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Review Article

Orthopaedics Section

Fracture Supracondylar Humerus: A Review

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ABSTRACT

Fracture supracondylar humerus is one of the most common fractures encountered in pediatric age group at all levels (both rural and urban). Thus it needs a special review in its management protocol as per the changing trend. Modified Gartland classification is the most accepted classification and has its importance in decision making regarding management and prognosis. Neurovascular complications are mostly associated with Type III A, III B and Type IV variety and they most of the time need surgical intervention for stabilization, exploration of brachial artery, sometimes median nerve exploration and reduction of fracture. Cubitus varus is the most common associated deformity associated with this fracture (especially in Type III A). The aim of the review was to develop an insight for the understanding of variations in presentation and management of supracondylar fracture of the humerus (both simplicity and complexity) and the flowing trend in addition to the recent advances to deal with this particular pediatric orthopaedic entity which often presents as an emergency.

Keywords: Cubitus varus, Gartland, Pediatric

INTRODUCTION

Pediatric fractures hold special attention owing to the fact that bones in this age group have an enormous growth as well as remodeling ability. Long term functional outcome and radiological appearance of a fracture treated in pediatric age group may be quite different from the immediate post-management status. Neurovascular complications associated with this fracture make it an orthopaedic emergency thus, understanding of this fracture is extremely important.

Supracondylar fracture of the humerus is one of the most talked about and often encountered injury (only after clavicle and both bone forearm fracture) in pediatric age group with a male predominance accounting for 16% of all pediatric fractures and 60% of all pediatric elbow fractures, classically occurring as a result of fall on an outstretched hand [1-3]. Immediate complications associated with it are limb threatening (by virtue of involving neurovascular structures) whereas late complications are a serious concern to functional status of the patient. Due to the above reasons they require a strict vigilance and a proper management protocol. In pediatric age group the more common age of presentation is 5-7 years (90% cases). Extension type injury is more common than flexion type [4]. It is frequently found in the non-dominant extremity. The flexion type is common in elderly children [5]. Certain studies have reported up to 30% incidence of open fractures in this subset of patient [6].

PERTINENT ANATOMY

Bone – In children, the supracondylar region consists of a weak, thin bone located in the distal humerus. This area is bordered posteriorly by olecranon fossa, anteriorly by coronoid fossa and on both sides by respective supracondylar ridges. The medial and lateral supracondylar ridges end into respective condyles and epicondyles. The trochlea is normally tilted 4° valgus in males and 8° valgus in females (carrying angle). The trochlea is also 3-8° externally rotated, resulting in external rotation of the arm when is flexed to 90° [2,7].

Soft tissue structures – Both supracondylar ridges, condyles and epicondyles give rise to attachment of various muscles which are responsible for the displacement and rotation of distal fragment. Neurovascular structures lie in proximity to supracondylar region. Brachial artery which commonly gets involved in supracondylar fracture of humerus lies along the antero-medial aspect of distal humerus just superficial to the brachialis muscle. Major neurological structures of the upper limb (median, radial and ulnar nerves) are also in close relation with supracondylar region [2].

PATHOANATOMY

The ossification process of distal humerus occurs at different ages. The first to appear is capitulum at 1 year of age. The radial head and medial epicondyle begins to ossify at 4-5 years of age, followed by trochlea and olecranon epiphysis at 8-9 years of age. The lateral condyle is generally the last to appear at approximately 10 years of age. The supracondylar area undergoes remodeling between 6 to 7 years of age and is typically thinner with a more slender cortex, predisposing this area to fracture. As elbow forced into extension, the olecranon serves as a fulcrum and focuses the stress on the distal humerus causing fracture [8].

APPROACH TO A CASE

History – In a case where there is a classical history of fall on an out stretched hand followed by pain and swelling over the elbow with loss of function of upper limb, onset of pain holds special consideration. It is of utmost importance to ascertain whether the pain is due to fracture or because of muscle ischemia which has a late onset (hours after the injury).

Clinical examination – Initial gross assessment should be aimed to rule out any associated systemic trauma and neurovascular involvement. The clinical presentation is that of a painful swollen elbow that the patient is hesitant to move, when a patient history includes a high energy trauma or a significant fall. Urgent orthopaedic review in Emergency Department is indicated in the following circumstances: when there is absence of radial pulse, ischaemia of hand (pale and cool extremities); severe swelling in forearm and or elbow, skin puckering or anterior bruising, open injury and neurological injury [9].

Both radial and ulnar pulses must be palpated at the wrist of injured extremity. In case of pulselessness, other signs of perfusion must be checked viz., color (the hand should be pink), temperature,

capillary refill and oxygen saturation on pulse oximeter. Ultrasound with Doppler flow should be performed in children with evidence of vascular injury (e.g., decreased or absent radial pulse) [8].

If a neurological involvement is noted, it warrants a careful evaluation and documentation such as when it first became apparent, the degree of involvement and possible progression/ regression of symptoms.

The median nerve along with the brachial artery crosses the elbow joint. Anterior Interosseous Nerve Branch (AION) of the median nerve is most prone to get involved in postero-lateral displacement of the distal fracture fragment [10].

AION syndrome in children and adolescents most of the time present with proximal forearm pain followed by weakness in the hand without any sensory deficit. A weak "OK sign" (e.g., more of a pincer grasp than an OK sign) can be elicited on physical examination. The radial nerve runs between the brachialis and brachioradialis muscles before crossing the elbow and penetrating the supinator muscle. Radial nerve impingement most commonly occurs when the distal fracture fragment is displaced postero-medially. This occurs because the proximal fracture fragment is displaced laterally. The ulnar nerve is prone to injury following flexion type of supracondylar fractures as the nerve crosses the elbow posterior to the medial epicondyle. If a neurological/vascular involvement appears following manipulation or splint placement, one must consider immediate re-manipulation. Neuropraxias are not uncommon and generally resolve with restoration of normal alignment and lengths.

A puckered, dimple and/or ecchymosis of the skin just anterior to the distal humerus may be suggestive of a difficult reduction probably due to the fact that the proximal, anteriorly directed fragment has penetrated the brachialis muscle and possibly the subcutaneous layer as well [8].

Radiographic Assessment- The standard radiographic study of the injured limb should include an Antero-Posterior (AP) and a lateral view of the elbow and any other sites of deformity, pain, or tenderness. Because of the association of supracondylar fractures with forearm fractures, the clinician should also obtain AP and lateral radiographic views of the forearm [11]. Radiographs should be obtained only after appropriate analgesia and splintage of the extremity so as to avoid any neurovascular injury or its exacerbation by the fractured fragments. Idea of splintage is to provisionally stabilize the limb and it should be done in a position of comfort (approximately 20°–30° of flexion) [12]. Splinting in displaced or unstable fractures with elbow in full extension or hyper-flexion is contraindicated because it stretches the neurovascular bundle over the fracture site or they may get impinged between fractured fragments [13].

The carrying angle (the varus or valgus attitude of the distal humerus and elbow) is evaluated on AP view by looking at Baumann's angle. Radiographs of the contralateral elbow should be used for comparison, if needed, as the Baumann's angle varies among all individuals [14].

On the lateral view, the following radiological parameters are looked for: (a) Anterior humeral line; (b) Coronoid line; (c) Fish tail sign; (d) Fat pad sign; (Anterior and Posterior) [5,15].

A positive fat pad sign (sail sign) is suggestive of occult fracture when no radiological fracture line is obvious.

Classification of Fracture Supracondylar Humerus [16]

Fractures of supracondylar humerus may be classified in a number of ways as per following:

a) Displaced or undisplaced fractures of supracondylar humerus

b) Open or close fractures of supracondylar humerus.

c) Uncomplicated or complicated fractures of supracondylar humerus (with/without neurological and/or vascular involvement).

d) Extension type (95%) or flexion type (5%).

e) Modified Gartland's staging system [17] is based on the lateral radiograph and widely used for extension type supracondylar fractures to classify further as it can help to guide treatment.

Type I fracture: Undisplaced.

Type II fracture: Displaced with angulation, but maintain with an intact posterior cortex.

II A fracture: Angulation.

II B fracture: Angulation with rotation.

Type III fracture: Completely displaced and lack meaningful cortical contact, but have a periosteal hinge (either medial/ lateral) intact.

III A fracture: Medial periosteal hinge intact. Distal fragment goes posteromedially.

III B fracture: Lateral periosteal hinge intact. Distal fragment goes posterolaterally.

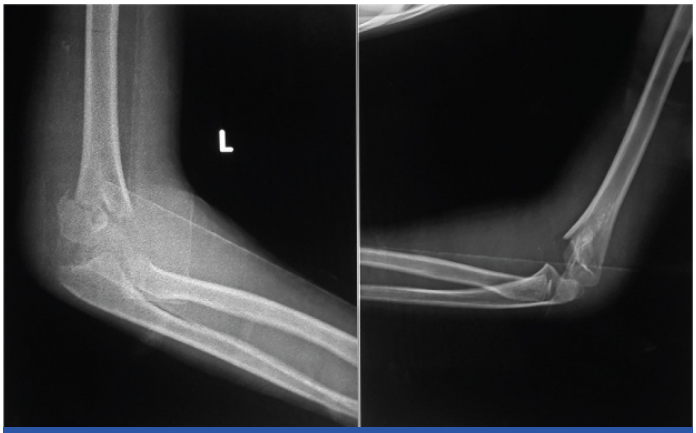
Type IV fracture: Have no periosteal hinge and are unstable both in flexion and extension i.e., they have multidirectional instability.

TREATMENT OF FRACTURES OF SUPRACONDYLAR HUMERUS

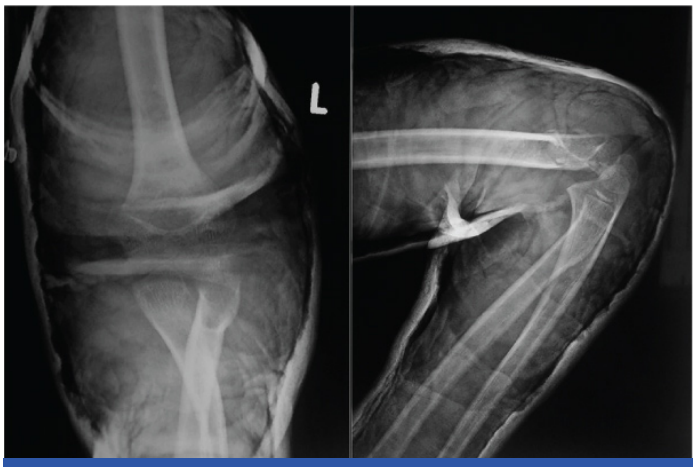
Undisplaced (Gartland Type I) or minimally displaced fractures in children can potentially be treated with an above-elbow splint in 90° of flexion for 3 weeks [9]. Circumferential casting and extremes of flexion should be initially avoided to prevent compartment syndrome and vascular compromise [15,18-20]. While it is often easiest to visualize displacement or angulation on the lateral radiograph, but varus mal-alignment/ impaction is best depicted by Baumann's angle on the AP radiograph. In case of varus at the fracture site of more than 10° (compared to the contralateral upper limb), closed reduction and percutaneous pinning should be strongly considered. In principle, larger diameter pins provide better stability and are more effective at maintaining fracture reduction and alignment. In a randomized trial by Ponce et al., in a study population of 50 children managed by per cutaneous pinning [20], they concluded that those immobilized initially in a posterior splint and sling returned to normal activity sooner than those immobilized in a collar and cuff sling (median two versus seven days, $p \leq 0.01$), but there is no difference between the two groups in daily pain scores or in resumption of normal activity or mobility at two weeks.

Gartland Type II fractures require close reduction [21]. Further, these may become stable after closed reduction and casting at 90° of flexion [Table/Fig-1a,b] but if more than 90° of flexion is needed to maintain reduction, then in order to minimize risks of complications associated with the increased elbow flexion, stabilization of the fracture with percutaneous pinning should be performed [Table/Fig-2a,b]. In the largest reported series by Skaggs et al., in management of Type II fractures [22], they reported an extremely low rates of complication after closed reduction and percutaneous pinning; secondary operations were also uncommon (0.5%). This series demonstrated a high probability of satisfactory outcome after operative treatment of Type II fractures compared to previous studies of children treated by closed reduction without pinning [22].

Reduction manoeuvres for supracondylar humerus fractures: With the patient preferably under General Anaesthesia (GA) and with fluoroscopy assistance-before pounding on to anatomic reduction freeing the proximal fragment from soft-tissue entrapment is essential. First step is to apply traction in line with the humerus, with the elbow in slight flexion. Traction in full extension has to be avoided as this may cause tethering of neurovascular structures



[Table/Fig-1a]: Pre-operative images showing gartland Type-II fracture.



[Table/Fig-1b]: Post-Reduction images in lateral and shoot through view.

[Table/Fig-2a]: Pre-operative images showing gartland Type-II fracture.

[Table/Fig-2b]: Post-operative images in lateral and AP view showing fixtion by percutaneous K –wires after close reduction.

over the proximal fragment. If there is suspicion that the proximal fragment has pierced through the brachialis muscle (clinically elicited by S sign), then a persistent, gradual traction is given in slightly flexed elbow for a full minute which often gives a palpable feeling of freeing of the proximal fragment. Alternatively, the same may be achieved by proximal to distal "milking" manoeuvre over the brachialis [23].

For the reduction maneuver, it should begin with hyper-flexing the elbow while simultaneously pushing in an anterior direction on the olecranon. While keeping the elbow in hyper-flexed state fluoroscopic assessment is done with an AP image, though difficult to interpret due to overlapping of proximal ulna and radius over the fracture site. However, Jone's view allows assessment of the continuity of the medial and lateral columns and Baumann's angle.

Rotation of distal fragment if present can be addressed by repeating the reduction with two additional maneuvers. If the distal fragment is internally rotated (most common), to press selectively harder on the medial side during the reduction, and pronate the forearm during the reduction as well, the opposite applies for an externally rotated distal fragment. If normal range Baumann's angle is not achieved, to repeat the reduction while stressing the arm in valgus.

Reduction maneuvers should not be attempted if the vascular status doesn't improve after gross reduction and stabilisation in a splint. Taking decision as per appropriate use criteria [24-26] is wise in such circumstances. Cases of an open fracture, significant swelling over the elbow, vascular deficit, unstable reduction (Gartland III and IV) pose certain limitations in reduction maneuvers for supracondylar humerus fractures. In these cases one must go for open reduction as attempting close reduction may further worsen the situation.

Gartland Type III fractures are particularly prone to neurovascular compromise. The closed reduction and percutaneous pinning is the preferred treatment for displaced fractures. Fractures with displacement treated by closed reduction and casting have a higher incidence of residual deformity as compared to those managed with close/open reduction and pinning, complication rates [27-30] or the quality of the reduction [31]. However, considering it as an orthopaedic urgency, optimal management of a displaced fracture should be done by close/open reduction and percutaneous pinning preferably within 24 hours. Sadiq et al., in a review of 20 cases of grade III supracondylar fractures who were managed conservatively with straight-arm lateral traction with arm in 90° abduction and full supination showed no complication in any patient with uneventful recovery [32]. They concluded straight-arm lateral traction as a safe and effective maneuver for treating these fractures.

In a study by de Gheldere A and Bellan D, on 74 patients with Gartland Type II and III fracture managed by closed reduction and immobilization with a collar sling fixed to a cast around the wrist in order to keep forearm in pronation, they found no statistically significant difference in the final outcomes as measured by Baumann's angle (except in posterolateral displacements) but humerocapitellar angles show statistically significant difference in Type III group [33]. The purpose of the study is to give a more precise limitation of this technique. This study suggests that Gartland Type II and pure posterior or posteromedial displaced Gartland type III fractures can be treated by closed reduction and immobilization with success, whereas Type III fractures with posterolateral displacements should preferably be fixed.

Effect of supination versus pronation in the non-operative treatment of pediatric supracondylar humerus fractures was studied prospectively by Seyed Ali MN et al., in which they concluded that considering late complication of malunion, no obvious difference was observed between the two positions of forearm after closed reduction and casting [34]. However, as cubitus varus and valgus

were reported in both the groups with unstable Type III fractures, so it is advisable to prevent this complication by operative fixation.

Indications of Surgical Intervention to be Considered in the Following Conditions [35]

a) If close manipulation fails to achieve the reduction.

b) If after close reduction fracture is unstable i.e., failure to maintain the reduction.

c) If neurological involvement occurs during or after the manipulation of fracture.

d) If vascular exploration is required.

e) In open fractures.

f) All Type II and III fractures requiring elbow flexion of more than 90° to maintain the reduction.

g) All Type IV fractures supracondylar humerus.

h) Polytrauma with multiple ipsilateral fractures requiring surgical intervention.

Ozturkmen et al., in a study on 34 children with displaced fractures of supracondylar humerus treated by close reduction and percutaneous lateral pinning observed no significant differences between the mean Baumann, humerocapitellar, and carrying angles of the normal and affected sides ($p>0.05$) [36]. They concluded that closed reduction and percutaneous lateral pinning proved an efficient, safe and reliable method in the treatment of displaced supracondylar fractures of the humerus in children.

In a systematic review by Brauer et al., of medial and lateral entry pinning versus lateral entry pinning for supracondylar fractures of the humerus, they observed that for operative fixation with medial/lateral entry pins, probability of ulnar nerve injury is 5.04 times higher than the lateral entry pins alone [37]. When all documented operative nerve injuries are included, the probability of iatrogenic nerve injury is 1.84 times higher with the medial/lateral entry pins, than with isolated lateral pins. The medial/lateral pin entry provides a more stable configuration, and probability of deformity or loss of reduction is 0.58 times lower than the isolated lateral pin entry. Considering intraoperative nerve injury as a surgical technique error, it is indicated medial/lateral entry pinning of pediatric supracondylar fractures, remains the most stable configuration and that care needs to be taken regardless of technique to avoid iatrogenic nerve injury and loss of reduction.

In another systematic review of four randomized controlled trials by Yousri et al., comparing efficacy of crossed versus lateral Kirschner -wire fixation in extension type Gartland Type III supracondylar fractures of the humerus in children [38], they found no study concluding any significant statistical difference in terms of loss of reduction between the two groups, suggesting similar stability of both constructs.

In terms of approach used for open fixation of fracture supracondylar humerus, Ersan O et al., in their prospective case series of 46 children evaluated the effectiveness and safety of using an anterior approach to address these fractures and concluded that it is a safe and reliable method with very good results [39]. In another study of 84 patients who underwent open reduction and Kirschner wire (K-wire) fixation through anterior or lateral approach were compared with regard to complications and end results with the conclusion that anterior incision offers the advantage of a smaller scar and easy access to structures that might be injured between the fractured fragments. Medial approach and cross-pinning for delayed surgical treatment (>24 hours) of Type III supracondylar humerus fractures is shown to be an effective and reliable treatment method by Eren A et al., in their prospective study on 30 patients [40].

Gartland Type IV fracture being a highly unstable fracture needs fixation, either close or open.

While going in for internal fixation one should be aware of the fact that in older children medial condyle sometimes remain with the proximal fragment making medial pin fixation worthless.

After management, next question which arises is that, when the patient should be called for follow up for clinical and/ or radiological assessment and when the wires should be removed for mobilization?

Study by Ponce et al., gives an answer to the above question. In their study they concluded that clinical and radiographic evaluation of routine displaced supracondylar humerus fractures requiring closed reduction and percutaneous pinning may be safely delayed until pin removal [20]. Pins were removed when the distal humerus is no longer tender, usually in 3 to 4 weeks [41] and there after active mobilization is begun.

After pin and cast removal, active range of motion exercises is recommended as tolerated. Studies on children with supracondylar fractures and no neurovascular deficit suggest that formal physical therapy does not appear to improve mobility in long term [42]. However, physical therapy is recommended for children with persistent contractures after three to four months or neurological deficits.

COMPLICATIONS OF SUPRACONDYLAR FRACTURE OF THE HUMERUS

Vascular Insufficiency

Absence of the radial pulse is reported in 6 to 20 percent of all supracondylar fractures [43,44]. Vascular injury evident by involvement of brachial artery is most commonly associated with Type II and III supracondylar fractures, frequently encountered in postero-laterally displaced fractures [3,45]. Patients without significant improvement in pulse after orthopaedic care, warrant emergent vascular exploration, especially if there is intractable pain, persistence of pain or increasing pain despite of fracture site stabilization which is suggestive of ischemia [3,45-49].

Griffin et al., in a systematic review of 161 children with supracondylar fractures and a pulseless hand found that closed reduction and percutaneous pinning resulted in return of the radial pulse in 51% (82 of 161) of cases [45]. A total of 63 of remaining 79 children with persistent pulseless hand after operative care underwent vascular exploration. Brachial artery injury or thrombus was found in 61 patients (97%). Mangat et al., in an observational study of 19 children who had a perfused but pulseless hand after Gartland Type III fracture concluded that in cases where there is vascular deficit along with neurological deficit (due to median/anterior interosseous nerve involvement) [48], early exploration is recommended, as these appear to be strongly predictive of nerve and vessel entrapment at the fracture site. Those with isolated vascular deficit can be managed by closed reduction and could be observed for return of vascularity and if needed secondary exploration. Blakey et al., in an observational study of 26 children who had a pink pulseless hand, wherein 3 underwent immediate surgical exploration of vessel with good functional results and remaining 23 who presented late (four days to one year after injury) and did not have early release of brachial artery obstruction developed ischemic contractions of hand and/or forearm muscles, and thus recommended urgent exploration of the vessels and nerves in such cases not relieved by reduction of a supracondylar fracture of the distal humerus and presenting with persistent and increasing pain suggestive of a deepening nerve lesion and critical ischemia [49]. In a study of 66 children by Korompilias et al., with displaced supracondylar fractures of the humerus, they encountered 4 patients with a pink yet pulseless hand after fracture reduction. On exploration brachial artery thrombus was found in 3 [50]. Subsequent thrombectomy was performed, which led to the restoration of a palpable radial pulse. In 1 patient

with open fracture, brachial artery contusion and spasm were found, and treated by removal of adventitia. They concluded that pulselessness even in the presence of viable pink hand after an attempt at closed reduction is an indication for surgical exploration of the brachial artery, to check for its patency.

Neurologic Deficit

The frequency of neurologic deficit reported after supracondylar fractures in children is 10 to 20 percent and increases in some series of children with Type III supracondylar fractures to as high as 49 percent [8,44,50-54]. Median nerve and its anterior interosseous nerve branch is at risk and gets most commonly involved in postero-lateral displacement of the distal fracture fragment, whereas radial nerve is most commonly involved with postero-medial displacement of the distal fracture fragment. Ulnar nerve injuries are commonly associated with flexion type supracondylar fractures [51,53,54].

Most often associated nerve injuries are neuropraxias that usually resolve within two to three months [8,10,54,55]. One should consider surgical exploration for nerve deficits that persist beyond three months [10,41,42,55]. Barret KK et al., in one of the largest retrospective, multicentric study conducted on 4409 patients with supracondylar fracture of the humerus presenting with anterior interosseous nerve injury (no sensory involvement) concluded that an isolated anterior interosseous nerve injury associated with this fracture in itself is not an indication for surgery [55]. In this huge series they showed complete neurological recovery in a mean time of 49 days with 90 percent of the patients recovering by 149 days.

Forearm Compartment Syndrome Resulting in Volkmann's Ischemic Contracture

Vascular injury and primary swelling from the injury can lead to the development of compartment syndrome within 12 to 24 hours [51]. If a compartment syndrome is not treated timely, the associated ischemia may progress to infarction and subsequent development of Volkmann's ischemic contracture: fixed flexion of the elbow, pronation of the forearm, flexion at the wrist, and joint extension of the metacarpal-phalangeal joint [51].

Malunion

One of the frequent long term complications of supracondylar fracture are angular deformities, of which cubitus varus or “gunstock” deformity is very common. The distal humerus physis, in contrast to the proximal humeral physis, contributes only 15 to 20 percent to the overall longitudinal growth of the humerus [56]. This suggests very limited remodeling in correction of fracture angulation in children with supracondylar fractures. Modern surgical techniques (e.g., closed reduction with percutaneous pinning) have reduced this frequency of cubitus varus from 58 percent to approximately 3 percent in children treated for supracondylar fractures [57]. Posttraumatic cubitus varus deformity has important problems, which are associated with tardy ulnar nerve palsy [58], tardy Postero-Lateral Rotatory Instability (PLRI) [59], and secondary distal humeral fractures [60]. Therefore, humeral osteotomy is used to correct this deformity and to avoid such later complications [61].

Eren A et al., conducted a study to evaluate the relationship between the fracture displacement and cubitus varus deformity in displaced supracondylar humerus fractures [62]. They observed that the carrying angle loss was more significant in Type III-A fractures compared with Type III-B and concluded that although anatomic reduction has been achieved by surgical treatment without loss of reduction, further there is still a risk for cubitus varus deformity for Type III-A fractures due to the initial compression of the medial column or, in other words, physical injury. Stiffness elbow-secondary to manipulation with or without development of myositis. Supracondylar fractures of the humerus are a common pediatric elbow injury that can be associated with neurovascular complications and skeletal deformity. The understanding of the anatomy, radiographic findings, complications, as well as the management options that associated with this fracture, allow physicians to limit the morbidity associated with this injury.

CONCLUSION

Supracondylar fracture of the humerus is a very common problem of pediatric age group and one frequently has to deal with such a fracture, with or without complication. A thorough history with a detailed clinical examination is a must. During radiographic evaluation one must not forget to verify three important points pertaining to a normal elbow: (a) On lateral view, the anterior humeral line should intersect the capitellum; (b) The head of radius should point to the capitellum in every view; and (c) Baumann's angle must be in valgus. In treatment, we should remember that a pulseless, poorly perfused hand needs an urgent reduction, not an arteriogram. It is always safer to use K-wires to maintain the reduction in case if more than 90° of flexion is required to keep the fracture reduced as there is risk of developing compartment syndrome in holding reductions beyond 90° of flexion. Even if it is a Type II fracture, when in doubt whether to fix it or not, it is better to fix as it is safe and outcomes are good. Usage of appropriate use criteria is wise in managing these fractures as it has been quite exhaustively designed. Prognosis in case of complications or possible complications should be explained.

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