Ulnocarpal arthrodesis for the treatment of radial agenesis in a dog

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Introduction

Radial agenesis, or congenital absence of the radius, is one of the more common single bone dysostoses of dogs (1, 2). It has been hypothesized that radial agenesis is due to a defect in the medial limb ray, which is one of the three rays of the thoracic limb bud that gives rise to the forelimb during embryonal development (3–5). However, the precise aetiology of radial agenesis is unknown. Maternal and environmental factors have been suggested, and an autosomal dominant and recessive inheritance has also been implicated (4, 6).

Radial agenesis manifests clinically as forelimb shortening with disuse muscle atrophy and flexural contracture (1, 3, 5, 7). Incomplete development of the medial compartment of the carpus results in varus deformity at the level of the ulnocarpal joint. Complete agenesis of the radial head can also result in humeroulnar joint subluxation (3, 7). Pain is an inconsistent finding, unless there is concurrent injury (5, 7). Radiographs typically reveal complete or partial absence of the radius, ulnar shortening, and ulnocarpal varus, with ulnar recurvatum and humeroulnar joint subluxation in some cases (1, 5).

The early reports of the treatment of radial agenesis in dogs and cats described forelimb amputation in cases of functional loss and potential self-trauma (3, 5, 7). Treatment by radial reconstruction with a rib autograft and Kirschner wire fixation (8), forelimb lengthening by distraction osteogenesis (1), and by a combination of simultaneous humeroulnar and dorsal ulnocarpal arthrodeses (9) have been described. However, recovery of limb function was compromised in the two latter cases by the need for additional surgeries to stabilize the ulnocarpal joint (1, 9).

Case report

A one-year-old, 9.0 kg, male Shih Tzu dog was referred because it had angular deformity and shortening of the left forelimb that had been evident since birth. According to the owner, the birth of the dog was uncomplicated. It had been using the limb since the owner acquired it at two months of age, and the only incident of lameness occurred one month prior to referral, when the dog became acutely non-weight bearing after being struck by a bicycle. Diagnostic imaging was not performed at that time and the lameness resolved within three days after administration of one dose of corticosteroid by the referring veterinarian. On examination we observed a moderate weight bearing left forelimb lameness when the dog was walked on a leash. Examination revealed a marked varus deviation of the left manus centered at the ulnocarpal joint and antebrachial shortening when compared to the contralateral, unaffected forelimb. There was not any pain on antebrachial palpation nor on manipulation of any joint; however, there was a decrease in range of motion of...
the humeroulnar joint. There was disuse muscle atrophy of the entire left forelimb. Neurological examination and the remainder of the physical examination were within normal limits. The patient was sedated with acepromazine\(^{a}\) (0.05 mg/kg IV) and hydromorphone\(^{b}\) (0.05 mg/kg IV) and orthogonal radiographs of the left antebrachium and humerus were taken. A radiographic diagnosis of radial agenesis was made (Fig. 1). The ulnar notch was deeper than normal due to the presence of prominent coronoid processes that might have arisen from fusion of a remnant of the radial head to the ulna, or from hypertrophy of the ulna. The humeral condyle was located in the ulnar notch with mild humeroulnar joint subluxation. A distal radial remnant was present and the ulnar diaphysis was hypertrophied. On the mediolateral radiographic view, approximately 22° of ulnar recurvatum, which was maximal at a point 45% down the ulnar length, was present. In addition, varus deformity was noted on the cranio-caudal radiographic view (Fig. 1). Marked ulnocarpal varus (70°) was associated with ulnocarpal joint subluxation. In addition, there was 13° of metacarpal valgus due to curvature of the metacarpal bones. The left humerus measured 78 mm from the proximal aspect of the greater tubercle to the caudal border of the medial epicondyle, and the left ulna measured 71 mm from the most proximal aspect of the olecranon to the distal aspect of the styloid process. The growth plates of these two bones were completely closed. The owners elected not to proceed with surgical intervention at this time.

The dog was re-examined five months later, at which time it was approximately one-and-a-half-years-old and it weighed 9.6 kg. In the interim, there had not been any appreciable change in limb function. Physical examination revealed a greater magnitude of ulnocarpal varus and muscle atrophy. Ulnocarpal arthrodesis was recommended. After pre-medication with acepromazine\(^{a}\) (0.1 mg/kg IM) and hydromorphone\(^{b}\) (0.2 mg/kg IM), anaesthesia was induced with propofol\(^{c}\) (3.125 mg/kg IV) and maintained with isoflurane\(^{d}\) in oxygen, and a continuous rate infusion of a solution of 0.0048% morphine\(^{e}\), 0.06% lidocaine\(^{f}\), and 0.012% ketamine\(^{g}\) in lactated Ringer’s\(^{h}\) at 5 ml/kg/hr. Cefazolin sodium\(^{i}\) (25 mg/kg) was given at induction and additionally two hours later.

The patient was positioned in right lateral recumbancy for surgery and a dorsal surgical approach to the left carpus was performed (14). Articular cartilage was debrided to the level of subchondral bone with a saline-cooled pneumatic burr from all of the carpals and carpometacarpal joints, except for the accessoriolunar and carpometacarpal I and II joints. The styloid process of the ulna was exposed and osteotomized perpendicular to the long axis with an oscillating saw\(^{k}\) to permit correction of the axial malalignment. The distal radial remnant was left in situ. Temporary stabilization of the carpus was achieved by retrograde insertion of a Kirschner wire through metacarpal bone V, the ulnar carpal bone, and the ulna. An eight-hole 2.0/2.7-mm arthrodesis bone plate\(^{i}\) was contoured and secured to the dorsolateral aspect of the distal ulna, the ulnar carpal bone, and metacarpal bone V. Initially, a 2.0-mm cortical bone screw\(^{j}\) was inserted in the neutral position into the ulnar carpal bone through the fourth hole in the plate. A 2.0-mm cortical bone screw was then inserted in the load position through

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\(^{a}\) Acepromazine maleate, Vedco, Inc., St. Joseph, MO, USA.

\(^{b}\) Hydromorphone HCl, Baxter Healthcare Corp., Deerfield, IL, USA.

\(^{c}\) Propofol\(^{®}\), Abbott Laboratories, North Chicago, IL, USA.

\(^{d}\) Isoflo\(^{®}\), Abbott Laboratories, North Chicago, IL, USA.

\(^{e}\) Morphine sulfate, Baxter Healthcare Corp., Deerfield, IL, USA.

\(^{f}\) Lidocaine, IVX Animal Health, Inc., St. Joseph, MO, USA.

\(^{g}\) Ketaset\(^{®}\), Fort Dodge Animal Health, Fort Dodge, IA, USA.

\(^{h}\) Lactated Ringer’s Injection, Baxter Healthcare Corp., Deerfield, IL, USA.

\(^{i}\) Cefazolin sodium, Sandoz, Inc., Broomfield, CO, USA.

\(^{j}\) SurgaRite Two\(^®\), Hall\(^®\) Surgical, Linvatec Corp., Largo, FL, USA.

\(^{k}\) Stryker System5, Stryker Instruments, Inc., Kalamazoo, MI, USA.

\(^{l}\) 2.0/2.7 mm DCP Carpal Arthrodesis Plate, Veterinary Instrumentation, Sheffield, UK.

\(^{m}\) Synthes Ltd., Paoli, PA, USA.
the fifth plate hole into the base of metacarpal bone V. Three 2.7-mm cortical bone screws\textsuperscript{a} were then inserted proximally into the distal end of the ulna after removal of the Kirschner wire. The screw in the third plate hole was in the load position. Three 2.0-mm cortical bone screws were then inserted distally in the neutral position into the diaphysis of metacarpal bone V. Autogenous corticocancellous bone graft, harvested from the ilial wing using an acetabular reamer\textsuperscript{b}, was inserted juxta-articularly (15). Post-operatively, orthogonal radiographs of the left antebrachium confirmed that the arthrodesis bone plate was attached to the distal end of the ulna, the ulnar carpal bone, and the metacarpal bone V (Fig. 2). The bone plate covered approximately 87% of the length of metacarpal bone V. Although alignment of the antebrachium was much improved, there was residual ulnocarpal varus and external rotation of the manus at the level of the ulnocarpal joint. Dorsally, articular surfaces that were debrided with the pneumatic burr\textsuperscript{c} were less distinct. Bone graft extended from the distal end of the ulna to the base of the metacarpal bones.

Post-operative care and re-evaluation

After extubation, naloxone\textsuperscript{o} (0.004 mg/kg IV) was administered. External coaptation, consisting of a cylindrical soft padded bandage was applied to the left forelimb during the recovery period. Cephalexin\textsuperscript{p} (25 mg/kg PO q 12 h) and deracoxib\textsuperscript{q} (2.5 mg/kg PO q 24 h) were administered for two weeks. The bandage was changed daily during the first three days post-operatively and then changed weekly for the following eight weeks. A fiberglass splint\textsuperscript{r} was incorporated into the bandage at the second post-oper-

\textsuperscript{a} 22 mm BFX acetabular reamer, Biomedtrix, LLC, Boonton, NJ, USA.
\textsuperscript{b} Naloxone HCl, Hospira, Inc., Lake Forest, IL, USA.
\textsuperscript{c} Cephalexin, Ivax Pharmaceuticals, Inc., Miami, FL, USA.
\textsuperscript{d} Deramaxx\textsuperscript{®}, Novartis Animal Health US, Inc., Greensboro, NC, USA.
\textsuperscript{e} Scotchcast\textsuperscript{®} Plus, 3M Health Care, St. Paul, MN, USA.

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\includegraphics[width=\textwidth]{Fig_2.png}
\caption{Digital, orthogonal radiographs of the left antebrachium taken post-operatively.}
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\includegraphics[width=\textwidth]{Fig_3.png}
\caption{Digital, orthogonal radiographs of the left antebrachium taken at the time of sixteen week post-operative re-evaluation from which a diagnosis of radiographic union of the ulnocarpal arthrodesis was made.}
\end{figure}
ative week. During this period, the dog was cage confined and restricted to short walks on a leash.

On examination eight weeks post-operatively, we observed a mild intermittent weight bearing lameness when the dog was walked on a leash. There was decreased humeroulnar joint range of motion, most notably in flexion, however, the range of motion was not quantified. There was not any pain on antebrachial palpation. Moderate diffuse muscle atrophy was present. Radiographs of the left antebrachium showed signs of bridging callus at the level of the ulnocarpal, middle carpal, and carpometacarpal joints, together with bone graft incorporation. Scant bridging callus was noted at the level of the medial ulnocarpal joint. The accessorionaral and carpometacarpal I and II joint spaces were appreciable, probably because the articular cartilage of these joints had not been debrided. Scant bridging callus was noted between the ulnar carpal bone and metacarpal bone V on the palmar aspect of the joint. The implants were unchanged in appearance. A radiographic diagnosis of progressive healing of the arthrodesis was made.

At the sixteen week re-evaluation, the owners reported that the dog had become progressively more weight bearing on the limb and had resumed a full level of activity. On examination, we observed a mild, intermittent weight bearing lameness when the dog was walked on a leash, which was improved from the eight week re-evaluation. The left humeroulnar joint range of motion (78° of flexion and 137° of extension) was less than that of the contralateral, unaffected forelimb (48° of flexion and 155° of extension). There was not any pain on antebrachial palpation. The muscle mass of the forelimbs was bilaterally symmetrical. Radiographs of the left antebrachium revealed complete union of the ulnocarpal, middle carpal, and carpometacarpal joints (Fig. 3). The distal radial remnant was united with the radial carpal bone. The previously noted bridging callus between the ulnar carpal bone and metacarpal bone V on the palmar aspect of the joint had resorbed. The accessorionaral and carpometacarpal I and II joint spaces were unchanged in comparison to the eight week re-evaluation. The implants were unchanged in appearance. The final ulnocarpal arthrodesis angle was 0°. Assessment of angular deformity revealed 29° of residual ulnocarpal varus and 13° of metacarpal valgus, resulting in 16° of varus deformity distal to the humeroulnar joint. Radiographs of the contralateral, unaffected humerus and ulna were taken for the purpose of forelimb length and angular deformity comparison. When compared to the right humerus (86 mm) and ulna (85 mm), the left humerus (78 mm) and ulna (71 mm) had a 9.3 and 16.5 % length deficit, respectively. The contralateral, unaffected forelimb had 19° of varus deformity distal to the elbow joint.

Discussion

We selected ulnocarpal arthrodesis in this case in an attempt to achieve acute, rigid fixation of the carpus with potentially more rapid healing and return to function, when compared to prior treatment methods. One of the problems of attempting ulnar lengthening is that residual shortening or angular discrepancies may require additional operations, and also ankylosis may develop despite attempts to preserve the ulnocarpal joint (1). Therefore, we believe that unless lengthening is being considered, then one-stage ulnocarpal arthrodesis should be performed. However, ulnocarpal arthrodesis with a bone plate requires precise intra-operative correction and it does not allow for progressive correction of shortening or angular deformity, as with circular external fixation (16).

The arthrodesis bone plate used in this case has been specifically designed with regard to screw hole size and orientation, and also plate width and thickness, to address concerns of metacarpal bone implant oversizing and soft tissue closure (17). Although dorsal, palmar, and medial bone plate applications have been described for pancarpal arthrodesis, there are not any previous reports of dorsolateral bone plate application for carpal arthrodesis (12, 13, 18, 19). Due to the inherent morphology of the distal antebrachium and manus, in this case we elected to apply the arthrodesis bone plate on the dorsolateral aspect of the carpus. Dorsal application may have resulted in problems with the screws being oversized, as well as other complications associated with both dorsal pancarpal and ulnocarpal arthrodesis (9, 17). The risk of metacarpal bone fracture with dorsal and medial bone plate application is lower if there is at least 53 and 40% metacarpal bone coverage by the bone plate, respectively (13, 19). In our case we achieved coverage of the entire diaphysis of metacarpal bone V. It has been proposed that this is advantageous since the distal metaphysis is more apt to absorb construct stiffness changes and evenly distribute forces through the screws, minimizing the risk of implant loosening and fracture (13, 19). This may be of specific importance with radial agenesis due to altered load transmission from the lack of an intact paired bone system. Treatment of radial agenesis in a dog by ulnocarpal arthrodesis with a dorsal bone plate application, in combination with humeroulnar arthrodesis, has been recently reported (9). In that report, complications similar to those reported with dorsal pancarpal arthrodesis were experienced. These complications included screw loosening and wound formation over the bone plate, which necessitated implant removal and stabilization with an acrylic external fixator (9).

The residual lameness observed in this case was likely due to humeroulnar joint subluxation, ulnar shortening and the ulnocarpal arthrodesis, since the latter can result in mechanical lameness (20, 21). Approximately 50 to 60% of people afflicted with radial agenesis also have ulnar shortening, but the mechanism for this is unknown (10). One explanation is that the absence of the radius from the paired bone system predisposes to distal ulnar physeal damage with subsequent ulnar shortening and recurrature. Despite different times of radiographic evaluation, our comparison should be valid because the dog was skeletally mature with closed growth plates at the time of initial examination.

Pancarpal arthrodesis angles of less than 10° are preferred due to the fact that hyperextension results in limb circumduction and stress riser formation at the distal aspect of the bone plate (13). The arthrodesis bone
plate used in this case is designed with a distal 5° bevel to ensure an acceptable dorsal angle of arthrodesis. We attained an ulnocarpal arthrodesis angle of 0°; however, due to the remaining recurvatum our functional angle was 22°.

In cases of carpal varus, dorsolateral or lateral application of this arthrodesis bone plate may be advantageous due to the potential to yield a functional axis shift by as much as 5° due to the distal bevel. We attained 29° of residual ulnocarpal varus, however, due to 13° of metacarpal valgus, there was 16° of varus deformity distal to the humeroulnar joint. We may have increased our corrective accuracy by concurrently addressing the recurvatum and varus deformities with corrective ostectomy (ies) at the centre of rotation of angulation or by cuneiform ostectomy of the desired corrective magnitude during ulnocarpal joint reduction. However, this may have resulted in an even greater length deficit, and would have resulted in a more technically challenging surgical procedure due to regional soft tissue tension.

While ulnocarpal arthrodesis is a salvage procedure, the benefits of this one-stage treatment include acceptable cosmesis and return to function. Therefore we suggest that ulnocarpal arthrodesis can be an acceptable treatment of radial agenesis in cases in which there is inherent humeroulnar joint stability.

References

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