Veterinary Surgery
35:618–625, 2006

Computed Tomographic Documentation of a Comminuted Fourth Carpal Bone Fracture Associated with Carpal Instability Treated by Partial Carpal Arthrodesis in an Arabian Filly

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Objective—To report treatment of a unilateral comminuted fourth carpal bone (C4) fracture associated with carpal instability by partial carpal arthrodesis (PCA) of the middle carpal joint (MCJ) and carpometacarpal joint (CMCJ).
Study Design—Case Report.
Animals—An 8-month-old Arabian filly.
Methods—A C4 slab fracture was diagnosed radiographically; however, fracture comminution was conclusively diagnosed after computed tomographic (CT) imaging. PCA of the MCJ and CMCJ was performed with 2 narrow dynamic compression plates.
Results—PCA provided appropriate carpal stability and correct limb alignment immediately after surgery. Complete bony fusion with substantial carpal flexion and no lameness at walk or light trot was observed 8 months after surgery.
Conclusions—Carpal CT was successfully used to define fracture configuration after standard radiographic examination failed to delineate comminution. PCA was selected because of joint instability and lateral carpal collapse of MCJ and CMCJ and can be successfully used to treat comminuted C4 slab fractures associated with carpal instability. Moderate MCJ osteoarthritis without radiocarpal joint involvement allows pain-free, substantial carpal flexion and thus, return to low-level pleasure riding may be possible.
Clinical Relevance—CT imaging may more adequately characterize traumatic carpal bone injury, particularly, when carpal bone fracture configuration cannot be determined on standard radiographs. Early PCA of the MCJ and CMCJ is an useful alternative to treat comminuted C4 slab fractures that cannot be reconstructed.

INTRODUCTION

THE EQUINE carpus is a complex anatomical structure involving the distal radius, proximal row of carpal bones (radial [RC], intermediate [IC], ulnar and accessory carpal bones), distal row of carpal bones (second, third [C3], fourth [C4], and occasionally first carpal bones) and the proximal metacarpus (second, third [MC3], and fourth metacarpal bones).[1] The integrity of the carpus is ensured by several ligaments and the joint capsule. The carpus includes the antebrachial (radiocarpal), the middle, and the carpometacarpal joints (CMCJ) whereby the latter 2 joint pouches mostly communicate with each other.[1]

Diseases of the carpus are frequently seen in equine athletes (including racing horses, hunters and jumpers) because of the tremendous forces experienced during training and racing.[2,3] Degenerative changes of the synovium, joint capsule, ligaments, articular cartilage and the underlying bone are often sustained during high speed exercise or excessive trauma.[2–5] In particular, the dorsal margins of the carpal bones are predisposed to fractures

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Submitted February 2006; Accepted May 2006

0161-3499/06
doi:10.1111/j.1532-950X.2006.00199.x

because of the focused concussive forces in these areas.[1] Generally, intraarticular fractures of the carpus are classified as osteochondral (chip), slab, comminuted and oblique fractures[6] from highest to lowest frequency of occurrence.[1]

Conservative and surgical management techniques, including arthroscopic removal of osseous fragments and fixation of slab fractures in lag fashion, are routinely performed.[1] Particularly, early surgical intervention can prevent additional intraarticular damage and development of osteoarthritis which may prevent the horse's return to function. However, advanced imaging techniques and surgical approaches for challanging carpal injuries like catastrophic breakdowns or comminuted fractures of individual carpal bones are rarely documented[7]; knowing though, that those injuries result in significant joint instabilty, pain and inability to ambulate. Usually, standard radiographic studies of the carpus are adequate for documenting most fractures. However, occasionally more accurate imaging modalities such as computed tomography (CT), are desired to depict exact fracture configuration and to plan surgical intervention as thoroughly as possible. Unfortunately, CT evaluation has not been described as frequently as radiographic and ultrasonographic imaging modalities to detect pathologic changes of the carpus.[8]

Our purpose was to report use of CT for aid in diagnosis and guiding surgical repair of a complex, traumatic, comminuted C4 fracture associated with carpal instability in an Arabian filly and to describe successful treatment by partial carpal arthrodesis (PCA).

CLINICAL REPORT

An 8-month-old, 275 kg Arabian filly was admitted for right forelimb lameness of 5 days duration that occurred after a fall during training. Mild swelling of the carpus occurred the morning after injury. A parasagittal C4 slab fracture identified on carpal radiographs, was treated by bandaging, stall-rest, and non-steroideal anti-inflammatory drug administration; however, the filly horse remained persistently lame.

On admission, there was a 3/5 lameness at a walk and mild swelling on the lateral aspect of the right carpus. On palpation, a mild carpal instability with lateral collapse was apparent and the horse was moderately painful after carpal flexion. No abnormalities were observed in the contralateral limb.

Radiographic Findings

On digital radiographic evaluation (EKLIN™, Digital Radiography Medical System Inc., Sunnyvale, CA) of the right carpus (lateromedial, flexed lateromedial, 45° DMPLO, 45° DLPMO, dorsopalmar projections), an oblique slab fracture of C4 with a remodeled fracture line was identified (Fig 1). Comminution was suspected, but could not be verified radiographically because of the complexity of the anatomic location. The dorsal fracture segment seemed to be minimally displaced dorsally. Small irregular chip fragments were associated with the dorsolateral surfaces of C3 and MC3. Another oblique fracture line was equivocally detected, but not confirmed on radiographs (Fig 1); effusion and soft tissue swelling was apparent.

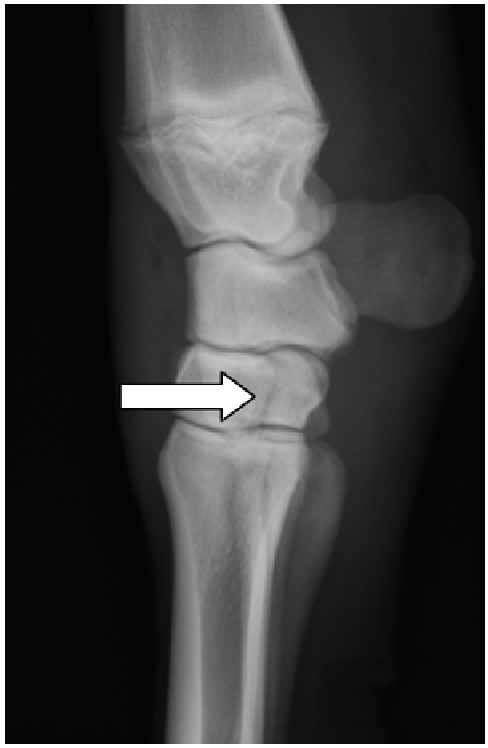

Fig 1. Preoperative lateromedial radiograph. A C4 slab fracture (arrow) is identified.

CT Findings

CT (Picker PQS CT scanner, Phillips Medical Systems, Bothell, WA) imaging of the carpus was performed to evaluate the exact fracture configuration. The horse was anesthetized and positioned in right lateral recumbency on a custom-engineered CT table. The forelimbs were placed parallel to each other and supported by a table extension and pads with the long axis of the forelimbs perpendicular to the CT gantry. Transverse images (3 mm thick, contiguous) of the right carpus were acquired (130 kV, 100 mA, DFOV 15 cm^2, matrix size 512×512) and processed for display using a bone algorithm.

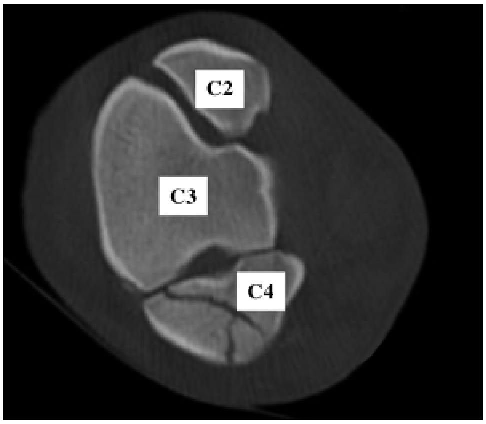

Fig 2. Preoperative CT image demonstrating a comminuted C4 slab fracture.

On CT images, a large parasagittal fracture of C4 was identified with several smaller fractures extending from it. The dorsal half of C4 was mildly dorsally displaced and 2 smaller triangular fracture fragments were present within the main fracture line. Chip fractures of the adjacent dorsolateral margins of C3 and MC3 were also present (Fig 2). A diagnosis of a comminuted C4 slab fracture associated with osteoarthritic changes of the middle and CMCJ was made.

Treatment Considerations

Continuation of conservative management or surgical correction were discussed and because the owner wished to continue conservative care, a fiberglass sleeve cast was applied to the limb extending from just below the elbow joint to just proximal to the metacarpophalangeal joint to assure limb alignment under general anesthesia. The filly walked without any problems for 7 days then became suddenly lame. The cast was removed with the filly anesthetized and although no cast sores were present, progressive carpal instability with marked lateral collapse and carpus valgus was identified.

On radiographic evaluation, mild, irregular periosteal reaction consistent with new bone formation was identified along the dorsolateral aspect of the distal aspect of the carpus (Fig 3). All fracture lines appeared remodeled. Because of the acute onset of lameness associated with carpal instability and the osteoarthritic changes already present, surgical management of the fracture was again recommended. Insertion of screws in lag fashion into C4 and a PCA of the middle carpal and CMCJ were considered as options to stabilize the carpus. The owner selected PCA.

Fig 3. Mild irregular periosteal reactions, indicating osteoarthritic changes, were already evident along the dorsolateral aspects of the carpus (arrow) and metacarpus 12 days after conservative management.

Surgical Technique

Ampicillin sodium (10 mg/kg intravenously [IV]), gentamicin sulfate (6.6 mg/kg IV), phenylbutazone (4.4 mg/kg IV) and tetanus toxoid were administered preoperatively. Once anesthetized, the horse was positioned in dorsal recumbency with the affected leg straightened. After aseptic preparation of the limb, a standardized surgical approach[9] was used to partially arthrodese the carpus with 2 narrow dynamic compression plates (DCP; Synthes® Inc., Paoli, PA). Briefly, two 20 cm long, vertical incisions penetrating skin and periosteum simultaneously were made on the dorsal aspect of the carpus beginning 4 cm proximal to the antebrachiocarpal joint and extending distally. The first incision was made medial to the extensor carpi radialis tendon, and the second one laterally between the extensor carpi radialis and common extensor tendons. Blunt dissection was used to expose the joint capsule. With the joint in moderate flexion, two 8 mm long arthrotomies through either site of the initial incisions were performed separating the joint capsule from its bony insertion to expose the articular cartilage of the middle carpal joint (MCJ). Sharp currettes were used to remove articular cartilage of the MCJ as thoroughly as possible to facilitate bony union. Four holes were drilled along the CMCJ using a 3.2 mm diameter drill bit to remove articular cartilage from this joint.

A nitrogen-driven oscillating bone saw (STRYKER® Instruments, Kalamazoo, MI) was used to remove excessive bone on the dorsal aspect of MC3 and to prepare a smooth surface for optimum plate placement. Subsequently, the entire surgical site, including the joints, was thoroughly lavaged with sterile lactated Ringers solution. An 8 hole narrow dynamic compression plate (Synthes® Inc., Paoli, PA) was contoured to the prepared site and placed along the dorsomedial aspect of the carpus, bridging the middle carpal and CMCJ with screws engaging the radiocarpal, C3, and MC3 bones. A second 7 hole narrow dynamic compression plate (Synthes) was contoured and affixed to the dorsolateral aspect of the carpus with screws engaging IC, C3, and MC3. Cortical bone screws (5.5 mm AO/ASIF; Synthes) were used in all bones immediately next to a joint space (IC, RC, C3, and the most proximal aspect of MC3). Compression was achieved using the plates between the proximal row of the carpal bones and MC3 (the 1st screws were applied in proximal row in standard technique to place the screws in a loaded position in MC3, followed by solidly tightening the screws). The remaining screw holes were filled with 4.5 mm AO/ASIF cortical bone screws (Synthes) in neutral position and final tightening was performed.

Both the MCJ capsule and the subcutaneous tissue were closed with 0 polyglactin 910 in a simple continous pattern after thorough lavage. The skin edges were reapposed with stainless-steel staples. On intraoperative radiographs, compression and alignment of the middle carpal and CMCJ was considered adequate (Fig 4). A sleeve cast was applied to the limb extending from just below the elbow joint to just proximal to the metacarpophalangeal joint. Head and tail rope-assisted recovery from general anesthesia was excellent. Twenty minutes after extubation, the horse got up after a single, strong attempt without any complications and with a nasotracheal tube in place.

IV ampicillin sodium (10 mg/kg every 6 hours), gentamicin sulfate (6.6 mg/kg once daily) and phenylbutazone (2.2 mg/kg every 12 hours) was continued for 72 hours. The filly was maintained on oral phenylbutazone (2.2 mg/kg) twice daily for another 72 hours and finally, once a day for another 10 days. Skin staples were removed at 10 days when the tube cast was replaced by a bi-valve cast which was changed twice weekly. Two superficial cast sores on the palmaromedial aspect of the carpus and over the accessory carpal bone healed completely by second intention. The filly was walking well and was discharged in a bandage at 16 days.

Strict stall rest for 60 days was recommended followed by hand walking for 10 minutes twice daily for another month. Thereafter, a gradual increase in exercise was recommended if healing was progressing satisfactorily. The owner was instructed to monitor the surgical site and degree of lameness. In addition to regular veterinary checks, re-examination at 6 months was recommended.

Fig 4. Postoperative lateromedial radiograph showing plate, screw, and joint alignment.

Outcome

Monthly follow-up information was obtained from the owner and referring veterinarian. Both reported that the filly had a persistent 1/5 lameness at the walk for 120 days after surgery, after which it resolved spontaneously. A mild firm swelling noted over the dorsal aspect of the right carpus did not increase in size. No complications associated with either incision lines or the contralateral limb were observed. Regular, standard radiographic evaluation of the arthrodesis site revealed progressive healing with bony fusion of the middle carpal and CMCJ. For this reason, unlimited pasture turnout with other horses was allowed during the day and the filly was kept in a stall overnight.

At 8 months, we re-examined the filly. A non-painful, 5×2 cm firm swelling was located at the dorsal aspect of the right metacarpus; however, the carpus was not swollen and was comparable in size with the contralateral limb (Fig 5). No angular or flexural deformity was observed in either limb. Carpal flexion was pain-free and the range of motion was limited to 90° (Fig 6). The filly was

Fig 5. Clinical picture of both front limbs demonstrating acceptable cosmesis and proper limb alignment without evidence of angular deformities of the carpal and metacarpophalangeal joints.

Fig 7. Dorsopalmar radiograph of the arthrodesis site 8 months after surgery showing complete bony union of the middle carpal and carpometacarpal joints associated with osteoproliferative bridging medially and laterally (arrow). All implants are in correct position and no evidence of loosening is seen.

free of lameness at a walk in straight lines and in circles on both hard and soft surfaces. On radiographs, complete fusion of the middle carpal and CMCJ was observed (Fig 7). Postsurgical limb alignment was maintained and both dynamic compression plates and all screws were in place without evidence of loosening. Irregular, periarticular, well-marginated bony callus was bridging the fused joints dorsally, laterally, and medially without involvement of the antebrachium (Fig 8).

Fig 6. Clinical picture demonstrating a pain-free, carpal flexion (90°) 8 months after arthrodesis.

Fig 8. Flexed lateromedial radiograph 8 months after surgery. No osteoarthritic changes in the radiocarpal joint are evident.

DISCUSSION

Athrodesis refers to a surgical fixation of a joint by a procedure designed to promote fusion of the joint surfaces, and may represent a type of ankylosis.[10] This surgical techique is successfully used in human and veterinary surgery for certain pathologic conditions of different joints. The main goals are joint stabilization and the elimination of persistent pain to enable more comfortable ambulation. In equine surgery, fusion of joints remains challenging even with recent advanced surgical techniques, mainly because of patient weight and size, biomechanical load, technical difficulties and postoperative complications.[10] In horses, arthrodesis of the proximal/distal interphalangeal,[11,12] metacarpo/metatarsophalangeal,[13,14] carpal (partial[15] and pancarpal[16]), scapulohumeral,[17] distal tarsal,[18] and talocalcaneal[19] joints has been described using different techniques. Generally, artificial fusion of low motion joints may preserve limited use of the horse and arthrodesis of high motion joints is considered as salvage procedure after severe injury or degenerative changes for valuable breeding stock.[10]

Detailed CT imaging of the equine skull,[20] tarsus,[21] distal extremities,[22] and carpus[23] has been reported. Although well documented for equine musculoskeletal conditions,[7,24,25] clinical application of CT has been mainly limited to the tarsus[21] and distal limbs,[24] but rarely described for diagnosis of carpal injuries.[8] We found CT was relatively easy and quickly performed, provided excellent imaging of the fractured C4 and related soft tissue structures, and was essential in making a correct diagnosis. Surgical planning and intervention were mainly based on findings obtained from CT. Ultrasonographic evaluation of the carpus, though well described[26–28] was not performed before surgery because soft tissue damage (intercarpal or collateral ligaments) can also be detected on CT.

There are limited reports on pancarpal[16] or PCA[15,29] in horses. General indications for carpal fusion are luxations, subluxations, severe degenerative joint disease, and comminuted fractures of one or more carpal bones that are usually associated with marked joint instability and inability to bear substantial weight.[9,15,30] In this report, PCA of the middle carpal and CMCJ was selected and successfully performed. Two narrow dynamic compression plates (7 and 8 hole) were applied dorsally to achieve maximal stabilization of a fractured C4, immobilizing the entire carpus to provide adequate bone healing while the horse was ambulating after surgery.

The second plate could have been applied to the lateral aspect of the carpal/metacarpal region to act as a buttress plate to prevent carpal collapse. Plate selection and application was based upon surgeon preference and experience with this surgical approach as well as the horse's anatomic carpometacarpal architecture (to engage as many screws as possible in the distal row of carpal bones). Several alternatives for PCA by internal plate fixation have been reported and combinations of 2 equally sized narrow DCPs, various sized broad and narrow DCPs as well as a broad DCP and T-plate have been successfully used.[9,15,30]

Although well described[2,31] and carefully considered, exclusive fixation by screws inserted in lag fashion was not performed. The comminuted C4 fragments may have been large enough to repair by one or two 3.5 mm screws inserted in lag fashion; however, it has been reported that single screw application may carry an increased risk of persistent carpal instability associated with angular deformity and severe osteoarthritis if accurate anatomic reconstruction is not achieved.[2,31] Excessive osteoproliferation on both radiocarpal and MCJ surfaces has been reported 4 weeks after surgical reconstruction because of incongruity between articular surfaces.[2,31] Therefore, this technique is reserved for simple slab fractures that are not highly comminuted and where carpal instability is not a concern. Since the fracture configuration in our patient was complex (comminuted and anatomical location), a decision to partially arthrodese the carpus was made. Alternatively, the C4 fracture gap may have been sucessfully reduced by means of one or two 3.5 mm screws inserted in lag fashion in conjunction with plate application, particularly with the information gained from CT imaging. Slight displacement of the fragments relative to each other after screw fixation would have been of minor concern because the joints would fuse anyway. This approach may have further stabilized the fracture site, accelerated bone healing, and would have been an alternative approach to management.

Radical removal of the MCJ articular cartilage with the joint in maximal flexion was crucial and contributed significantly to complete joint fusion and is currently recommended to maximize carpal stability.[9] Aggressive osteostixis of the CMCJ may have assisted bony fusion by permitting vascular ingrowth and bony bridging.

Although the benefits of tricalcium phosphate granules and high molecular weight gels in accelerating bony fusion after arthrodesis are reported in human and veterinary literature,[10] neither was used because they were not readily available in our hospital at the time of surgery. Cancellous bone graft, although available, was considered as an alternative, but was not harvested since focus was placed on minimizing anesthesia time and a high potential for rapid bone fusion was anticipated because of the filly's young age.

Experience gained from this case confirmed that conservative treatment of highly comminuted carpal fractures associated with joint instability is unrewarding for long-term recovery.[30] The advantages of an early aggressive PCA technique compared with conservative management (external coaptation) include prompt joint stabilization and immediate postsurgical weight bearing and ambulation. A young horse has a great potential for substantial, rapid healing and bony union as observed on radiographs (Fig 7). Surgical management resulted in less excessive osteoproliferation, fewer cast sores, and earlier recovery with a greater degree of flexion than previously reported.[29] Pancarpal arthrodesis was not performed and should be reserved for comminuted fractures involving both carpal rows or severe degenerative carpal joint disease in older horses that develop carpus valgus.[16]

CT imaging of the carpus was easily performed, enabled detailed evaluation of the traumatized carpal bones, allowed exact determination of fracture configuration and thus, was essential for making a correct diagnosis, and prompted early surgical intervention. PCA of the middle carpal and CMCJ using 2 narrow dynamic compression plates provided stable internal fixation for a comminuted C4 slab fracture associated with carpal instability. The early and aggressive arthrodesis technique along with the horse's young age resulted in rapid bony union, eliminated signs of pain, and preserved adequate carpal flexion. Return to pasture soundness or light trail riding is possible when the condition is correctly diagnosed, treated early, when general arthrodesis principles are followed, and close attention is paid to achieve correct limb alignment.

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