Abstract

Lateral humeral condyle fractures in children are easily missed and often associated with complications. These complications include malunion, delayed union or nonunion, lateral spur formation, fishtail deformity and growth disturbances. There is also controversy related to best treatment options including closed vs open reduction and K-wire vs screw fixation. Though some complications like malunion are avoidable, others like lateral spur formation are inevitable. Knowledge about these complications would help in counseling patients and their families. The purpose of this article was to review common complications related to these fractures and suggest tips to avoid some of them.

Keywords: Paediatric, Lateral condyle fracture, Internal oblique X-ray, Arthrogram, Anatomical reduction, Complications, Tips to overcome

Introduction

Lateral Humeral condyle fractures (LHCF) are the second most common elbow fractures in children, after supracondylar humerus fractures. LHCF account for 12%-17% of all distal humerus fractures [1, 2]. When the fracture is minimally displaced, its diagnosis is challenging and it is missed more often than any other type of elbow fracture in children. In a series of 23 children with LHCF, Flynn et al found that 35% of nonunions were due to unrecognized fracture at the time of injury [3]. Therefore, a strong clinical suspicion and accurate radiographic interpretation are recommended to diagnose LHCF [4].

The widely used Jakob classification for LHCF is based on the degree of displacement and rotation of the lateral condyle fragment and comprises of three stages [5].

Stage 1: < 2 mm displacement indicating intact cartilaginous hinge.
Stage 2: 2–4 mm displacement without rotation of the fragment.
Stage 3: > 4 mm displacement and rotation of the fracture fragment.

The Weiss classification system which is based on degree of displacement and articular congruity can help predict the risk of complications. Compared to surgical treatment outcomes for type 2 fractures (more than 2 mm displacement but intact articular surface/hinge), type 3 fractures (more than 2 mm displacement with articular surface breached) had 3 times higher complication rates [6].

LHCF require special attention to ensure appropriate diagnosis and treatment as their clinical and radiographic outcomes are often associated with complications [7]. Understanding these complications would help to minimize some of them as well as help with patient and family counselling. The purpose of this article is to review common complications related to LHCF and suggest tips to recognize them and hopefully avoid them.
Loss of Reduction / Non-anatomic Reduction

Since the lateral condyle of the humerus in children is primarily unossified, accurate reduction of LCHF and recognition of inadequate reduction are challenging. The classification and treatment principles are based on the amount of fracture displacement on radiographs. As the fracture line is oriented in a posterolateral direction, conventional radiographs frequently underestimate the true displacement. The internal oblique view demonstrates the maximum displacement and should be performed in borderline cases to aid in treatment decision [4].

4 mm displacement on the metaphyseal side of the fracture has been used as predictive of articular surface disruption [6]. Though MRI can show the articular surface well, it is seldom required in clinical practice.

At surgery, open reduction can provide direct visualization and confirmation of articular surface reduction. If closed reduction and internal fixation are to be performed, an arthrogram would help to assess the articular surface and aid in internal fixation by delineating the articular surface. A common error during internal fixation is to place the K-wire or screw too proximal and close to the metaphyseal side of fracture since this part is visible on plain radiographs. This can lead to inadequate fixation and subsequent loss of fixation (Figure 1). A properly inserted screw through the cartilaginous fracture fragment may appear to be insufficiently seated, as the screw head would be positioned away from the ossified part of the lateral condyle. Besides suboptimal fixation, other reasons for loss of reduction after internal fixation with K-wires may be related to premature removal of K-wires.

Malunion

Malunion has been amply reported after LCHF in children. Cubitus varus deformity is most common in undisplaced and minimally displaced fractures [9, 10, 11]. One theory is that these seemingly nondisplaced fractures lose reduction, with the condylar fragment separating distally or tilting medially [11, 12]. However, Tan et al attributed this deformity to prolonged hyperaemia and growth stimulation of lateral condyle [13]. Cubitus valgus, which is much less common, is believed to be caused by lateral physeal arrest, non-union, avascular necrosis or malunion [12, 13]. Skak et al reported that none of their 7 patients with varus deformity were more than 8 years age at time of injury, whereas valgus position in 8 patients was found with equal frequency among all age groups [8].

Closed reduction and percutaneous internal fixation may lead to malunion if there is suboptimal visualization of fracture reduction on fluoroscopy (Figure 2). When in doubt, an arthrogram or open reduction approach can prevent malunion by direct visualization of the articular surface reduction.

Minor deformities and those not limiting the elbow function can be treated conservatively [14]. Supracondylar humeral osteotomy has been used to improve symptomatic cubitus varus/varus alignment in pediatric elbow malunions. The advantage of such an osteotomy is the minimal risk to the articular cartilage, distal humerus blood supply and elbow motion. Although proximal osteotomy can improve varus and valgus malalignment, it does not address elbow motion deficits or prevent long-term arthrosis from articular malunion.

For LCHF malunion involving the articular surface of the distal humerus, Bauer et al [15] reported on intra-articular corrective osteotomy to improve elbow motion, pain and radiographic alignment. They emphasized careful selection of patients and meticulous surgical technique. The authors observed significant improvement in the elbow range of motion and suggested that intra-articular corrective osteotomy can be
successful when performed in the first year after the initial fracture. They cautioned performing this procedure in Milch type 2 fracture malunion as there was less satisfactory improvement in elbow motion and alignment.

Growth Arrest
Growth arrest or premature epiphyseal closure after LCHF are uncommon and may not be obvious for years [10, 12, 17, 18]. Tan et al reported a growth arrest rate of 5.4%. As LHC are typically Salter-Harris type IV fractures [12, 13] with the fracture line extending through the metaphysis, physis, and epiphysis, growth arrest can occur if there is initial or persistent displacement after treatment. A number of factors may contribute to premature physeal arrest, including fracture displacement, soft tissue injury and vascular insult, non-anatomic reduction, and compression across the physis with implants [19]. Since the distal humerus has limited growth (compared to the proximal humerus), the sequelae of growth arrest may be minimal or may not manifest until later. Mehlman et al [19] reported 3 cases of physeal arrest after a mean of 2.6 years after injury (Figure 3, 4). All patients had increased carrying angle; 2 were asymptomatic and 1 patients had pain and loss of terminal extension. The authors recommend diligent monitoring of patients and long-term follow-up till skeletal maturity. If this is not feasible, the family should be counselled about the possibility of late deformities and to follow-up in case such deformities occur.

Loss of Motion
Loss of terminal range of motion is more prevalent with LCHF fractures than with other elbow fractures. Minor (5°) loss of flexion-extension motion has been reported in up to 40% patients after LCHF and 15.6% patients had >15° loss of flexion-extension movement in one series [20]. Tan et al [13] reported that extension and flexion limitations affected 9.7% and 11.5% of LCHF respectively. Compared to supracondylar humerus fractures which start healing at 3 weeks post-injury, LCHF may take about 4 to 6 weeks for initial healing to be apparent. It is not infrequent to have long-arm cast immobilization for about 6 weeks following LCHF treatment. Besides duration of immobilization, other reported risk factors associated with loss of motion include intra-articular fracture and scar tissue, inappropriate treatment, K-wires as opposed to screw fixation and delayed presentation [13]. Though most motion deficits decrease at follow-up, Sinikumpu et al [20] reported >10° loss of elbow motion in 9 of 32 patients and >10° loss of forearm rotation in 6 of 32 patients at a mean follow-up of 12 years. Anatomic reduction of the fracture and screw fixation could allow for early mobilization of elbow thereby minimizing loss of motion in patients with LCHF. After initial fracture healing, our preference is to allow the patient to regain range of motion without formal physical therapy. Those with significant loss of motion may benefit from formal physical therapy after 2 – 3 months. Very rarely, surgery may be required for treatment of elbow arthrofibrosis [21, 22].

Delayed Union
Delayed union is defined as a lateral condyle fracture that does not exhibit radiological evidence of fracture healing by eighth week of follow up [23] (Figure 5). Risks for delayed healing include multiple attempts at reduction and amount of residual displacement after reduction [23]. Tan et al. [13] reported delayed union in patients treated conservatively or those that were inadequately reduced when managed operatively. They recommend prolonged immobilisation or open reduction and internal fixation with or without bone grafting.

Lateral Spur / Overgrowth
The most frequently seen complication after LCHF treatment is the lateral spur or overgrowth [7, 13, 24, 25] (Figure 6). This complication is frequently seen on radiographs and sometimes on clinical evaluation. When there is focal overgrowth, it

Figure 3: A 7-year-old girl with completely displaced lateral condyle fracture (3 a, b). The fracture was treated with open reduction and pinning (3 c, d). Radiographs at 5 months postop, show acceptable fracture alignment (3 e, f). At 3 years follow-up, the fracture is united but there is mild increase in the valgus alignment at the elbow due to lateral-sided growth arrest (3 g, h). CT scan is in the next figure. Image courtesy of Charles T. Mehlman, DO, Cincinnati Children’s Hospital.

Figure 4: CT scan of the same patient as in Figure 3 shows growth arrest (white arrows) on coronal and sagittal section. Also seen is some avascular necrosis of trochlea. Image courtesy of Charles T. Mehlman, DO, Cincinnati Children’s Hospital.
The long-term natural history of lateral spur is not known but based on the growth pattern of the distal humerus, it is unlikely to remodel and more likely to persist at skeletal maturity [7, 24, 26]. It is advisable to inform the patients and families about the likelihood of lateral spur formation prior to initiation of treatment.

**Fish Tail deformity / AVN**

Avascular necrosis is a rare and devastating complication and poses a vexing problem to treating surgeon. Minor degrees of AVN and slight deepening of trochlear groove, however, is more commonly reported in recent literature [8]. When significant, it leads to a concavity which is visible on AP radiographs where the lateral trochlear ossification centre fails to develop because of disrupted blood supply to the trochlea, leading to fish tail deformity [7, 13, 24, 29, 30]. It occurs when the lateral vascular tributaries are disrupted, whereas frank osteonecrosis occurs when both the medial and lateral blood supplies are injured. Tan et al [13] reported 14% incidence of fishtail deformity and 1% incidence of AVN in their systematic review. Though it is recommended to avoid posterior soft tissue stripping when trying to visualise the fracture to decrease vascular insult, AVN has been reported after nonsurgical treatment as well [7, 24, 30].

Increased risk of AVN has been correlated with displaced Milch Type 2 fractures, Jakob Type 3 fractures as well as delayed treatment for these fractures [13]. Instability, mal-reduction and lack of compression at fracture site have all been reported to increase the risk of AVN [6, 8, 9, 13, 31].

The manifestation of AVN and deformity occurs late; about 4-8 years after the initial injury and can be difficult to evaluate early. It can lead to limited ROM, pain, loose bodies, and/or cubitus valgus deformity, leading to degenerative arthritis, and ulnar neuropathy [7, 8, 13, 24, 30, 32]. MRI can help to visualize AVN before radiographs in patients with late developing stiffness or pain [7, 24, 30]. Treatment for this rare complication can be challenging. The spectrum of treatment includes observation for asymptomatic patients, removal of loose bodies, epiphysiodesis, osteotomy, and/or ulnar nerve transposition [29, 30]. Tonolino et al described osteonecrosis of two types, type A with lesions lateral to medial crista of trochlea which are more likely to lose range of motion and develop arthritis. They typically do not develop angular deformities. Type B lesions which involve the entire trochlea and part of the metaphysis are more likely to create a progressive varus deformity [30]. Glotzbecker et al [30] reported on 15 cases of fishtail deformities; 4 were related to LCHF at a follow-up of 3.9 years. Their report lacks details and specific recommendations for LCHF. A treatment algorithm was suggested in which children with functional ROM (25-130), minimal symptoms and small...
defects were treated with observation. Children with severe symptoms and deformity were treated surgically by joint debridement and growth modulation/osteotomy for deformity correction. They reported good short term results but at long term follow up, 43% had persistent pain and only 14% regained full ROM.

**Screws vs Pins**

Good results have been reported with both K-wires and screw fixation for LCHF in the literature [7, 13, 24, 33, 34, 35, 36]. Recent studies have favoured screw fixation over K-wires due to reduced cast time, earlier mobilisation, reduced infection rates, fewer non-union rates, faster time to union due to compression at fracture site and overall better motion at follow up [7, 13, 24, 27, 33, 34]. The disadvantage of screw fixation is that it requires a second surgery for removal and may increase overall treatment costs. The disadvantage of K-wires is the higher risk of pin tract infections and earlier removal which may lead to non-union, delayed union or malunion.

The other controversy is whether to bury the K-wires or to leave them out of the skin. Qin et al, in their meta-analysis, found no significant differences related to infection, delayed union reoperation or total complications in buried vs unburied K-wires. Unburied K-wires were not associated with higher infection rates and had the benefit of early removal and cost savings [37, 38, 39].

**Rare Complications**

Tan et al [13] in their systematic review reported 10% incidence of neurological deficits with the commonest being tardy ulnar nerve palsy associated with non-union and cubitus valgus deformity. Neuropraxia of the anterior and posterior interosseous nerves have been reported as rare occurrences [6, 7, 13, 31, 32, 40]. Other complications reported in literature with LCHF are persistence of pain [6, 7, 13, 24, 31, 32, 40], radio-capitellar osteoarthritis [3, 13] and heterotopic ossification [13, 41].

**Conclusion**

The propensity for lateral condyle fractures to develop complications is well established. Missed fractures and inadequate management are the most common causes of non-union and deformity; thus, a high index of suspicion and adequate clinical evaluation with appropriate radiographic views are necessary. An arthrogram can aid in confirming adequate closed reduction. Understanding the common pitfalls and complications can help minimize them and allow surgeons to counsel families appropriately.

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**Declaration of patient consent:** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

**Conflict of interest:** Nil; **Source of support:** None

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**References**


