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Arthrodesis Masterclass for Advanced Practitioners Mini Series

Session One: Arthrodesis of the carpus

Stephen Clarke BVM&S DSAS(Orth) DipECVS MRCVS
RCVS Specialist in Small Animal Surgery (Orthopaedics)
European Specialist in Small Animal Surgery

Carpal Arthrodesis

Carpal joint anatomy is complex and the intricate relationship between the bones and ligamentous supporting structures is required for normal joint function and maintenance of normal distal thoracic limb posture. The carpus can be affected by a variety of developmental, traumatic, degenerative and inflammatory conditions which can have a profound impact on limb function and for which medical management or a straightforward surgical solution may not be possible or effective. In such situations carpal arthrodesis may allow limb function to be restored. Arthrodesis, like joint replacement and/or excision arthroplasty is a salvage surgical procedure, which aims to restore limb function when other treatment options for doing so are considered suboptimal. However conversely to joint replacement or excision arthroplasty, arthrodesis restores function through abolishing movement of the joint by osseous fusion. Irrespective of the fixation system used to stabilise the carpus, the principles of arthrodesis should be adhered to, in particular meticulous articular cartilage debridement, use of bone grafting and achieving a functional joint position (arthrodesis angle).

Pancarpal arthrodesis

Pancarpal arthrodesis (PCA) can be considered for pathology affecting any of the carpal joints. Stabilisation for PCA has historically been performed using internal fixation with placement of a dynamic compression plate (DCP) and screws to the dorsal aspect of the carpus. Dorsal plate constructs are susceptible to failure through cyclical loading as the fixation is placed on the compression aspect of the joint. Biomechanics are further compromised by the plate being secured distally to a single metacarpal bone. The single bone is subjected to all the axial loads placed through the bone-implant construct as well as dictating the size of implant which can be used and thus the mechanical strength of the construct. Although theoretically advantageous, the application of a bone plate to the palmar (tension) aspect of the carpus (Chambers and Bjorling 1982) has never gained favour due to the complexity of the surgical approach. Developments in plate fixation for PCA have primarily occurred through innovative plate design, resulting in a more appropriate selection of implants for a range of patient sizes, as well as facilitating execution of the arthrodesis. Recently plate design and / or plate application has become more focussed on optimising the mechanics of the bone-implant construct. In doing so it is hoped that frequency of postoperative complications: screw loosening, plate failure and metacarpal fracture will be reduced, and that adjunctive external coaptation will not be required. Postoperative fixation issues usually require implant removal or surgical revision.

The currently available internal fixation options include:

Hybrid Dynamic Compression Plate (HDCP): This implant represented the first shift away from the use of the DCP for PCA. Developed by Veterinary Instrumentation, (Sheffield, UK) and produced in a variety of sizes and lengths from 4.5mm/3.5mm to 2.0mm/1.5mm, the design of distal portion of the HDCP allows for more appropriate selection of screw size with respect to metacarpal bone diameter, whilst still retaining implant strength. Wininger and others (2007) reported a small but significantly greater bending strength at load to failure with a 3.5/2.7mm HDCP PCA compared to a 3.5mm DCP PCA construct. More appropriate positioning of both the radial carpal bone and proximal metacarpal plate holes facilitates plate application. The tapering thickness of the distal portion of the HDCP provides an inherent arthrodesis angle of 5° of hyperextension and facilitates soft tissue closure. Use of the 3.5mm/2.7mm plate was described by Li and others (1999). The outcome was good in the majority of the patients, however screw loosening and metacarpal fracture occurred in 3/13 and 1/13 procedures respectively. External coaptation was used in the initial postoperative period. Currently the HDCP remains the most popular implant for PCA

Hybrid dynamic compression plate and cross pins: The concept of plate / rod fixation for diaphyseal fracture stabilisation is well described (Hulse and others 1997). The pins increase the plates resistance to bending, optimising the biomechanics of the PCA construct (Arnott and others 2008), which may negate the need for external coaptation. In our experience, accurate pin placement, especially avoidance of the radial carpal bone screw is challenging. Particular attention should be paid to irrigation of the pin during placement, to help avoid thermal bone necrosis, which can predispose to pin loosening.

Double Dorsal Plating: Has been described as a technique for large dogs. The bone plates are placed on the cranial aspect of the radius, with one being attached to metacarpal 2 or 3 and the other attached to metacarpal 4.

Medial plating: Medial plating using a pre-contoured 2.7mm bone plate to provide an arthrodesis angle of 10-12° has been described by Guerrero & Montavon (2005). Application of bone plate in this position exploits the increased implant stiffness associated with ‘edge loading’ of the DCP. This coupled with screw engagement of multiple metacarpal bones distally due to their mediolateral orientation should offer a mechanical advantage. In spite of the proposed mechanical advantage, external coaptation was still used in the early postoperative period in the reported cases. All reported dogs ultimately became sound. Screw loosening occurred in 3/10 procedures. A plate spanning > 40% of the length of the metacarpal bones is recommended to prevent screw loosening.

CastLess Plate: A novel PCA plate (CastLess Plate, Orthomed Ltd, UK) has been developed for dorsal application to the carpus. The CastLess plate (CLP) comes in either a 3.5/2.7mm or 2.7/2.0mm size, providing an inherent arthrodesis angle of 8°. The proximal aspect of the plate contains 5 screw holes and is identical for each plate within the same size range.

Plate length is attributed to the variation in the length of the distal component of the plate, which has a unique design allowing screw placement across the diagonal axis of both metacarpals three and four. Unpublished provisional mechanical data pertaining to 3.5/2.7mm CLP PCA constructs has shown them to have a higher yield load than both a 3.5/2.7mm HDCP and HDCP & 1.6mm cross pin PCA constructs. Clinical use of the 3.5/2.7mm CastLess plate (CLP) has been described (Clarke and others 2009). External coaptation was only used in 3/11 dogs, 2 of which developed iatrogenic metacarpal fissure fractures during plate application, and one bilateral PCA. No postoperative fixation complications or metacarpal fractures were encountered in the mean follow up period of 14 months (range 12-20 months) likely reflecting the mechanical advantage this implant provides. All patients had a good or excellent outcome. The main issue identified was the risk of technical errors during application of the distal component of the plate.

Biaxial plating: Placement of a dorsal HDCP combined with a medial plate and has been reported (Pink and others 2009). Screw loosing was reported in 2/10 procedures. The authors suggested that adjunctive splint or cast support was not required with biaxial plating. Difficulty with wound closure was not reported, though might be envisaged with inappropriate patient or implant selection.

Stepped hybrid plate: A stepped hybrid plate has been developed (Diaz-Bertrana and others 2009) for PCA in dogs, aimed at preserving the normal bone contact of the articular surfaces as much as possible. This may reduce healing time as well as maximising frictional stability and construct strength. The single and double stepped plates provide 15° and 10° of carpal hyperextension respectively, which the authors propose may result in a more acceptable gait as well as potentially reducing the stress riser at the distal end of the plate. In a case series (Diaz-Bertrana and others 2009a) all patients were described as regaining good or excellent limb function. 10/52 procedures had screw loosening or failure and 1/52 had a metacarpal 3 fracture. Plate breakage and bending occurred in opposite limbs in one patient who had bilateral PCA. Although not alluded to in the publication, adjunctive splints or casts were not used. A Robert- Jones bandage was used in the majority of patients until suture removal and thereafter used for a variable time (2 – 8 weeks) in some patients (I. Durrall, personal communication).

Locking pancarpal arthrodesis plates: A small selection of plates which offer both compression and locking holes have been produced by Veterinary Instrumentation and Depuy Synthes. In theory the use of compression across the carpus coupled with fixed angular stability, particularly in the metacarpus, may well provide a mechanical advantage. There are no reports at time of writing regarding the clinical use of this plate.

Small dogs & cats: PCA in these patients will be most easily accomplished using the small 2.0/2.0mm or 2.0/1.5mm HDCP (Figures 5a and 5b) although Veterinary Cuttable Plates –VCP (Theoret and Moens 2007) can also be used. If a stacked VCP is used, stacking of only the portion of the plate which crosses the carpus is appropriate to help reduce the potential stress riser at its distal end on metacarpal 3. We do not use adjunctive external coaptation in these patients, although cage confinement is advised for the first 4-6 weeks.

Calvo and others (2009) recently described PCA in 18 cats using either a: DCP, HDCP or VCP. 6/18 had supplementary internal fixation using cross pins. 8/18 had adjunctive external coaptation. A satisfactory or excellent outcome was reported in patients who had long term follow up. Postoperative fixation issues associated with the plate & screws was reported in 1/18 patients. Medial plating has also been reported in cats using a 2mm maxillofacial locking plate system (Streubel and others 2011).

At first glance the plethora of available implants which are suitable for PCA may make appropriate implant selection confusing. However, with an appreciation of the different available implant systems, an understanding of the techniques described and with particular attention to surgical decision making for each individual patient, PCA can be successfully achieved in a wide variety of patients. The two most commonly used implants for PCA are the hybrid dynamic compression plate (HDCP) and the CastLess plate (CLP) (Bristow and others 2014).

External support involving a period of bandaging in the immediate postoperative period followed by cast or splint application for approximately 6 weeks is commonplace following PCA, having been considered a necessity for many years. Recently the use of cast application in particular, has become an area of increasing debate. Meeson and others (2011) reported morbidity associated with external coaptation in 67% of patients who had either partial or pancarpal arthrodesis. These authors also reported that the financial cost to the client of treating the resultant soft tissue injuries associated with cast application to the distal limb ranged from 4-121% of the original orthopaedic procedure. A mechanical study (Woods and others 2013) to assess the effect of cast application on a HDCP strain did show a protective effect, the difference was considered unlikely to be of clinical significance. Bristow and others (2014) reported that following a period of initial bandaging, casting was used in 56% (HDCP) and 11.4% (CLP) of cases with cast associated complications occurring in 43% and 17% respectively. When both bandaging and casting were considered together, the associated complication rates were 32% (HDCP) and 18% (CLP). **The study also concluded that external coaptation had no measurable clinical benefit.** In the authors' opinion a soft support bandage, maintained for 3-7 days after surgery is appropriate for the vast majority of PCA procedures.

In addition to morbidity from bandages or casts, postoperative complications are common following PCA surgery. Infection is the most commonly documented complication with others including screw loosening, metacarpal fracture and failure to achieve arthrodesis; plate failure rarely occurs. Multiple complications can occur concurrently. At present there does not appear to be a significant difference in intra or postoperative complication rates or in outcome between the HDCP or CLP (Bristow and others 2014). Appropriate pre-operative planning, strict asepsis and good surgical technique are all paramount in attempting to minimise the postoperative complication rate.

Despite being a major intervention, the outcome following PCA is good in most patients; no or mild lameness was reported in 73% and 83% of dogs using a HDCP or CLP respectively (Bristow and others 2014). PCA can be considered in active working dogs; Jerram and others (2009) reported 83% of such dogs to resume most or all of their working duties normally.

Partial carpal arthrodesis

Partial carpal arthrodesis (PaCA) is less commonly performed but can be considered when the antebrachiocarpal joint is spared from the pathological process affecting the carpus. Determining that this is the case can be challenging, as antebrachiocarpal joint pathology may not be readily apparent at the outset. Preservation of the joint which provides the majority of mobility is an attractive idea and has been proposed to facilitate limb function particularly on rough / uneven terrain. Andreoni and others (2010) found that following partial carpal arthrodesis, carpal extension angles were maintained during weight bearing although the range of motion in flexion was reduced to approximately half of normal values. The same study reported largely comparable objective outcome measures of limb function between patients who had either partial or pancarpal arthrodesis.

Various fixation systems for PaCA have been described. Multiple intramedullary (IM) K-wires can be placed from the distal aspect of multiple metacarpal bones and driven across the carpometacarpal and middle carpal joints to be seated in the radial carpal bone or cross K-wires can be used. Alternatively plate fixation using either a dynamic compression plate (DCP) or T-plate can be used. A novel canine Castless partial carpal arthrodesis plate has recently been developed; an *ex-vivo* biomechanical study (Burton and others 2013) showed that both this novel partial arthrodesis plate and T-plate fared similarly, being superior to cross pinning in some but not all respects. To date there have been no clinical studies describing the use of CastLess partial arthrodesis plate but it is hoped that its design features will help overcome the challenges that have been associated with straight or T-plate application and reduce the postoperative morbidity that can be seen with other fixation systems. Unlike PCA, there is currently no evidence to suggest that adjunctive external coaptation is not required in the early postoperative period, irrespective of the fixation system used. PaCA complications can include: infection, implant problems, morbidity associated with external coaptation and development of antebrachiocarpal pathology.

From the small number of PaCA case series which have been published, a substantial variation in outcome is reported. Despite a high postoperative complication rate, Haburjak and others (2003) reported good to excellent outcome with cross pin fixation. Willer and others (1990) reported resolution of lameness in 70% of patients who had predominately trans-articular, intra-medullary K-wire and less commonly T-plate fixation, whilst Denny and Barr (1991) reported a satisfactory outcome in only 50% of patients when a DCP was used. A suboptimal outcome may in part be due to the development of degenerative pathology in the antebrachiocarpal joint. This may be secondary to residual or developing antebrachiocarpal hyperextension, an undetected concurrent low grade soft tissue injury (Willer and others 1990, Denny & Barr 1991, Haburjack and others 2003), subsequent overloading of the antebrachiocarpal joint, or impingement of the dorsal aspect of the antebrachiocarpal joint by the proximal edge of a bone plate.

Given the challenges that PaCA presents and given the difficulty in excluding possible concomitant antebrachial carpal joint pathology, many surgeons would rather perform a PCA at the outset.

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