TREATMENT OF INCOMPLETE OSSIFICATION OF THE HUMERAL CONdyLE AND RECAlCITRANT ELBOW FRACTURES

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The humeral condyle in the normal developing dog has two (medial and lateral) centres of ossification, which are separated by a cartilaginous intermediate zone, and appear at a mean (±SD) of 14 ± 8 days after birth. These ossification centres are reported to unite by 70 ± 14 days of age with completion of ossification by 32 weeks of age. A condition affecting the integrity of the humeral condyle in spaniels was reported by Meutstege in 1989 as a rare finding and subsequently to primarily affect medium and large breed dogs. Now commonly termed incomplete ossification of the humeral condyle (IOHC), it is over-represented in the cocker spaniel, in which a recessive mode of inheritance has been proposed. The author and others have seen the condition in several breeds, including the Labrador Retriever, Labradoodle and German Shorthaired Pointer.

IOHC may be a subclinical condition, and has been reported as an uncommon cause of forelimb lameness in dogs. Lameness may be mild and intermittent to non-weight bearing in nature and may precede complete humeral condylar fracture (HCF). It is proposed that IOHC decreases stability of the humeral condyle predisposing to complete fracture often after a minimally traumatic event.

IOHC was first diagnosed radiographically as a linear sagittal radiolucency in the humeral condyle in the region of the developmental cartilage zone separating the two condylar centers of ossification. Subsequently bone scintigraphy and arthroscopic examination were reported useful in establishing a diagnosis but it is now appreciated that diagnosis may prove elusive using these modalities. Magnetic resonance imaging (MRI) or computed tomography (CT) may be necessary for definitive diagnosis. The author has found that both modalities are sensitive and accurate. The author has also found that cases which are clinically affected by lameness generally tend to have intercondylar fissures propagated into the joint itself, and are readily seen arthroscopically, with relative motion of the two condylar segments on pronation and supination.

Management of IOHC remains controversial. Conservative treatment of IOHC is associated with HCF. Marcellin-Little reported that 3/7 condyles (43%) with a partial radiolucent line and 1/12 condyles (8%) with a complete radiolucent line fractured 11 days to 18 months after diagnosis. The author has anecdotally observed high rates of fracture of untreated intercondylar fissures. Surgical treatment aims to prevent HCF, to encourage osseous fusion of the transcondylar fissure and to resolve lameness in the long-term. Current surgical treatment of IOHC generally involves use of a transcondylar screw, either fully or partially threaded, applied in either a position or in lag fashion. Screw placement may be combined with transcondylar bone tunnels created by drilling (forage) to allow vascular in-growth. A single case report prior to the author’s own work on transcondylar bone graft, suggested use of such a graft but this was not performed because of concerns about potential for the bone graft to communicate with the joint via the transcondylar fissure.

After transcondylar screw application, resolution of lameness usually occurs; however, complications include failure to achieve bone union, recurrence of lameness, fissure widening, loss of transcondylar compression, implant failure, and HCF. Failure to achieve bone union and condylar stability may result in cyclic loading of the screw with bending, stress fatigue, and failure. Some surgeons advocate changing the screw at regular intervals such as every other year and others advocate re-examination if lameness recurs, in an effort to prevent osseous fracture if the screw cycles to failure at the non-ossified interface. What is clear is that without biologic augmentation, union is never achieved. Some surgeons therefore advocate placement of screws of significantly large diameter (5.5 or even 6.5 mm).

Histologic features of the fissure site were consistent with atrophic non-union fracture in an English Pointer and were composed of fibrous tissue in two Cocker Spaniels with no evidence of chondrocytes or cartilage matrix. These findings may suggest that IOHC might be approached similarly to treatment of atrophic non-union fractures, so treatment modalities promoting transcondylar bone osseous union are worthy of consideration. Autogenous cancellous bone graft application in the area of incomplete ossification has been proposed to optimize bone formation and remodeling by providing trabeculae necessary for bone conduction and osteoprogenitor cells, as well as cytokines and growth factors for osteoinduction and osteogenesis. No study has reported the effect of IOHC on condylar stability but resultant instability may be in part or wholly responsible for observed lameness. In such cases, use of bone graft alone may not promote bone healing because of the effects of excessive movement at the fissure site inhibiting healing, similar to unstable atrophic non-unions where AO principles support the combination of a graft with rigid internal fixation to promote bony union.

Surgery Chapter
The Acutrak™ bone screw (AT screw, AcutrakTM, Acumed, Beaverton, OR) used since 1992 in human patients, is composed of titanium alloy (ASTM F136), and is a cannulated, headless, tapered, variably-pitched, self tapping and fully threaded compression screw. The AT screw is inserted using a customized cannulated application system. The osteochondral autograft transfer system (OATS™, Arthrex, Naples, FL) has been used in humans for treatment of articular cartilage defects including osteochondritis dissecans. The author reasoned that both systems had features that might facilitate graft collection and treatment of IOHC.

Direct visibility of the cranial and caudal aspects of the humeral condyle is achieved and the narrowest isthmus of the articular surface is marked by 2 temporary 1.1mm Kirchner (K)-wires placed within the joint contiguous with the articular surface. A calibrated K-wire (Acumed, Beaverton, OR) is driven medial to lateral across the humeral condyle at its most distal extent, using an inverted AT screw placed over the K-wire as a spacing guide to ensure that the maximal diameter of the screw would not encroach on the articular cartilage at the narrowest part of the isthmus. When the wire has penetrated the trans cortex, bone depth is measured using the etch mark on the calibrated K-wire held against the scale on a customized depth gauge. The base of the inverted AT screw placed over the K-wire acts as a spacer allowing an OATSTM reamer (OATSTM, Arthrex, Naples, FL) of maximal diameter to be centralized proximal to the AT screw on the medial aspect of the humeral condyle without encroaching on the intended screw position. The reamer position is maintained by advancing a guide drill across the condyle through the cannulated reamer. Parallelism of the drill guide/reamer and the wire/screw is desirable, but in some dogs with limited humeral condylar bone stock it is necessary to drive the screw parallel to the medial humeral joint surface rather than parallel to the transverse axis of the condyle. In these dogs, the screw passes obliquely from distomedial to proximolateral, craniodistal to the position of the intended bone core as marked by the guide drill. A hole is prepared for the AT screw using the customized AT insertion system (Acumed, Beaverton, OR). The guide K-wire is advanced through the trans cortex, soft tissues and skin and is secured with wire graspers on the lateral aspect of the condyle to minimize wire movement. A customized drill bit is advanced over the guide wire in increments of 3-4 mm and intermittently removed to allow removal of bone debris. External drill calibrated markings measured against the cis cortex allows advancement of the drill tip to within 2-6 mm of the trans-cortex. The reamer is then repositioned on the central guide drill. The intended socket depth is 75% of condylar width and is estimated from preoperative radiographs. Calibrated markings on the external barrel of the reamer allow socket depth measurement during reaming. An AT screw 2 mm shorter than the drill hole depth was threaded over the guide wire and inserted to finger tightness using a customized screw driver.

Core socket depth and alignment are confirmed using a calibrated alignment rod before cancellous bone dowel collection. When free autogenous cancellous bone is used, it may be collected from the proximal aspect of the ipsilateral humerus through a small fenestration created using a bone curette. Corticocancellous bone dowels of appropriate length may also be collected from the proximal aspect of the tibia or distal femur using an OATSTM core harvesting chisel 1 mm wider than the transcondylar recipient socket. The core harvester is a calibrated, cylindrical cutting chisel with louvered grooves at 4 equidistant points on the circumference. The louvers engage the bone core when hammer-tapped into the donor site and the bone dowel is extirpated by a twisting motion axial to the harvester, or by slight rocking (‘toggling’) whereupon the louvers engage the cancellous bone and break the dowel off at its base, which is subsequently removed within the chisel. Graft dowels are trimmed to fit recipient socket length where necessary. Grafts are transferred to the recipient socket by packing the free cancellous graft firmly with a tamping rod to the level of the cis-cortex or placing a dowel as a press fit using the OATSTM system. Humeral epicondylar augmentation may be performed with pin(s) or plates if the intercondylar fissure is deemed significantly unstable. In a study population of eight dogs operated by the author, time to resolution of lameness ranged from 4 - 84 days (mean, 35 days). Partial (≥50% width of central portion of condyle) or complete bone union was identified in 7/9 elbows by CT examination, 11 – 16 weeks postoperatively. Failure of bone union was observed in one dog where free cancellous graft was employed and the author therefore generally recommends application of trabecular bone dowel cores. 8 of 9 operated limbs in this series were deemed free of lameness up to 45 months postoperatively and several had returned to function as working dogs. Trabecular ‘spot-weld’ was consistently observed in all elbows with corticocancellous dowel grafts evaluated by CT. In contrast to an inert metallic implant which is susceptible to cyclic fatigue, the dowel should theoretically function as a biologically active transcondylar bridge capable of responding to chronic stress by active regeneration, repair, and remodelling in keeping with Wolff’s law.

Surgery Chapter
Bone dowel diameter is intrinsically limited by humeral condylar isthmus dimension and by the concurrent use of a transcondylar screw. Use of an AT screw allows placement of a mechanically robust but narrow implant whilst maximizing bone dowel diameter. The cannulated system allows accurate insertion, using the guide wire of the screw and the reamer centralizer as trajectory guides for the screw and bone dowel respectively, without need for fluoroscopy, although fluoroscopic guidance may further facilitate accurate screw placement. The fully threaded, tapered nature of the screw provides constant new bone purchase as it is inserted, minimizing strip-out and maximizing pullout strength, providing strong internal fixation.

Where it is perceived that a transcondylar bone dowel of diameter 5mm or greater cannot be placed in addition to a screw, the author’s preference is to use a screw only as he does not perceive that a bone graft alone provides adequate structural resilience, in the face of unstable motion of the two condylar segments in a clinically affected patient. Screw diameter is important and where possible the author employs at least a 4.5mm diameter cortical screw, since structural resilience will be dependant on the core diameter of this screw indefinitely. The author prefers to place this screw in a minimally invasive fashion by arthroscopic guidance. Other transcondylar implants are currently being investigated to try preventing cycling to failure in future iterations of technique.

Where IOHC is present, elbow fractures can be difficult to treat because of general inability to achieve osseous union at the intercondylar interface, such that epicondylar structural integrity is important. Non-union is common and can give rise to transcondylar implant loosening and resorption of bone around the implant. In recalcitrant cases this can be overcome using a transcondylar threaded rod and nuts on either side of the humeral condyle (Webb Bolt). Tissue glue may be applied to prevent nut loosening.

Simple condylar fractures usually affect the lateral condyle, with the lateral epicondyle being intrinsically weaker than the medial. The author prefers to reverse drill the fracture fragment from the condylar isthmus to the lateral collateral region, then reversing the drill bit through this fragment, reducing the fracture and driving the drill into the medial aspect of the humeral condyle. Then epicondylar support is provided using a k-wire to hold the segment in orientation allowing a transcondylar screw to be placed either as a position or lag screw. Particular attention must be applied to make sure that the epicondylar region is accurately reconstructed, otherwise mismatch at the intercondylar area is inevitable and fragments with short epicondylar segments are prone to rotate around the condylar screw and become malaligned. Augmentation of the medial epicondylar ridge using locking plates such as the 2.0 or 2.4 mm Synthes LCPTM or the 2.0 mm or 2.7 mm string-of-pearls SOP™ plate may be beneficial and as a general guideline, if the author feels that there is any possibility of aberrant healing or tenuous implant purchase, an epicondylar plate is applied.

Complex T and Y-fractures of the humerus can readily be repaired without olecranon osteotomy and the author does not recommend osteotomy because of difficulties with healing at this tension site. Two approaches are valid – either reconstruction of the medial condylar fracture first, with subsequent repair of the lateral condylar fracture; or repair of the humeral condyle first and then reconstruction of the humerus. The author favours the latter approach and frequently employs a fracture distractor to overcome muscle contracture prohibiting satisfactory reduction. Fixation can be applied using standard or locking plates or plate-rod techniques. The author previously used hybrid 3.5/2.7 pancarpal arthrodesis plates applied medially and laterally but now favours 2.7mm and 3.5mm SOP™ plates. An intramedullary pin placed in the medial epicondylar and exiting the proximal humerus via the sububtubercular region can facilitate realignment and may obviate requirement for two plates, facilitating a plate-rod technique. Cerclage wire can be important or vital for re-apposition and stabilisation of spiral fragments, and can be used to sequentially realign long spiral fragments under guidance of a fracture distractor.

In small fragments or comminuted juxtaarticular fractures of cats or dogs, external skeletal fixation may be very useful including application of small half-pins, self-compressing threaded pins or olive wires on arches distally to facilitate condylar reconstruction. Such arches and stretch-rings mounted with linear components further proximally and constituting hybrid fixation systems offer tangible advantages over conventional linear frames and where conventional circular frames cannot be mounted on the proximal thoracic limb. However, external skeletal fixation of the humerus in dogs is a high-maintenance technique in that pin tract discharge and prolonged healing times may be issues. Therefore the author prefers internal fixation unless there is very valid rationale to choose fixator constructs.