition and breeding of such animals should be avoided. (J Am Vet Med Assoc 2019;255:1047–1056)
distal physis of the fused metatarsal 3 and 4 bones (ie, cannon bone). This would create a slightly divergent metatarsus but allow the patient to bear weight perpendicular to the metatarsophalangeal joint surface.

For surgical planning, the size of the wedge to be removed was calculated from measurements obtained from dorsoplantar radiographs by use of digital imaging software. Two lines were drawn that diverged at the degree of angulation. The first line was drawn parallel and just proximal to the distal physis of the cannon bone. The second line was drawn beginning at the endpoint of the first line at the medial cortex of the cannon bone and diverged from the first line at 21° (ie, the degree of angulation) in a proximolateral direction to the lateral cortex of the cannon bone. A third line was drawn connecting the endpoints of the other 2 lines. This created a triangle that approximated the size and location of the wedge to be removed from the lateral aspect of the cannon bone, with the length of the third line (1.5 cm) representing the length by which the lateral aspect of the cannon bone was to be shortened (Fig).

Figure 1—Dorsoplantar radiographic images of the metatarsophalangeal region of the right pelvic limb of a 1-month-old 64-kg (141-lb) mixed-breed bull calf (patient 1) before (A and B) and after (C) a closing wedge ostectomy with transfixation pin–cast stabilization was performed to correct an approximately 21° varus deformity centered at the metatarsophalangeal joint. A—To determine the extent of deformity angulation, a line was drawn through the horizontal plane of the distal tarsometatarsal joint. Another line was drawn at the approximate horizontal plane of both metatarsophalangeal joints; when the horizontal plane for the medial metatarsophalangeal joint deviated from that for the lateral metatarsophalangeal joint, the deviation was halved to approximate the mean location of the horizontal plane for both joints. Two additional lines were drawn (one perpendicular to the line representing the horizontal plane of the distal tarsometatarsal joint and the other perpendicular to the line representing the horizontal plane of the metatarsophalangeal joints) along the midsagittal plane of the respective joints. Those 2 lines were extended until they intersected, and the acute angle at that intersection was measured as the degree of angulation for the deformity. B—To estimate the size of the wedge to be removed, a line was drawn parallel and just proximal to the distal physis of the fused metatarsals 3 and 4 bones (cannon bone). A second line was drawn beginning at the end point of the first at the medial cortex of the cannon bone and diverged from the first line at 21° (ie, the degree of angulation) in a proximolateral direction to the lateral cortex of the cannon bone. A third line was drawn connecting the lateral end points of the other 2 lines. This created a triangle that approximated the size and location of the wedge to be removed from the lateral aspect of the cannon bone, with the length of the third line (1.5 cm) representing the length by which the lateral aspect of the cannon bone was to be shortened. C—Measurement of the degree of angulation following the closing wedge ostectomy revealed that the varus deformity had been substantially reduced to approximately 2°. Lateral is to the left in all images.
ure 1). For valgus deformities, the process for estimating the size and location of the wedge was the same except the medial and lateral endpoints of the lines were transposed because the wedge was removed from the medial aspect of the cannon bone.

Procaine penicillin G (22,000 U/kg [10,000 U/lb], IM), florfenicol (20 mg/kg [9 mg/lb], IM), and flunixin meglumine (1.1 mg/kg [0.5 mg/lb], IV) were administered to the calf 1 hour before anesthesia induction. A catheter was aseptically placed in the left jugular vein, and anesthesia was induced by IV administration of a mixture of ketamine (2 mg/kg [0.9 mg/lb]) and 5% guaifenesin (2 mL/kg). Following orotracheal intubation, anesthesia was maintained with isoflurane. The patient was positioned in left lateral recumbency. The right pelvic limb was aseptically prepared for surgery, and the patient was draped in a routine manner. A 6-cm longitudinal incision was made along the lateral aspect of the right cannon bone just proximal to the distal physis and extending proximally. The periosteum of the cannon bone was elevated with a periosteal elevator to the dorsal and plantar extents of the surgical field. The soft tissues on both sides of the incision were retracted and protected with Senn retractors. Then, an oscillating bone saw was used to remove the wedge of bone from the cannon bone. The first cut was made just proximal and parallel to the distal physis and extended through the entire cannon bone. The second cut was initiated on the lateral aspect of the cannon bone 1.5 cm proximal to the first cut. It was extended in a distomedial direction to intersect with the first cut at the medial cortex of the cannon bone. The wedge of bone was removed, and the ostectomy site was closed by rotating the distal portion of the limb to bring it into alignment and correct the varus deformity. The periosteum was closed with 2-0 polyglyconate suture in a simple continuous pattern. The subcutaneous tissue was apposed with 2-0 polypropylene suture in an interrupted horizontal mattress pattern.

A transfixation pin cast was applied to the right pelvic limb to stabilize the ostectomy site. A stab incision was made through the skin and soft tissues to the cannon bone 1.2 cm distal to the tarsometatarsal joint on the lateral aspect of the limb. A positive-profile centrally threaded fixation pin (shaft diameter, 3.2 mm; thread diameter, 4.8 mm) was transcortically inserted from lateral to medial through the cannon bone. Owing to the young age of the patient, the bone was deemed sufficiently soft to place the self-tapping pin without predrilling. Sterile saline (0.9% NaCl) solution was used to lavage the area and reduce thermal injury during drilling for pin placement. A second pin of the same size was placed in a similar manner 2 cm distal to and at 30° horizontally divergent from the first pin. The second pin was placed through the bone in a different horizontal plane relative to the first pin because such a construct has been shown to be stronger than constructs with both pins oriented in the same horizontal plane. Stockinette and cotton padding were placed over the affected limb and pins, and an extended half-limb cast was applied with 3-inch fiberglass cast material. The cast included the medial and lateral malleoli of the tibia and extended distally to the toes. The pins were incorporated into the cast as it was applied, and the cast was reinforced with polymethylmethacrylate where it engaged the pins and at its distal aspect. The patient received morphine (0.05 mg/kg [0.023 mg/lb], IM) for additional analgesia during surgery. The time required for the ostectomy and cast application was 65 minutes.

Evaluation of postoperative radiographs revealed that the ALD had been substantially reduced to a 2° varus deformity (Figure 1). The patient was able to bear weight on the affected limb immediately after surgery. The patient remained hospitalized for 2 weeks, during which time it appeared comfortable while standing and ambulating. The patient received procaine penicillin G (22,000 U/kg, IM, q 24 h) for 2 days after surgery and florfenicol (20 mg/kg, IM) on the second day after surgery. The calf continued to grow well, and 2 weeks after surgery, the cast was judged to be excessively tight and was changed. The calf was sedated with xylazine (0.1 mg/kg [0.045 mg/lb], IV), the cast was removed, and radiographs were obtained. Evaluation of the radiographs revealed an incompletely mineralized callus with periosteal and endosteal proliferation at the ostectomy site and moderate disuse osteopenia of all bones distal to the transfixation pins. The limb was gently manipulated, and the surgical site was determined to be sufficiently stable to sustain a greater load. The transfixation pins were removed on the basis of radiographic and clinical evidence of adequate healing. Because the pins were still firmly inserted in the bone, they had to be unscrewed from the bone for removal. An extended half-limb fiberglass cast was applied from the distal portion of the tibia to the tip of the toes.

The patient was discharged and returned to the hospital 2 weeks later for reevaluation. At that time, the calf was sedated with xylazine (0.1 mg/kg, IV) for cast removal and the acquisition of radiographs. Palpation and manipulation of the limb following cast removal indicated that the ostectomy site was stable. Evaluation of the radiographs revealed evidence of continued healing with bone proliferation within and around the ostectomy site in addition to persistent static osteopenia. The patient was sent home with no coaptation. The owner was contacted by telephone 17 months after the procedure was completed to obtain follow-up information. The owner reported that the patient performed satisfactorily as a feeder steer with only mild lameness evident at a walk until slaughter. The owner was very satisfied with the procedure, but only mild lameness evident at a walk until slaughter. The patient performed satisfactorily as a feeder steer with no evidence of joint on the lateral aspect of the limb. A positive-pro
tial limb deformity. Physical examination revealed flexural deformities of the metatarsophalangeal region of both pelvic limbs, with external rotation and a varus deformity centered at the metatarsophalangeal joint of the right pelvic limb and external rotation of the remaining 3 limbs. In both pelvic limbs, the deformity caused flexion of both the metatarsophalangeal and proximal interphalangeal joints, which was suggestive of superficial digital flexor tendon and joint capsule involvement. The calf walked on the abaxial aspect of the lateral claw of the right pelvic limb owing to the severity of the varus deformity but was able to walk on the solar surface of both claws of the left pelvic limb. No other remarkable abnormalities were identified during physical examination. Owing to the presence of multiple limb deformities, a CT evaluation of the distal aspect of both hind limbs was performed to better characterize the deformities. The varus deformity of the right pelvic limb was characterized by medial subluxation of P1 of digits 3 and 4 at the metatarsophalangeal joint. The degree of angulation was determined in the same manner as that described for patient 1 and was estimated to be 32°. Closing wedge ostectomy with transfixation pin–cast stabilization was recommended and performed. The size and location of the wedge to be removed from the cannon bone were determined as described for patient 1. It was estimated that 2 cm of bone would need to be removed from the lateral aspect of the cannon bone.

The procedure was performed 2 days after the initial physical examination. The patient received florfenicol (20 mg/kg, IM), potassium penicillin G (22,000 U/kg, IV), and flunixin meglumine (1.1 mg/kg, IV) 1 hour before surgery and morphine (0.05 mg/kg, IM) during surgery. Anesthesia was induced and maintained, the patient was positioned and aseptically prepared, and the closing wedge ostectomy was performed as described for patient 1. Two centimeters of bone were removed from the lateral aspect of the cannon bone. It was believed that this would reduce the varus deformity as well as the flexural deformity because removal of the wedge of bone would shorten the limb slightly. The congenital defects in the other limbs were not addressed at that time because it was believed the calf would not recover well from bilateral surgical procedures.

A transfixation pin cast was applied to the right pelvic limb to stabilize the ostectomy site in a manner similar to that described for patient 1. The proximal pin was placed 1.2 cm distal to the tarsometatarsal joint, and the distal pin was placed 1.5 cm distal to the proximal pin. The time required for the ostectomy and cast application was 135 minutes.

Postoperative radiographs were obtained and evaluated. The closing wedge ostectomy reduced the varus deformity to 9°. The patient received a second dose of potassium penicillin G (22,000 U/kg, IV) 6 hours after the first. The patient remained hospitalized for 3 days after surgery and was able to bear weight and ambulate well on the right pelvic limb for that duration. A recheck examination was performed 2 weeks after surgery. The calf was sedated with xylazine (0.1 mg/kg, IV) and ketamine (2 mg/kg, IV) for cast removal. The transfixation pins remained firmly seated in the cortical bone and could not be manipulated by hand. The ostectomy site was stable, and palpation revealed a firm swelling over the site, which was presumed to be callus. Because the pins were stable within the bone, they were left in place and a new fiberglass cast was applied as previously described.

The patient was reevaluated 3 weeks later (5 weeks after surgery). The calf was sedated with xylazine (0.1 mg/kg, IV) and ketamine (3 mg/kg [1.4 mg/lb], IV) for cast removal and the acquisition of radiographs. The ostectomy site was stable during palpation and manipulation of the metatarsal region following removal of the cast. Radiographic evaluation revealed osseous proliferation around the ostectomy site and moderate osteopenia in all bones distal to the transfixation pins. The pins were removed, and an extended half-limb fiberglass cast was applied as described for patient 1.

The patient was reevaluated 4 weeks later (9 weeks after surgery) and sedated with xylazine (0.1 mg/kg, IV) and ketamine (1.5 mg/kg [0.7 mg/lb], IV) for cast removal and radiograph acquisition. The ostectomy site was palpably stable following removal of the cast. Radiographic evaluation revealed osseous callus formation at the ostectomy site and resolution of osteopenia in the bones distal to the transfixation pins sites. A splint was applied to the right pelvic limb to provide continued support to the ostectomy site for an additional 3 weeks.

The patient was reevaluated 10 months after the procedure. The owner indicated that the calf was performing satisfactorily as a pet but was smaller than similarly aged cohorts. The calf was not visibly lame on the right pelvic limb, and both claws of that limb were oriented correctly and appeared to be bearing weight equally. However, the flexural deformities of the metatarsophalangeal joints persisted in both pelvic limbs, and there was external rotation of all 3 limbs that were not surgically treated (Figure 2). Radiographic evaluation revealed that the ostectomy site was completely healed; there was also persistent medial subluxation of the third and fourth digits at the metatarsophalangeal joint, but the digits were oriented in an appropriate weight-bearing direction. A blood sample was obtained for genetic testing. Results revealed that the calf was a heterozygous carrier for 2 genetic disorders (PHA and DS) that involve the axial aspect of the lateral claw of the right pelvic limb.

A 10-day-old 48-kg (106-lb) American Shorthorn heifer (patient 3) was examined because of a congenital limb deformity. Physical examination revealed the presence of a varus deformity centered at the metatarsophalangeal region of the left pelvic limb. That limb was also internally rotated, in part because the
The calf was walking on the abaxial aspect of the lateral claw. Additionally, there were flexural deformities of the metatarsophalangeal joints of both pelvic limbs, most likely involving the superficial digital flexor tendon and joint capsule, similar to those described for patient 2. No other remarkable abnormalities were identified during physical examination. Radiographic evaluation of the left pelvic limb revealed a varus deformity centered at the metatarsophalangeal joint characterized by medial subluxation of P1 of digits 3 and 4 and lateral subluxation of the second phalanx of digit 4 with a varus deformity of the proximal interphalangeal joint. The degree of angulation, as determined in the same manner described for patient 1, was 54° (Figure 3). The owner elected to have a closing wedge ostectomy with transfixation pin–cast stabilization performed. The size and location of the wedge to be removed from the cannon bone was determined as described for patient 1. It was estimated that 2.2 cm of bone would need to be removed from the lateral aspect of the cannon bone to correct the varus deformity.

The patient received ceftiofur hydrochloride (2.2 mg/kg [1.0 mg/lb], SC) and flunixin meglumine (1.1 mg/kg, IV) immediately prior to anesthesia induction and morphine (0.05 mg/kg, IM) during surgery. Anesthesia was induced with alfaxalone (2 mg/kg, IV) and maintained with isoflurane. The patient was positioned and aseptically prepared and the wedge ostectomy was performed as described for patient 1. The ostectomy-induced shortening of the limb was expected to help address the flexural deformities at the metatarsophalangeal joints.

A transfixation pin cast was applied to the left pelvic limb to stabilize the ostectomy site in a manner similar to that described for patient 1. The proximal pin was placed 1.3 cm distal to the tarsometatarsal joint, and the distal pin was placed 2.2 cm distal to the proximal pin. The time required for the ostectomy and cast application was 90 minutes.

Postoperative radiographic evaluation revealed that the varus deformity had been reduced to 2°. The calf was hospitalized for 2 days after surgery and received ceftiofur hydrochloride (2.2 mg/kg, SC, q 24 h) for 2 days and flunixin meglumine (1.1 mg/kg, IV, once) the day after surgery.

Figure 2—Photograph of both pelvic limbs (A) and a dorso-plantar radiographic image of the right pelvic limb (B) of an approximately 10-month-old American Shorthorn heifer (patient 2) 10 months after a closing wedge ostectomy with transfixation pin–cast stabilization was performed to correct a 32° congenital varus deformity of the right pelvic limb. A—Notice that the calf is standing on the solar surface of both claws of the right pelvic limb and that the toes of the left pelvic limb are externally rotated. Both limbs also have flexural deformities of the metatarsophalangeal joints, which is more evident on the left limb in this photograph. B—The ostectomy site has healed, and the degree of angulation for the varus deformity was reduced to 9°. However, there is medial subluxation of P1 of digits 3 and 4 at the metatarsophalangeal joint. The arrows are oriented perpendicular to the distal articular surface of the cannon bone and point to the exposed articular surface that should be in contact with the proximal articular surface of P1. Lateral is to the left.
The patient was reevaluated 4 weeks after surgery. It was sedated with xylazine (0.05 mg/kg, IV) for cast removal and radiograph acquisition. Following cast removal, the ostectomy site was palpably stable. Mild cast sores, as evidenced by hair loss and superficial skin ulcerations, were present on the limb near the proximal end of the cast. Additionally, the transfixation pins were loose, and there was purulent discharge at the pin-skin interface. The pins were removed, and the pin holes and ulcerated skin lesions were cleaned with povidone iodine scrub and lavaged with saline solution. Radiographic evaluation revealed osseous callus at the ostectomy site characterized by periosteal proliferation along the medial and lateral cortices of the cannon bone with poorly distinct ostectomy margins and disuse osteopenia in bones located distal to the transfixation pins. An extended half-limb cast was applied to the left pelvic limb as previously described, and the calf was sent home.

The patient was reevaluated 3 weeks later (7 weeks after surgery) and sedated with a combination of xylazine (0.05 mg/kg [0.014 mg/lb], IV), ketamine (2 mg/kg, IV), and midazolam (0.1 mg/kg, IV) for cast removal and radiograph acquisition. The ostectomy site was palpably stable. Radiographic evaluation revealed the presence of osseous callus at the ostectomy site similar to that observed in the radiographs obtained 4 weeks after surgery. The calf was discharged from the hospital without coaptation.

The patient was reevaluated 9 months after surgery. At that time, the owner reported that the calf was growing appropriately but was noticeably lame on the left pelvic limb when walking. Physical examination revealed that the left pelvic limb was slightly shorter than the right pelvic limb and a grade 1 (mild lameness with altered gate) out of 4 lameness on the Anderson lameness scale. Radiographic evaluation revealed that the ostectomy site had healed, but there was persistent medial subluxation of P1 of digits 3 and 4 at the metatarsophalangeal joints, albeit with the digits oriented in a normal weight-bearing direction, and persistent subluxation of the second phalanx of digit 4 with a varus deformity of the proximal interphalangeal joint. A blood sample was collected for genetic testing, and results revealed that the patient was homozygous for the allele associated with DS (ie, was phenotypically affected).

A 6-month-old 300-kg (660-lb) Angus heifer (patient 4) was examined for a left pelvic limb lameness of 3 weeks’ duration. Physical examination revealed a valgus deformity at the distal aspect of the left metatarsal region and a grade 3 (severe non-weight-bearing lameness) of 4 lameness of the left pelvic limb. The distal aspect of the left metatarsal region was substantially enlarged and had the palpable consistency of osseous callus. Flexor tendon laxity and a varus deviation were observed in the metatarsophalangeal joints of the right pelvic limb, which were attributed to compensatory overload of the limb owing to the non-weight-bearing lameness of the contralateral pelvic limb. Radiographic evaluation of the left metatarsophalangeal region revealed a Salter-Harris type II fracture of the distal physis of the cannon bone with malunion and development of a 16° valgus deformity (Figure 4). The decision was made to surgically correct the deformity with a closing wedge ostectomy. It was estimated that 2 cm of bone would need to be removed from the medial aspect of the cannon bone to correct the valgus deformity.

The patient received florfenicol (20 mg/kg, IM), flunixin meglumine (1.1 mg/kg, IV), and a morphine epidural (0.01 mg of morphine/kg added to 27 mL of sterile saline solution) administered in the sacrococcygeal space 1 hour before anesthesia induction. Anesthesia was induced by IV administration of a mixture of ketamine (1.1 mg/kg) and 5% guaifenesin (1.1 mL/kg) and maintained with isoflurane. The patient was positioned in left lateral recumbency with the left pelvic limb extended off the table and the right pelvic limb abducted with a hoist so that it would not interfere with aseptic preparation and surgery of the left pelvic limb. An 8-cm longitudinal incision was made on the medial aspect of the distal portion of the cannon bone beginning at the distal physis and ex-
tending proximally. A closing wedge ostectomy was performed as described for patient 1. The chronic nature of the injury made the procedure more difficult. Periosteal proliferation made elevation of the periosteum challenging, and cuts were made through bone as well as reactive periosteum. Following removal of the osseous wedge, the limb was aligned and the ostectomy site was closed in a routine manner.

A transfixation pin cast was applied to the left pelvic limb to stabilize the ostectomy site. The cast ing procedure was modified from that used for the other 3 patients because this patient was older and heavier, and consequently, its bones were harder. A stab incision was made through the soft tissues on the medial aspect of the left pelvic cannon bone 2.2 cm distal to the tarsometatarsal joint. A 4.8-mm drill bit was used to create a pilot hole through both cortices in a medial-to-lateral direction. The site was lavaged with sterile saline solution and the swarf was manually cleared frequently during drilling to minimize thermal damage to the bone. A positive-profile centrally threaded fixation pin (shaft diameter, 4.8 mm; thread diameter, 6.0 mm) was transcortically inserted in the pilot hole in a medial-to-lateral direction. The pin was placed in a self-tapping manner. A second pin of the same size was placed in a similar manner 2.5 cm distal to and approximately 30° horizontally divergent from the first pin. The time required for the ostectomy and cast application was 95 minutes.

Postoperative radiographic evaluation revealed that the valgus deformity was reduced to 0°. The patient was moderately lame after surgery. It received another dose of flunixin meglumine (1.1 mg/kg, IV) the day following surgery and was discharged from the hospital 2 days after surgery. The patient was reevaluated 5 weeks after surgery, at which time it was sedated with xylazine (0.03 mg/kg, IV) for cast removal and radiograph acquisition. The ostectomy site was palpably stable following cast removal. Radiographic evaluation revealed osseous callus formation across the ostectomy site and mild diuse osteopenia in the bones distal to the transfixation pins (Figure 4). The pins were removed, and the patient was sent home with no coaptation. The owner was contacted by telephone to obtain follow-up information 6 months after the surgery. The owner indicated that the patient was not visibly lame when walking, the flexor tendon laxity and varus deviation of the contralateral pelvic limb had resolved, and the animal was performing satisfactorily. The owner also reported that there was a small bump on the lateral aspect of the cannon bone just proximal to the metatarsophalangeal joint.

Discussion

In cattle, ALDs may be congenital or acquired. Congenital ALDs typically occur at the middiaphyseal level and are likely the result of in utero bending stress. Angular limb deformities can originate as an autosomal recessive disorder in Jerseys and may have a genetic basis in the Holstein, Simmental, Gelbvieh, Polled Hereford, and Angus breeds. Other causes of ALD in cattle include fracture with malunion, collateral ligament damage, septic physitis, and Salter-Harris fractures. Differential physcal growth is rare in cattle, but when it is present, it is often caused by compensatory overloading of the physis secondary to abnormalities in the contralateral limb and results in a varus deformity. Three of the 4 calves (patients 1, 2, and 3) described in the present report had similar congenital deformities characterized by medial sub-
luxation of P1 of digits 3 and 4 at the metatarsophalangeal joints resulting in varus deviation.

Valgus ALDs of ≤ 7° in cattle are often clinically irrelevant and left untreated. If treatment is pursued for mild valgus deformities, it typically involves cor- rective hoof trimming or the application of acrylic to the hoof of the affected limb. Surgery is recommended for more severe ALDs. Previously described surgical options for correction of ALDs in calves include transphyseal bridging by use of screws and a wire tension band,5 closing wedge ostectomy with dynamic compression plate application,3–10 and cylindrical ostectomy with a locking compression plate.11 Periosteal elevation as an adjunct to other methods has been reported but is no longer recommended.3,7

All 4 patients of the present report were managed with a closing wedge ostectomy, despite the fact that they were all immature animals with open physes and theoretically should have been manageable with a less invasive transphyseal bridging technique. Patients 1, 2, and 3 had such severe varus ALDs that they were ambulating on the abaxial surface of the lateral claw of the affected limb. Abnormal weight bearing on the lateral aspect of the affected limb resulted in constant compression on the medial aspect and unloading of the lateral aspect of the distal physis of the cannon bone, potentially slowing and accelerating medial and lateral longitudinal growth, respectively, of that bone.5 Therefore, we elected a more aggressive treatment approach than transphyseal bridging to prevent further damage to the soft tissues and synovial structures in the region. We chose a closing wedge ostectomy because of our familiarity with the procedure as well as availability of the necessary equipment. However, a cylindrical ostectomy has been described for correction of an ALD in a calf12 and could have been attempted in combination with transfixation pin–cast stabilization in patients 1, 2, and 3 in an effort to avoid potential shortening of the affected limb as described for patient 3.

Patient 4 had a Salter-Harris type II fracture of the distal epiphyseal growth plate of the cannon bone of the left pelvic limb that had healed in a malunion and was non-weight bearing on that limb. It also had evidence of flexor joint laxity and interosseous medius muscle breakdown with development of a varus deformity in the metatarsophalangeal region of the contralateral pelvic limb, which were likely the result of compensatory weight bearing by that limb.3,12,13 Because the fracture affected the physis, we felt that a transphyseal bridging procedure might not be successful and chose the more aggressive closing wedge ostectomy.

Internal fixation with plates and screws were avoided in all 4 patients of the present report owing to the high cost of that type of fixation relative to external coaptation. Additionally, regulatory concerns and public perception should be considered whenever permanent implants are considered for animals that may eventually be used for human consumption. The transfixation pins used in the cast were removed from all 4 patients of this report, thereby obviating any concerns about implant retention in animals destined for human consumption. Although the osteotomy site could have been stabilized during transfixation pin–cast application with 1 to 2 screws, cerclage wire, or other methods with minimal increase to the procedure cost, in our experience, we found such stabilization unnecessary. For the patients of the present report, particularly patient 2, any limb angulation remaining after surgery was attributed to inadequate removal of bone (ie, the wedge removed was too small), despite preoperative imaging, measuring, and planning. Nevertheless, the postoperative degree of angulation for all 4 patients was small and deemed clinically irrelevant. Even patient 2 (the calf with the greatest postoperative degree of angulation [9°]) was walking on the solar aspect of both claws of the affected limb following cast removal and was no longer lame on that limb at the time of the final long-term follow-up.

Transfixation pin–cast application is an effective method for stabilizing long bone fractures distal to the stifle and elbow joints of cattle14–17 and has been used in combination with an osteotomy for correction of a severe metacarpal torsional deformity in a calf.18 The positive outcomes for the cattle of those reports14–18 made transfixation pin–cast application an attractive alternative for adjunct stabilization of closing wedge ostectomy sites that was simpler and less invasive than bone plates. Additionally, all 4 calves of the present report had ALDs centered at the metatarsophalangeal joints. The use of bone plates for internal stabilization would have required a plate to cross the physis, thereby potentially disrupting the growth plate and resulting in iatrogenic shortening of the limb or a secondary ALD. Transfixation pin casts are easily removed, adjusted, and reapplied as animals grow.19 They are also less expensive than internal fixation.3,13

The duration between ostectomy and removal of the transfixation pins and all coaptation varied for the 4 patients of the present report. The timing of pin and cast removal for each patient was determined on the basis of the clinical judgement of the veterinarians who evaluated the patients during the recheck appointments, owner compliance in terms of bringing the patient back to the hospital for reevaluation, and the duration of external coaptation suggested for long-bone fractures of cattle in the veterinary literature.19,20 For the patients of the present report, the transfixation pin casts were extended slightly more proximal than standard half-limb casts so that the cast did not end in close proximity to and cause undue stress on the transfixation pins, thereby increasing the risk of cast failure.

For the 4 patients of the present report, admin- istration of flunixin meglumine 1 hour before sur- gery and morphine before (epidural) or during (IM) surgery appeared to provide excellent analgesia for the closing wedge ostectomy. All 4 patients used the affected limb well after surgery, and none required
rescue analgesia during the postoperative period (as determined on the basis of physical examination findings and patient attitude and use of the affected limb).

In cattle, congenital ALDs are often concomitant with rotational or flexural limb deformities. Patients 2 and 3 of the present report had other congenital limb deformities in addition to the ALD, which was corrected with the closing wedge ostectomy procedure. However, all those deformities were mild or moderate, and the patients ambulated on the solar aspect of both claws of the affected limbs. Therefore, those deformities were managed with conservative treatment. That treatment was successful for patient 3 but not patient 2, which continued to have gait abnormalities associated with the congenital deformities in the 3 limbs that did not undergo surgery. For patient 3, resolution of the concomitant flexural deformity in the operated limb might have been facilitated by shortening of the limb induced by the closing wedge ostectomy.

Complications associated with the closing wedge ostectomy were minor for the patients of the present report. All 4 patients developed some degree of disuse osteopenia in the bones distal to the pins, likely owing to stress shielding induced by the transfixation pin cast. The osteopenia was addressed by removing the transfixation pins and providing continued support of the ostectomy site with a standard cast when necessary. One patient (patient 3) also developed cast sores, which were cleaned and allowed to heal without further intervention. Disuse osteopenia and cast sores are commonly associated with transfixation pin–cast use in cattle and generally resolve without any long-term adverse effects, as they did for all patients of this report.

Two of the 4 patients (patients 2 and 3) remained lame on the affected limb at the time of the last follow-up. Both of those patients had varus deformities characterized by medial subluxation of P1 of digits 3 and 4 at the metatarsophalangeal joints. The closing wedge ostectomy corrected the varus deformity but did not address the phalangeal subluxations. It is possible the residual lameness in those 2 patients was associated with pain or poor mechanical function of the subluxated metatarsophalangeal joints.

Digital subluxation is an undesirable genetic condition recognized by the American Shorthorn Association. It is an autosomal recessive disorder that involves the same chromosome as PHA, another undesirable and fatal genetic disorder. This leads to an unusual gene interaction. For example, when a carrier of DS but not PHA is crossed with a carrier of PHA but not DS, the resulting offspring will have a 25% chance of having deformed pelvic limbs. Interestingly, although animals that are homozygous for DS will typically have only 1 affected pelvic limb, often with only mild to moderate abnormal angulation, animals that are heterozygous for both DS and PHA will often have severe abnormal angulation of both pelvic limbs.

Closing wedge ostectomy with transfixation pin–cast application provided satisfactory results for cattle with ALDs of the metatarsophalangeal joints and should be considered an option for management of cattle with severe ALDs to improveambulation and quality of life. Although DS is a genetic disorder currently recognized only in American Shorthorn cattle, a genetic disorder should be considered for all young calves with metatarsophalangeal deformities, especially those that involve subluxation of the digits, and a recommendation that those animals not be used for breeding purposes should be made. Many cattle with an ALD characterized by DS walk on the side of the affected claws rather than the solar surface, which causes trauma to affected tissues and signs of pain that will become worse if the animal is not treated. Therefore, euthanasia should be considered if treatment is not pursued. There are ethical concerns associated with treating animals with heritable disorders, and exhibition and breeding of such animals should be avoided.

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Footnotes
a. eFilm Workstation 3.3, Merge Healthcare Inc, Mississauga, ON, Canada.

References
13. St Jean G, Anderson DE. Decision analysis for fracture man-
Ruminants


From this month’s AJVR

**Effect of site of sample collection and prandial state on blood glucose concentrations measured with a portable blood glucose meter in healthy dogs**
Jove L. Guevara et al

**OBJECTIVE**
To compare glucose concentrations in peripheral venous and capillary blood samples collected before and after consumption of a meal and measured with a veterinary-specific portable blood glucose meter (PBGM).

**ANIMALS**
12 dogs (96 blood samples).

**PROCEDURES**
A veterinary-specific PBGM was used to measure blood glucose concentrations. Glucose concentrations of capillary blood obtained from the carpal pad, medial aspect of a pinna, and oral mucosa were compared with glucose concentrations in blood obtained from a lateral saphenous vein. Samples were collected after food was withheld for 12 hours and again 2 hours after consumption of a meal.

**RESULTS**
Location of capillary blood collection had a significant effect on glucose concentrations measured with the PBGM. Glucose concentration in capillary blood collected from the medial aspect of the pinna did not differ significantly from the glucose concentration in peripheral venous blood, whereas glucose concentrations in blood collected from the carpal pad and oral mucosa differed significantly from the glucose concentration in peripheral venous blood. There was no significant difference between the measured preprandial and postprandial blood glucose concentrations.

**CONCLUSIONS AND CLINICAL RELEVANCE**
Glucose concentrations in capillary blood collected from the medial aspect of the pinna of dogs better reflected glucose concentrations in venous blood than did concentrations measured in capillary blood collected from the carpal pad or oral mucosa. (*Am J Vet Res* 2019;80:995–1000)