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Not Kidding! Sequalae of elbow trauma in children

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ABSTRACT

Elbow injuries are common in children and while majority heal very well, some result in deformities of the elbow. Although deformities such as cubitus varus and non-progressive cubitus valgus are considered cosmetic by the paediatric orthopaedic surgeons and intentionally ignored, they are not always benign and can result in functional deficit due to instability, pain, tardy nerve palsies and osteoarthritis later in life. Similarly congenital and developmental conditions that do not cause major functional loss in childhood, become very disabling in adults due to increasing functional demands. Congenital radial head dislocation and radioulnar synostosis fall into this category. In this paper we discuss clinical presentation, treatment options and outcomes of common elbow conditions presenting later in the life.

1. Introduction

Fractures around the elbow result from a fall on the outstretched arm. Supracondylar (SC) fracture of humerus is the commonest injury followed by the lateral humeral condyle (LHC) fracture. Monteggia Fracture Dislocation, although not as common as supracondylar fracture, can be easily missed and liable to late presentation. A unique feature of fractures around the distal end of humerus is that they may result in angular deformities of the elbow such as cubitus varus and valgus if inadequately managed. Often such deformities are not painful, and it is difficult to convince parents to accept further reconstructive surgery for their children, which often involves ‘breaking’ the bone again. It is important to alert the parents to the potential difficulties in the long term and probably seek treatment early in adulthood before developing secondary effects[1]

2. Cubitus Varus

Cubitus Varus is the commonest elbow deformity that can result from a malunited supracondylar fracture of the humerus and occasionally from malunion or growth stimulation of lateral humeral condyle fractures. Popularity of pinning techniques has decreased the incidence of cubitus varus. It still occurs in countries where access to such treatment is limited. It presents as varying degrees of reduction of normal carrying angle or even reversal of it (Fig. 1). Anatomically, cubitus varus results from the triple displacement of the distal fracture fragment – varus tilt, internal rotation, and extension - of varying degrees. Varus tilt is the most visible aspect of the deformity whereas rotation is often difficult to assess. Extension deformity presents as loss of terminal degrees of flexion. Occasionally one or the other deformity predominates (Fig. 2). Often the deformity doesn't become obvious until the child regains full range of movement at 6–8 weeks post injury.[2] Since majority of patients regain good function after malunited SC fracture and the deformity is mainly a cosmetic issue, parents are reluctant to subject the child to another operation. Furthermore, risks of complications of osteotomy, irrespective of the technique, are not insignificant[3,4] which make both the surgeon and parents hesitant to consider corrective surgery. There is emerging robust evidence in the literature[5–9] that cubitus varus can result in Postero Lateral Rotatory Instability (PLRI), tardy ulnar nerve palsy, snapping triceps, which may aggravate ulnar nerve symptoms and triceps tendon dislocation, later in life. A cadaveric study by Beuerlein et al.[10] found increasing strain in the Lateral Ulnar Collateral Ligament (LUCL) and widening of medial ulnohumeral joint beyond 20 of varus deformity at the elbow in patients. Although this study did not investigate what happens in vivo, it highlighted the mechanical effects of the varus deformity at the elbow. Badre et al.[11] have

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Fig. 1. Varying degrees of cubitus varus from malunited supracondylar fracture.

Fig. 2. Hyperextension and mild cubitus varus. Corresponding loss of flexion on the left side.

shown that application of even small amounts of external torsion on the forearm with the arm in varus position increases rotational instability. O'Driscoll et al.[5] have highlighted, in their landmark paper, how PLRI can develop secondary to cubitus varus.

2.1. Clinical examination and preoperative planning for corrective osteotomy for cubitus varus (Fig. 3)

Clinical assessment should include a detailed history of pain, neurological symptoms, functional demands, and assessment of all three components of the deformity – varus, extension, and internal rotation. Varus component should be assessed with the elbow fully extended but not hyperextended (Often elbow goes into hyperextension with proportionate loss of flexion (Fig. 2) and compared with the opposite normal side. Internal rotation deformity is not easy to quantify on plain x-rays, although patients tend to demonstrate more internal rotation at the shoulder on the affected side. External and internal rotations at the shoulder can be better assessed with arms abducted to 90°. Yamamoto et al.[12] described a clinical method with patient leaning forward slightly, locking the shoulders in to hyperextension, elbows flexed to 90 and using the forearm as a protractor to demonstrate increased internal rotation. The stability of the elbow is assessed both in extension and in flexion. A thorough neurological and vascular examination of hand should be performed and documented. Ulnar nerve should be palpated behind the medial epicondyle for tenderness and Tinel's sign. Occasionally the triceps tendon snaps medially over the medial epicondyle aggravating ulnar nerve symptoms.[13,14]

2.1. Imaging

Radiological assessment of cubitus varus includes anteroposterior (AP) and lateral radiographs of the elbow. Cubitus varus from a malunited lateral condyle fracture is easy to differentiate from the malunited supracondylar fracture on x-ray. Good AP view with lower half of humerus and proximal half of forearm, with elbow in extension and forearm in supination is essential to assess and plan correction of cubitus varus. Hyperextension of the elbow tends to exaggerate cubitus valgus but since all radiographs are obtained with the arm resting on a flat surface, hyperextension is automatically excluded. Humeral-Elbow-Wrist (HEW) angle closely represents the carrying angle[15] and easy to measure even in short elbow films. If forearm radiological landmarks are not clear on the radiographs, then distal humeral joint line angle can be used. Humeroulnar angle (HUA) has also been used in some studies[16] to assess the cubitus varus angle. However, it may not be the true measurement of cubitus varus as the proximal ulna varus can develop in young children with this deformity,.[17] Extension deformity of distal humerus is measured on a lateral view by drawing anterior humeral line, which normally cuts through the centre of capitellum. In extension deformity capitellum is posterior to this line. Once an optimal correctional angle is calculated from these measurements it can be incorporated into the surgical plan (Fig. 3 B)

Several different types of osteotomies through lateral, posterior, and less commonly medial approach have been described to correct the cubitus varus deformity but none of them is perfect.[18,19] Each technique has its advantages and disadvantages (Table 1). Similarly, a range of stabilization methods including internal fixation with K-wires, screws, plate and screws and external fixators including circular frames[16,20–23] have been used. A lateral closing wedge osteotomy through a lateral or posterior approach with or without medial displacement and fixed with a plate is a popular option for adult patients. Additional correction of the extension and internal rotation components of cubitus varus deformity remains controversial.[24,25] It also increases the complexity and risks of the procedure; hence majority of surgeons correct only varus deformity and add correction of extension if there is block to flexion. If the cosmesis, with only moderate functional limitations, is the indication for surgical correction, the surgeon should only use the familiar technique, bearing in mind the advantages and risks of the surgery. The risks of under or over correction, nerve injury, unsightly scars, and the need for removal of metal implant, should be clearly explained and discussed with the parents/patient.

Cubitus varus can be associated with late posterolateral instability of the elbow. These patients need, not only corrective osteotomy, but also additional soft tissues procedures such as lateral collateral ligament reconstruction, lateral transposition of triceps tendon and ulnar nerve transposition.[5]

3. Cubitus Valgus

Nonunion and malunion of the lateral humeral condyle (LHC) fracture is a common cause of cubitus valgus and, unlike cubitus varus, this deformity is often symptomatic and functionally disabling due to lateral instability and stiffness of elbow. It is also a common cause of tardy ulnar nerve palsy. Nonunion is common after closed treatment of LHC fracture[26] and it may remain unrecognised and often asymptomatic until later in life,. Toh et al.[27] identified two types of nonunions of LHC based on the disruption of the normal radiocapitellar relationship (Fig. 4). In Group 1 nonunion, the radiocapitellar joint migrates proximally with the displaced fracture of LHC, commonly seen after Milch type 1 fractures. In Group 2, which develops after Milch type II fractures, the radiocapitellar joint is congruent and remains at or distal to the ulnohumeral joint level. They also reported that the carrying angle in Group 1 was 28° and in Group 2, 18°. The report concluded that the patients having Group 1 nonunions consistently developed pain, stiffness, instability, tardy ulnar nerve palsy and loss of function and should be treated as soon as possible.

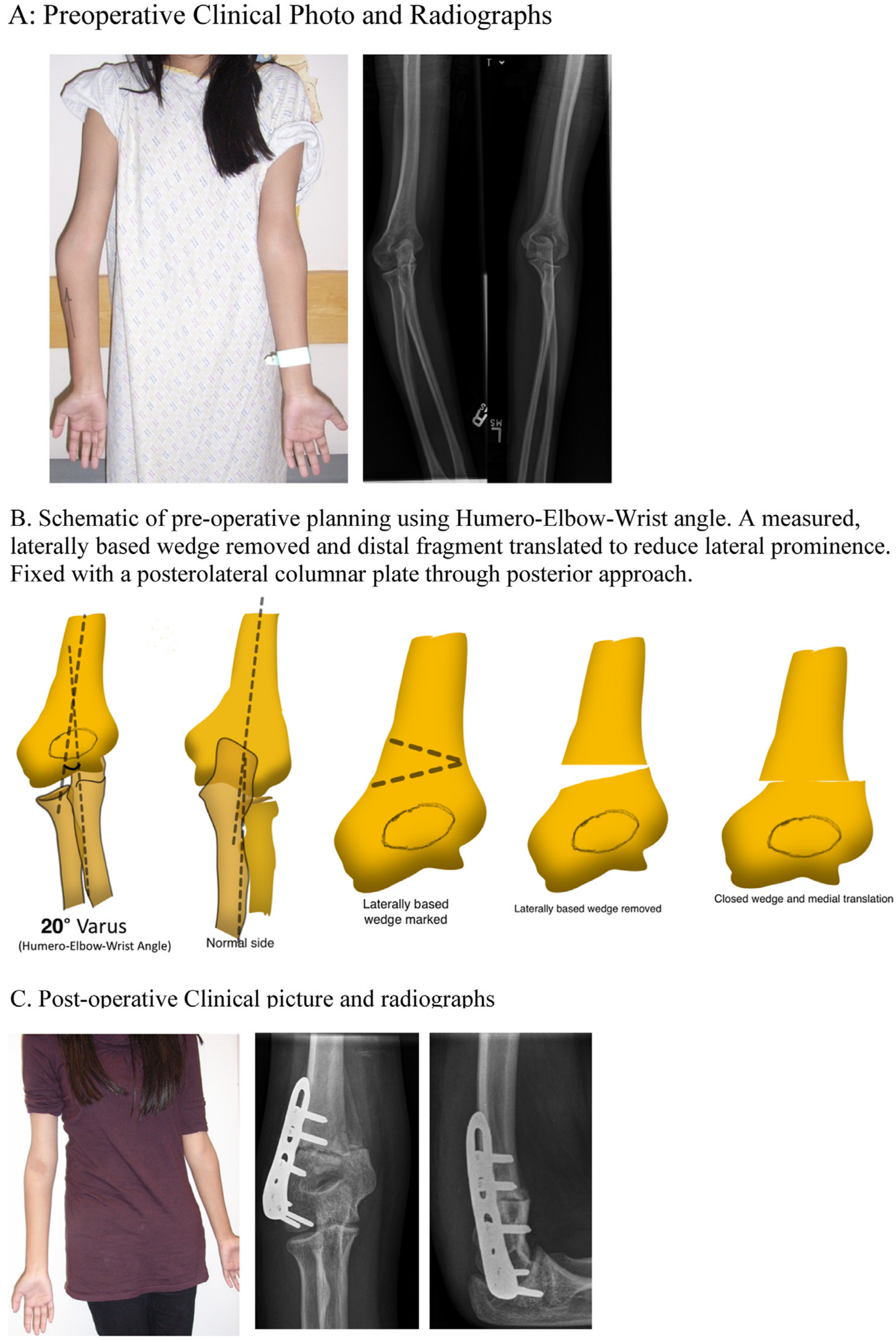

Fig. 3. Cubitus Varus preoperative planning and correction. A: Preoperative Clinical Photo and Radiographs.

Although tardy ulnar nerve palsy is common in the cubitus valgus deformity, it can also occur in absence of it due to instability of ulnar nerve caused by excessive mobility at the nonunion site or alteration of elbow arc of movement. Other causes of tardy ulnar nerve palsy after childhood elbow trauma include cubitus varus[28–30] and Monteggia fracture dislocation.[31,32] Treatment of tardy ulnar nerve palsy secondary to cubitus valgus remains controversial and recommendations include anterior transposition with or without osteotomy.[33–36]

There is no unanimity on the treatment of established nonunion of LHC.[37] Ununited lateral condyle fragment is often enlarged due to the remodelling process so doesn't fit well with the metaphysis. Extensive soft tissue dissection is often required to relocate the displaced fragment to its bed which may disrupt its precarious blood supply and can result in avascular necrosis of the fragment. Furthermore, contracture of common extensor muscles can result in stiffness of the elbow. Correction of cubitus valgus with corrective osteotomy and anterior transposition of ulnar nerve is a popular choice.[36–38] It can be combined with corrective osteotomy and anterior transposition of ulnar nerve, a popular operative

Table 1
Types of osteotomies for Cubitus Varus.

Type of osteotomy	Pros	Cons
Lateral Closing Wedge Only	Simple and familiar technique, stable	Produces a lateral bump Doesn't correct flexion and internal rotation
Closing Lateral Wedge and Translation (several configurations)	Cosmetically better as lateral bump is reduced Stable configuration can be created Possible to correct extension and internal rotation to some extent	Technically demanding Larger exposure including posterior approach Risk of injury to nerves Scarring similar when lateral approach is used
Dome Osteotomy	Rotational correction through dome shaped osteotomy, so no bone loss Good contact Good correction of lateral bump Useful in both varus and valgus Rotational deformity can be corrected	Technically demanding Often large posterior exposure Special osteotomes need to get accurate dome shape
Distraction Osteogenesis correction	Helps form new bone Good for complex multidirectional deformities – can address all components of cubitus varus Can add length if needed Minimally invasive Stable fixation	Technically demanding Can be cumbersome for the patient
Patient Specific Computer Aided Jig	Multiplanar correction with one osteotomy Tailor made for the deformity and bone dimensions	Complex pre op work up Expensive Not universally available Scarring issues like open osteotomies Superiority of this technique is not proven

A. Child's elbow at age 4 and 11 yrs showing progressive cubitus valgus due to LHC non-union. LHC fracture was treated non operatively.

B. Types of LHC non-unions. In Type I the radiocapitellar joint is disturbed whereas in Type II it is maintained

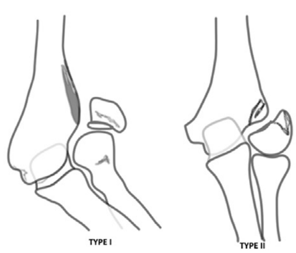

Fig. 4. Cubitus Valgus from lateral humeral condyle (LHC) non-union and non-union groups. A. Child's elbow at age 4 and 11 yrs showing progressive cubitus valgus due to LHC non-union. LHC fracture was treated non operatively.

procedure in itself.[33–35,37,39] Milch[40] described an elegant translation and angulation correction technique (Fig. 5). It consists of a transverse osteotomy through posterior approach just proximal to the lateral condylar nonunion. A notch is created at the midpoint of the distal end of the proximal humerus segment, to receive the medial corner of the distal fragment. The distal fragment is then translated in the lateral direction until forearm axis line intersects the mid-axial line of humerus. The medial corner of the distal fragment is rotated and locked into the notch to achieve normal carrying angle. Osteotomy is fixed with a plate.

Dome osteotomies are another option for correcting cubitus valgus deformities. They are very versatile but technically demanding. Tien et al.[39] described a dome osteotomy technique to correct cubitus valgus along with in situ fixation of LHC nonunion with good outcome. Distraction osteogenesis techniques have also been used successfully (Table 2).[41]

4. Missed Monteggia lesion

Monteggia fracture dislocation is a relatively uncommon injury in children with an incidence of 1.1% of all upper limb fractures,[42] but missed diagnosis and late presentation are seen in the paediatric orthopaedic clinics.[43,44] The fact that not all missed lesions are symptomatic, at least in the short term, makes it difficult to diagnose and treat it early. Unfortunately, in the long term, majority of missed Monteggia injuries develop pain, progressive cubitus

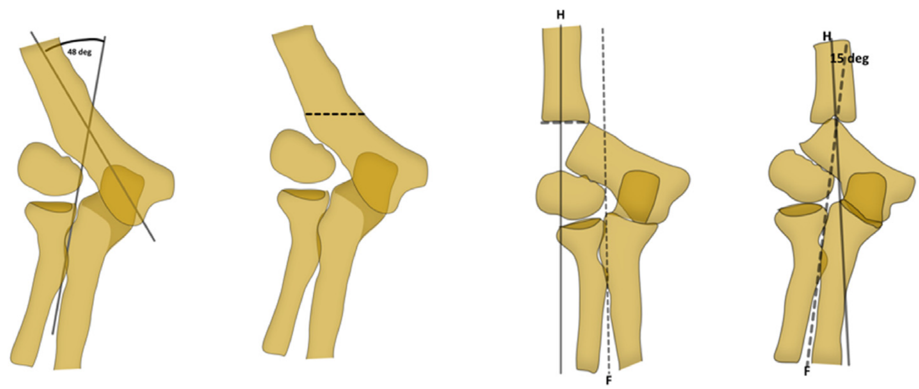

Fig. 5. Milch angulation-translation osteotomy. A 48° HEW (Humerus Elbow Wrist angle) cubitus valgus angle correction. Osteotomy is marked approximately where the HEW lines cross. Correcting the angulation alone will increase the prominence medially. Distal fragment is then translated laterally until normal carrying angle is restored.

Table 2
Types of osteotomies for cubitus valgus.

Type of Osteotomy	Pros	Cons
Milch Osteotomy	Corrects translation and angular deformities, simple technique	Osteotomy through diaphysis hence bone contact is limited, stable fixation is needed
Closing Wedge Osteotomy	A familiar technique. Excised wedge can be used as a bone graft for repair of nonunion. Option to correct extension deficit by extending the distal segment.	Doesn't correct translational deformity so medial bump can become prominent.
Dome Osteotomy	Corrects translation and angular deformities Stable osteotomy	Technically demanding. Special dome osteotomes are needed Difficult to achieve good dome without specially shaped osteotomies

valgus deformity, valgus instability of the elbow, stiffness, osteoarthritis, and occasionally tardy posterior interosseous nerve (PIN) palsy.[32,45–49] Delayed surgical management even in children is not as easy as acute management and satisfactory outcome is not always guaranteed even after relocation of the radial head.[50–52] Skeletal growth with the dislocated radial head, alters the morphology of the radial head, geometry of sigmoid notch of proximal ulna and relative lengths of radius and ulna.[53,54] Often the ulnar fracture heals and remodel to a normal shaped ulna obscuring any sign of previous deformity. Changes in the soft tissues including contracture of the interosseous membrane[55] and effect on the wrist joint are not fully understood. Hence an adult patient with a radial head dislocation, which developed during childhood, presents a surgical conundrum.

Current consensus is that these elbows deteriorate gradually hence many surgeons recommend intervention mainly to prevent further deterioration of the deformity and to reduce pain. Rotational movements do not always return to normal even after corrective surgery. Hence the treatment should be individualised, including non-operative option for those with low functional demand on the elbow. It is important to recognise that not all ‘delayed’ radial head dislocations are post traumatic. Some are congenital radial head dislocations which would require a different approach to treatment.

Pre-operative work up includes detailed history to identify aetiology, range of movement, functional scores, and neurological examination. Xray of entire forearm including elbow and wrist is essential. It is important to assess the shape of the radial head and the status of the articular cartilage of the elbow. Loss of concavity of radial head is generally seen as a poor prognostic sign.[53] CT and or MRI scan is essential to assess the pathoanatomy of radial head and annular ligament.

Although surgical principles and approaches for adults are chiefly based on the experience with the paediatric cases, namely, ulnar osteotomy and radial head relocation with or without the repair of annular ligament, there are important differences (Fig. 6). Bone healing in adults is less vigorous, hence risk of nonunion is high if angulation and lengthening of ulna leads to the loss of bone contact across the osteotomy. Bone graft should be used if it happens. An oblique osteotomy might be preferable.[56] Bone remodelling is not as vigorous in adults as it is in children, so the angulation created at the ulnar osteotomy must be minimal. Rigid fixation of osteotomy, based on AO principles, is essential to avoid prolonged immobilization of the elbow. Trans capitellar radial head stabilization with a wire, even for couple of weeks, should not be attempted because of the risk of stiffness or breakage of the wire. Annular ligament repair is not always needed in children if the radial head relocates by angulating the ulna; and in adults, it may not be possible due to fibrous tissue in the radio capitellar area. If annular ligament repair is required and suitable tissue is not available locally, triceps aponeurosis (Bell-Tawse)[57] or palmaris longus autograft can be used.

5. Congenital radial head dislocation

Congenital radial head dislocation is a rare condition with an estimated incidence of 0.06–0.16% but it generates a considerable interest in the paediatric orthopaedic clinics because it can be confused with traumatic dislocation of radial head – particularly when the child presents after a minor trauma. This condition is often, but not always, bilateral, and frequently associated with the other anomalies with a positive family history. The radiological appearances are typical (Fig. 7) with hypoplastic dome shaped radial head lacking normal concavity at the proximal end and hypoplastic capitellum. Posterior dislocation is common in this group. Elbow is generally held in 10–15° of flexion with forearm in

A. Xrays and clinical picture: Ulna doesn't show any residuals of a fracture. Radial head is well formed so it is not a case of congenital radial head dislocation

B. Dorsal and radial angulation osteotomy of ulna fixed with a plate. Radial head reduced after ulna correction and did not need open reduction. Osteotomy fixed with a compression plate. Post op improvement in flexion and stability of radial head (Case courtesy Mr. Anand Arya).

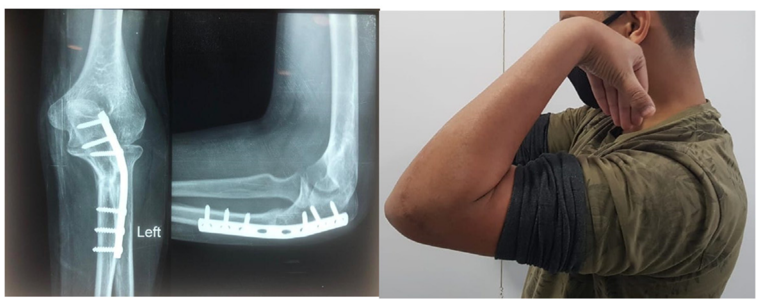

Fig. 6. A case of late presenting missed Monteggia lesion in a 19 yr old. A. Xrays and clinical picture: Ulna doesn't show any residuals of a fracture. Radial head is well formed so it is not a case of congenital radial head dislocation.

Fig. 7. 10 yrs old boy with bilateral congenital radial head dislocation (right elbow xrays only shown here). Hypoplastic radial head with posterior dislocation on x-ray. Note the cubitus valgus and lack of supination. Posteriorly located radial head is easily noticed as a bump.

pronation and severe restriction of supination. At wrist ulnar positive variance is common with restricted wrist movements.[58] Typically, restrictions of the elbow and forearm movements are noted in the late childhood and remain unchanged. Patients commonly present with painful elbow, prominence of radial head and restriction of range of movement, particularly supination. It is important to recognise this group and advise patients accordingly. Conventionally open reduction of radial head is not recommended because of the adaptive changes in the radial head and Proximal Radioulnar Joint (PRUJ), but recent reports have shown some encouraging results of ulnar osteotomy and radial head relocation in carefully selected patients.[59,60] Radial head excision is an option in adult patients, and it is known to improve pain and removes the bump, but rotational movements do not improve.[61] Patients should be alerted about the long-term effects of radial head excision such as cubitus valgus and proximal migration of radius leading to wrist pain.

6. Congenital radioulnar synostosis (CRUS)

CRUS is a congenital anomaly due to failure of cavitation affecting elbow during 7th foetal week. Forearms are in pronated position at this stage of gestation, so all synostosis forearms are fixed in pronation. Since all other organ systems are forming in the foetus around 7th week, CRUS is seen in conjunction with other anomalies such as Apert syndrome(acrocephalosyndactyly), Carpenter syndrome (acropolysyndactyly), arthrogryposis and Klinefelter syndrome. It is bilateral in 60% and can be bony, cartilaginous, or fibrous. It is often painless but can be functionally disabling in bilateral cases.

Treatment depends on the degree of fixed pronation and functional deficit. Rotational osteotomy is the preferred surgery than the excision of synostosis.[62] Site of osteotomy, single or both bones osteotomies, extent and mode of correction and fixation methods remain controversial. Neurovascular compromise and compartment syndrome are main complications of acute rotational correction. Gradual correction in a circular frame is an option to minimize acute neurovascular compromise. Similarly, single bone (radius diaphysis) osteotomy is also a safer alternative. Both bones osteotomy is preferred if more than 45° rotational correction is planned. Optimal position after osteotomy is also controversial but 30–45° supination appears to be the preferred position. Successful excision of synostosis has also been reported.[63]

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