Pediatric Lateral Humeral Condyle Fractures

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Abstract: Lateral humeral condyle fractures are common and potentially challenging injuries to treat. The Weiss and Song classifications are helpful to guide treatment and prognosis. Nonsurgical management is the mainstay for nondisplaced or minimally (<2mm) displaced fractures, though one needs to watch for progressive displacement during casting. Delayed union and nonunion can occur, though, with appropriate vigilance and early surgical treatment, chronic nonunion can be avoided. Surgical management is performed for displaced fractures with closed or open reduction, depending on the amount of displacement and the need to visualize the articular surface for an anatomic reduction. Kirschner wires or screws are both appropriate methods of fixation. Elbow stiffness and lateral bump formation are common complications, though may not lead to major functional disability.

Key Points:

- Weiss and Song classifications help guide treatment and prognosis of lateral humeral condyle fractures.
- Closed treatment of lateral condyle fractures requires vigilance to ensure displacement does not occur.
- The goal of surgical treatment is to obtain an anatomic reduction of the distal humerus joint surface stabilized by either pin or screw fixation.
- Delayed union can be treated to prevent chronic nonunion and associated complications such as cubitus varus or valgus.

Introduction

Lateral humeral condyle fractures (LHCF) provide a unique challenge for pediatric orthopedic surgeons as the fractures are physeal, intra-articular, and mostly cartilaginous. The blood supply of the lateral condyle arises from the anastomotic vessels of the brachial artery along the posterior aspect of the distal humerus. The trochlea typically ossifies at around 8 years in girls and 9 years in boys, leading to difficulty in identifying the articular fracture line on radiographs. LHCF account for 10-20% of pediatric elbow fractures, making these injuries the second most common intra-articular fracture in children.[1–3] The mean age of injury is 6 years with a slight male predominance of 67%.[4] The most common mechanism of injury is fall on an outstretched hand, and the most common associated injuries are ipsilateral elbow dislocation (11.4%) and ipsilateral upper arm fracture (8.3%).[4]

The fracture typically starts in the posterolateral metaphysis between the origins of the extensor carpi radialis longus (ECRL) and brachioradialis with the

ECRL and extensor carpi radialis brevis (ECRB) attached to the distal fragment along with the lateral collateral ligaments. Increasing displacement is typically caused by more extensive injury to both the anterior and posterior aspects of the elbow capsule. Two theories exist for the mechanism of injury. The “push-off” theory claims that falling onto an outstretched hand can cause the radial head to impact into the lateral condyle, causing a fracture. The more accepted “pull-off” or avulsion theory claims that the fracture is a result of a varus moment on the lateral condyle.[5] Likely both contribute to varying types of LHCF. The more common fracture pattern extending to the apex of the trochlea is more likely a result of the “pull-off” theory while the fracture through the ossific nucleus of the capitellum is more likely a result of the “push-off” theory.[6]

Evaluation

A thorough history and physical exam are important with a focus on concomitant injuries, swelling, bruising, and neurovascular status. Unlike supracondylar humerus fractures, neurovascular injury is rare in LHCF. Plain radiographs are the mainstay for evaluation of LHCF, which should include AP, lateral, and internal oblique views.[7,8] The importance of obtaining an internal oblique view of the elbow has been well documented, as fractures may appear minimally displaced on the AP view, but will show maximal displacement on the internal oblique radiograph (Figure 1).[9–11]

Figure 1. *AP (left) and internal oblique (right) radiographs demonstrating maximal displacement on the internal oblique*

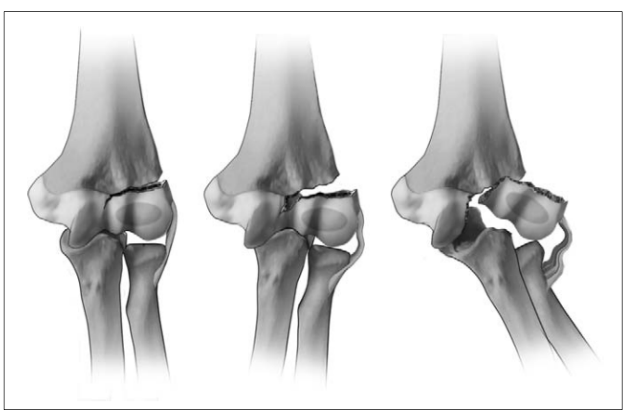


Figure 2. *(From left to right) Weiss Type 1: <2 mm displacement; Weiss Type 2: 2 – 4 mm displacement with intact cartilage; Weiss Type 3: ≥ 4 mm displacement with articular incongruity.*
(Reprinted with permission from Weiss, JM, Graves, S, Yang, S, et al.: A new classification system predictive of complications in surgically treated pediatric humeral lateral condyle fractures. J Pediatr Orthop 2009;29:602–605.)

Both ultrasound[12,13] and MRI[14] can be used to distinguish fractures with an intact cartilaginous hinge from those without. A 2019 study by Li et al. described a transverse ultrasound technique used to visualize the presence or absence of a cartilage hinge in minimally displaced LHCF. In their series, none of the fractures with an intact cartilage hinge on ultrasound displaced further.[12] Ultrasound, however, is often limited by the availability of a skilled technologist. MRI can also be used to assess the integrity of the cartilage hinge; however, it is associated with increased cost and the need for sedation in young children. Thus, MRI is not routinely used for evaluation of LHCF. In 2017, Thévenin-Lemoine et al. described a limited protocol MRI which they used for LHCF that did not require sedation.[14]

Classification

Multiple classification systems exist for LHCF. The Milch classification is an anatomic classification that describes whether the fracture passes through (Type 1) or medial to (Type 2) the capitellar ossification center.[15]

It is rarely used as it does not guide treatment and has frequently found to be inaccurate.[16] The Jakob classification describes three stages of displacement to include nondisplaced with an intact articular surface (Stage 1), nondisplaced with disruption of the articular surface (Stage 2), and completely displaced (Stage 3), fractures.[5] This was modified by Weiss et al. to define the measurement of displacement and attempt to determine whether an articular hinge was present. In the Weiss classification, Type 1 fractures are displaced by less than 2mm. Type 2 fractures have more than 2mm, but less than 4mm of displacement and have a presumed intact cartilaginous hinge. Type 3 fractures have 4mm or more of displacement and no cartilaginous hinge (Figure 2). Weiss et al. found that the amount of displacement was predictive of both the presence or absence of a cartilage hinge, as well as the likelihood of complications, which allows this classification system to guide treatment and determine prognosis.[17] Song et al. have produced the most detailed classification, which consists of a five-stage system based on fracture stability (Figure 3).

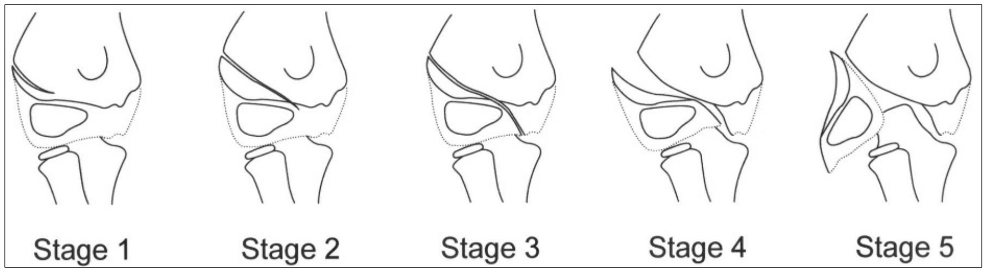


Figure 3. *(From left to right) In Stage 1, the fracture is stable, displacement is ≤2 mm, and the fracture line is limited to within the metaphysis. In Stage 2, the fracture is indefinable, displacement is ≤2 mm, the fracture line extends to the epiphyseal articular cartilage, and there is a lateral gap. In Stage 3, the fracture is unstable, displacement is ≤2 mm, and there is a gap that is as wide laterally as it is medially. In Stage 4, the fracture is unstable, and displacement is >2 mm. In Stage 5, the fracture is unstable, and displacement is >2 mm with rotation. (Reprinted with permission from Song, KS, Kang, CH, Min, BW, et al.: Closed reduction and internal fixation of displaced unstable lateral condylar fractures of the humerus in children. J Bone Joint Surg Am 2008;90:2673–2681)*

Figure 4. *Arthrogram with an arrow demonstrating articular gap. This case converted to open reduction when articular malreduction was noted on arthrogram.*

Stage 1 describes a fracture in which the fracture line remains in the metaphysis and is therefore stable. In Stage 2, the fracture line progresses from the metaphysis into the cartilaginous distal humerus and leaves a lateral gap of ≤2mm. The stability of Stage 2 fractures is unknown. Stage 3 is a minimally displaced, complete fracture with fracture gap that is the same medially and laterally and is ≤2mm. Stage 4 fractures have displacement >2mm, and Stage 5 fractures demonstrate rotation of the fragment.[7] Stages 3-5 are inherently unstable. Recently, the Song classification was validated by demonstrating a high interobserver and intraobserver reliability and by successfully guiding treatment and prognosis.[18]

Treatment: Nonsurgical Management

Most authors recommend initial cast immobilization with close follow-up imaging for nondisplaced and minimally displaced (≤ 2 mm) LHCF (Weiss Type 1; Song Stage 1-2).[17,19,20] Follow-up radiographs are essential as up to 18% of fractures will displace despite immobilization.[19,21,22] A systematic review of minimally displaced LHCF by Knapik et al. revealed a 14.9% rate of subsequent displacement[21] while Greenhill et al. found that 18% of Song Stage 2 fractures in their series displaced.[19] Long-arm cast immobilization should be used with the elbow flexed to approximately 90° and the forearm placed in neutral rotation. Follow-up radiographs should be obtained at 4 to 8 days after the initial injury.[7,22] Weekly radiographs, including AP, lateral, and internal oblique views, are recommended for

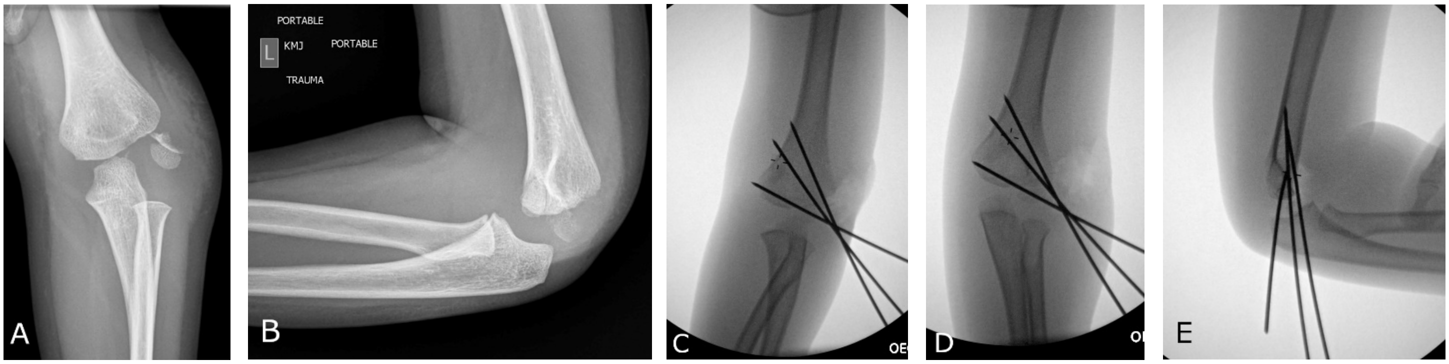


Figure 5. Preoperative (A, B) and Intraoperative (C, D, E) radiographs of a 3-year-old boy who sustained a Weiss Type 3, Song Stage 5 LHCF. Open reduction and pin fixation were performed.

2-3 weeks to identify interval displacement.[8] Some advocate that the cast be removed prior to radiographs. For fractures that do not displace, healing usually occurs within 4 to 6 weeks after initiation of immobilization. The cast may be removed when there is bridging callus visualized at the metaphysis, and the patient is no longer tender at the fracture site.[8,22] Range of motion is then initiated with a gradual return to full activity over the following 4 to 6 weeks.

Treatment: Surgical Management

Surgical management of LHCF involves closed or open reduction and fixation with the goal of increasing stability for union and restoring the articular surface of the distal humerus to an anatomic position. Indications for initial surgery include fractures that are displaced > 2mm suggestive of instability or disrupted articular surface, progressive displacement on serial radiographs, and failure of nonsurgical treatment with delayed healing greater than 8 weeks.[7,20,23]

Closed Reduction & Fixation

A closed reduction technique is most commonly used for fractures with > 2mm displacement and an intact hinge at the articular surface, fractures without rotation, and those that were initially nondisplaced but subsequently displaced on follow-up imaging.[7,17] Fracture reduction can be obtained via a valgus force applied to the elbow with the forearm positioned in supination.[7,23] Reduction should be confirmed using intraoperative fluoroscopy and an arthrogram (after fixation) to confirm anatomic alignment of the articular surface.[17] The fracture can then be stabilized with two or three 0.062-inch (1.6mm) Kirschner wires (K-wires) placed percutaneously. Percutaneous 3.5mm to 4.5mm cannulated screw fixation has also been described for stabilization of these fractures.[24–27] (Additional link #1: POSNA Academy Closed Reduction and Screw Fixation for Displaced Lateral Condyle Fractures) The distal humerus in young children is largely cartilaginous and is not well visualized on plain radiographs. Thus, intraoperative arthrography, most often used in conjunction with closed reduction and surgical fixation, is often recommended to either confirm an anatomically reduced joint surface or to better delineate the characteristics of a fracture (Figure 4).[8,17] Conversion to open reduction must be performed if there is a malreduced articular surface on arthrogram. However, a recent study by Vorhies et al. showed that the use of intraoperative arthrogram changed surgical management in only 8% of cases.[28] These results did not differ if the arthrogram was performed before or after fixation. The authors concluded that the use of arthrography may be useful for confirmation of final fracture alignment; however, it is unlikely to result in a change in treatment.t

Open Reduction and Fixation

Open reduction is most often used for LHCF that are grossly displaced (>4mm) or with joint surface disruption, and in those that present with malrotation (Figure 5). Open reduction is also indicated when closed reduction has failed or an anatomic joint surface

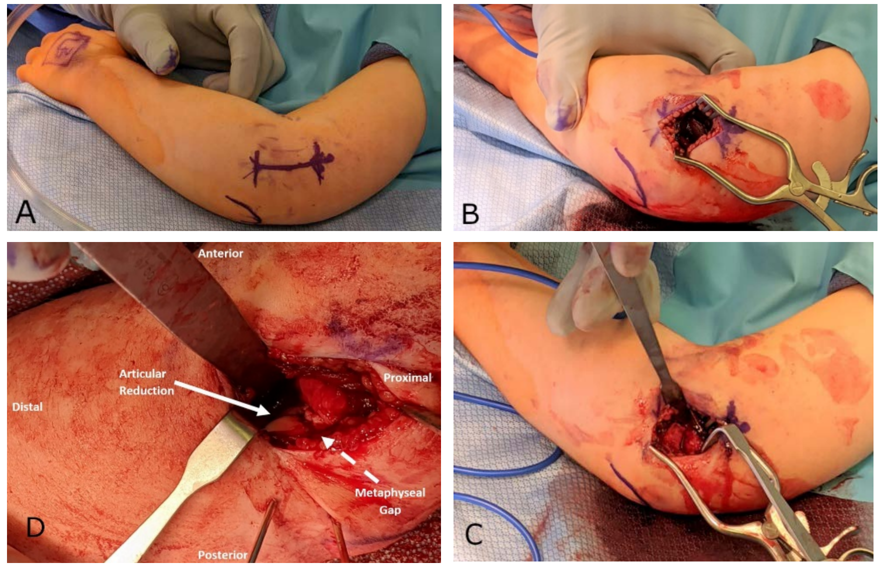


Figure 6. *Intraoperative photographs for the same 3-year-old patient demonstrated in Figure 5. A) Marked incision along distal lateral humerus B) Exposure with hematoma and traumatic plane between brachioradialis and radial wrist extensors C) Displaced & rotated fracture fragment D) After reduction and pinning, articular reduction is anatomic (solid arrow) even though a slight gap persists in the metaphysis (dotted arrow).*

reduction cannot be confirmed intraoperatively. In the series by Weiss et al., all Weiss Type 3 fractures with greater than 4mm of displacement were treated with open reduction[17], and a prospective protocoled study by Nazareth et al. used 4mm of displacement as the cut off for conversion to an open reduction[20].

An open reduction is performed via a lateral approach to the distal humerus (Figure 6). Particularly in the case of a grossly displaced fracture, the interval for deep dissection is already created by the injury between the wrist extensor muscles. During exposure, posterior soft tissue dissection should be avoided. Care should be taken to obtain direct visualization of the joint line, and the goal of reduction should be anatomic alignment of the joint surface. Visualization can often be achieved with a small Bennett or Hohmann retractor placed across the anterior aspect of the distal humerus and gently retracting the brachialis and anterior capsule. An Army-Navy retractor can also be used to lift the musculature anteriorly for visualization of the joint. The fracture at the lateral cortex often has associated comminution or plastic deformation and can thus be misleading if relied upon for fracture reduction. The use of a headlight or lighted suction can aid in improved visualization of the articular surface. If the fracture is displaced or rotated, a Kirshner wire may be used as a joystick to maneuver the fracture fragment. A towel clip or dental pick may also be used to manipulate the fragment. As in the case of closed reduction, either pin fixation or screw fixation may be used. Pins should be placed percutaneously through the skin, posterior to the incision. If a cannulated screw is chosen, it may be placed percutaneously or through the incision. The joint surface should be again visualized after fixation to confirm anatomic reduction. (Additional Links 2a & 2b: POSNA Academy Open Reduction and Fixation of Lateral Condyle Humerus Fractures)

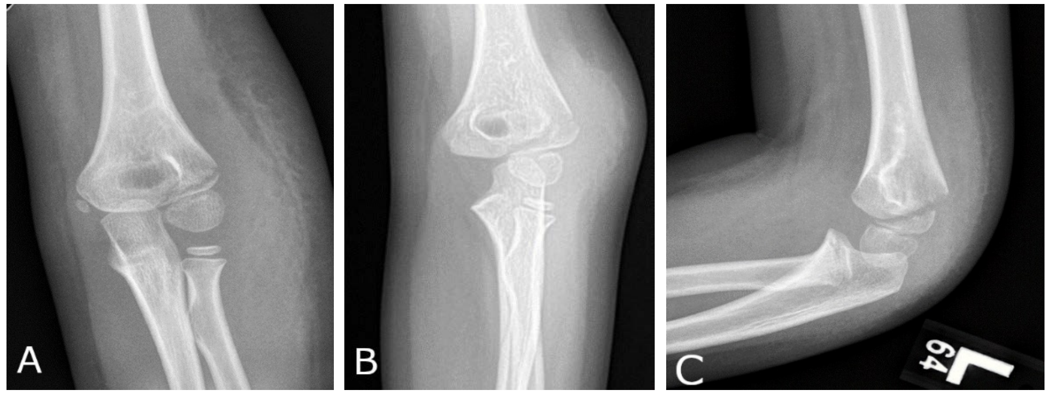
Postoperative Care

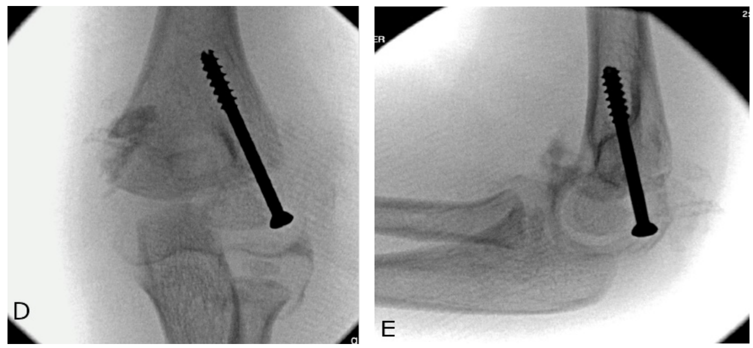
If K-wires are used for fixation, they are left in place for 3 to 4 weeks after surgery and are removed in clinic. A cast is then potentially reapplied for an additional 2 to 4 weeks, depending upon radiographic and clinical healing. There is some evidence that screw fixation results in faster healing times[25–27], and the cast can be discontinued at 4 to 6 weeks in these cases. After cast removal, active range of motion is begun with slow return to usual physical activities.

Kirschner Wire Fixation Versus Screw Fixation

For fractures treated with both open and closed reduction techniques, both K-wires and cannulated screw fixation (Figure 7) are accepted forms of stabilization. Biomechanically, two lateral pins which diverge at 60° have been shown to be superior than less divergent pins or parallel pins, and a three divergent pin construct is superior to all two-pin constructs in valgus and torsional loading.[29] Schultz et al. found a single 4.0mm

Figure 7. *Preoperative (A, B, C), and intraoperative (D, E) imaging demonstrating closed reduction, screw fixation, and arthrogram confirmation of joint surface reduction in a 5-year-old female with a LHCF.*





cannulated screw to be biomechanically superior to two divergent lateral pins, though the clinical superiority of this mechanical benefit is unclear.[30]

Advocates for K-wire fixation cite the high success rate for fracture healing and the ease of removing Kirshner wires in an office setting.[20] Cannulated screws have the advantage of providing compression across the fracture site and requiring shorter postoperative immobilization.[25–27] Cannulated screws have also been shown to have a lower infection and nonunion rates when compared to K-wire fixation. Li et al. showed a 16.7% rate of superficial skin infections in LHCF treated with open reduction and percutaneous pinning, compared to zero infections in those treated with screws.[25] Stein et al. reported pin site infections (including one deep infection) in 5 of 22 fractures treated with Kirshner wires, again compared to no infections in groups treated with screw fixation.[26] Infection rates associated with K-wires in these smaller series, however, are higher than those in previously reported larger series, which range from 1.8-3.4%.[17,31] There have also been reports of lower nonunion rates with screw fixation compared to K-wire fixation.[27,32] Nazareth et al. showed delayed healing in Weiss Type 2 and 3 fractures stabilized with pins in 11% of their LHCF, and all of these healed with conversion to screw fixation.[20] Gilbert et al. reported a 7% nonunion rate in their series of LHCF treated with pins, compared to no nonunions in those stabilized with screws.[27] In a case series of 96 LHCF treated with either closed or open reduction and screw fixation, Shirley et al. reported one case of a fracture treated with primary screw fixation that lost fixation and was revised.[24]

The largest disadvantage of screw fixation is the need for subsequent surgery for implant removal, along with the cost and risks associated with a second surgery.[27] Further research is required to determine which fractures are amenable to K-wire fixation and which are at an increased risk for nonunion and should be treated with primary screw fixation.

Outcomes

The prognosis of appropriately treated LHCF is generally good to excellent with regard to union rates, avoidance of complications, and clinical function. Return to normal function and functional elbow range of motion can be expected in most cases. Avoidable complications and poor prognosis often result from misdiagnosis or undertreatment.

Fractures Treated Nonsurgically

The prognosis for nondisplaced or minimally displaced ≤2 mm LHCF depends on early recognition of displacement. LHCF can displace with cast treatment

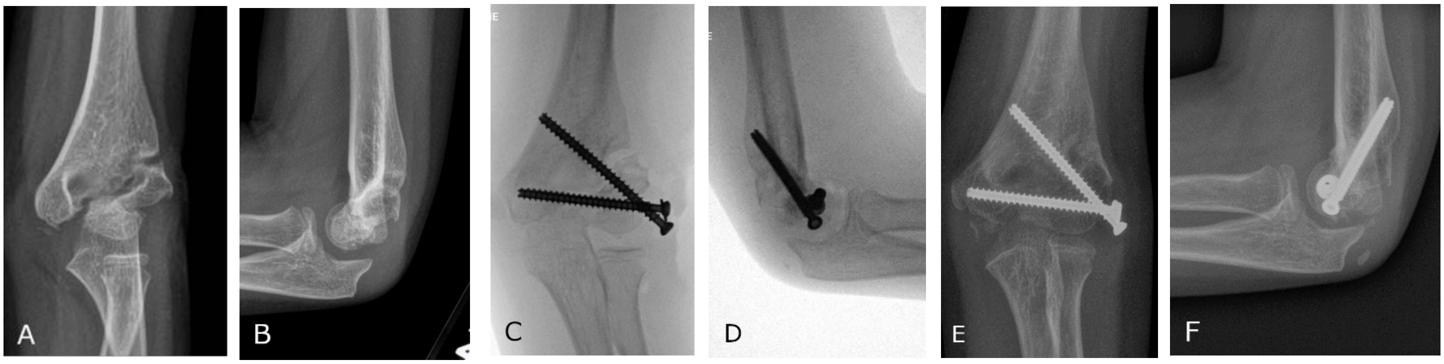


Figure 8. *Preoperative (A, B), Intraoperative (C, D), and 10-weeks postoperative (E, F) radiographs of a 5-year-old female with a long standing left LHCF nonunion treated with in-situ bone grafting and screw fixation.*

8.5%-18% of the time,[19,21,33] ultimately affecting prognosis. Fractures that displace in a cast have 14.5% nonunion rate despite immobilization.[21] Difficult to treat nonunions are rare if displacement is recognized and delayed union addressed surgically. The mean time to union for nonsurgically treated fractures is not widely reported though immobilization time in a cast ranges from 17 days to 12 weeks, with an average of approximately 6 weeks. Reported elbow range of motion in nonsurgically treated fractures is excellent, with symmetric motion obtained in 91% of patients and <10° loss of motion in the remaining 9%.[21] Other studies demonstrate 7.1 - 8° mean loss of extension,[34,35] which did not differ from surgically treated fractures.

Fractures Treated Surgically

The prognosis for surgically treated LHCF overall is also favorable. Surgically treated fractures demonstrate mean time to union of 6.4 - 6.6 weeks.[23,36] Good to excellent outcomes can be achieved in nearly 90% of cases, in which elbow extension is within 15° of the uninjured side, and there are no major complications. Perioperative complications include neurovascular injury, infection, and loss of reduction. Radial nerve palsy has been reported in conjunction with LHCF as a result of the initial injury,[37] but not as a complication of treatment. Infections are relatively uncommon and not uniformly reported. Silva and Cooper reported a 1.8% rate of infection for closed reduction and pinning compared to 3.4% for open reduction and pinning.[31] Loss of fixation in the short term is also not well reported, though can occur.

Approximately 10-16% of cases demonstrate a poor outcome with loss of motion, delayed union or nonunion, infection, avascular necrosis, malunion, cubitus varus, or ulnar neuropathy.[23,31,38] Salgueiro et al. reported a 16% delayed union rate in a series of 210 surgically treated LHCF, with 3% requiring further intervention.[23] They reported that residual displacement >1mm following reduction and fixation was associated with an increased risk of delayed union. When reported as nonunions, rates for surgically treated fractures vary from 0-3%. A large series by Pace, et al. reports 5/168 (3%) nonunion in patients with Weiss Type 3 fractures.[39] These results suggest that improving quality of reduction may be a modifiable risk factor for delayed union or nonunion. Additionally, some studies suggest the rate of nonunion may be lower with screw fixation compared to pin fixation.[27,32]

Long Term Complications

Long term complications, including lateral overgrowth, growth disturbance, and permanent loss of elbow motion, can occur in both nonsurgically and surgically treated fractures. Lateral overgrowth is a frequent occurrence (up to 73%) following LHCF treated either surgically or nonsurgically.[40] The condyle may simply be wider or may have a spur which projects from the metaphysis. The etiology is unknown, but speculation includes hyperemia and bone formation from displaced periosteum. It is typically of no functional consequence but informing patients about the likelihood prior to treatment may prevent later misgivings about the explanation.

In addition to widening or spur formation, alteration in growth may change the carrying angle, resulting in cubitus varus or valgus.[1] Growth disturbance from mild avascular necrosis (AVN) of the trochlea laterally can result in a deepening of the groove between the capitellum and trochlea or "fishtail" deformity, which m ay not lead to significant functional impairment. When AVN is more extensive, involving both the medial and lateral trochlea, it may lead to severe deformity, loss of motion, and pain. Although the etiology remains unclear, especially given that AVN is also reported in nonsurgically managed cases, conventional wisdom remains that soft tissue stripping should be minimized to that necessary to visualize reduction, especially posteriorly.

Long-standing nonunions can occur with nonsurgical or surgical fractures, which often lead to functional range of motion limitations, and/or deformity. Long standing nonunions are treated with revision fixation with or without bone grafting, with concomitant deformity correction osteotomy as needed (Figure 8).

Development of valgus deformity from nonunion may lead to tardy ulnar nerve palsy. Typically symptoms develop 10-12 years after the initial injury, often initiated by a mild re-injury.[41] Symptoms usually respond to nerve decompression and transposition with or without corrective osteotomy.

Although long term loss of range of motion of > 5 degrees can occur frequently, Sinikumpu et al. demonstrated that at mean 12.4 years follow-up after injury, the overall function of the injured extremity using the Mayo Elbow Performance Score was not significantly different from the uninjured contralateral elbow.[42]

Summary

LHCF are common injuries in children. These injuries require special attention to ensure adequate and appropriate healing. With appropriate treatment and vigilance, excellent outcomes can be expected. General guidelines for surgical indications can be obtained from the Weiss and Song classifications. An arthrogram can aid in decision making for confirming an adequate closed reduction or performing an open reduction. Either pins or cannulated screws are appropriate fixation methods. Understanding the common pitfalls and complications can help minimize them and allow surgeons to counsel families appropriately.

Additional Links

POSNA Academy Closed Reduction and Screw Fixation for Displaced Lateral Condyle Fractures: http://www.posnacademy.org/media/Closed+Reduction+Screw+Fixation+for+Displaced+Lateral+Condyle+Fractures/0_293pszdc

POSNA Academy Open Reduction and Fixation of Lateral Condyle Humerus Fractures: http://www.posnacademy.org/media/ORIF+Lateral+Condyle+Humerus+Fracture/0_7u4r083nhttp://www.posnacademy.org/media/1_7mkgrxtl

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