Posttraumatic proximal radioulnar synostosis: Current concepts on the clinical presentations, classifications, and open surgical approaches

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ABSTRACT

In the forearm, posttraumatic heterotopic ossification usually forms as a proximal radioulnar synostosis. It can occur after soft tissue injury involving the interosseous membrane or after surgery involving the radio and ulna, such as distal biceps tendon repair. It can also be induced by radial head dislocation or fracture. Screening radiography can be used to select the appropriate time for excision. The synostosis can be resected when the ectopic bone margin and trabeculation appear mature on radiographs. An interval of 6–12 months from the injury is generally recommended based on ectopic bone maturity. Selection of the surgical approach depends on site, extension (elbow joint or proximal radioulnar joint), severity of the initial articular surface, and periarticular tissue injury. The posterolateral approach is indicated for synostoses: at or distal to the bicipital tuberosity, at the level of the radial head, and proximal radioulnar joint. The posterior global approach is recommended when the forearm synostosis is associated with complete bony ankylosis of the elbow involving the distal aspect of the humerus. After surgical resection of a proximal radioulnar synostosis, the exposed bone surfaces can be covered with interposition material to minimize recurrence.

Current concepts

- Radioulnar cross-union commonly forms as a result of musculoskeletal injury, burns, or head injuries.
- The decision to remove the synostosis is made by evaluating its anatomy, size, and location and the state of the humeroulnar joint and proximal radioulnar joint and on the functional limitations.
- The surgical approach is dictated by the extension and site of the synostosis.

Future perspectives

- The early phase of synostosis formation is clearly depicted on radiographs, although the bone margin separating the heterotopic ossification from surrounding soft tissue may be indistinct.
- Computer tomography scans can be useful to map the location of lamellar bone formation and the extent of the bony involvement and assist in the evaluation of heterotopic ossification geometry.
- The timing of surgical treatment is considered critical. An interval of 6–12 months from the injury is generally recommended based on ectopic bone maturity.
- Selection of the surgical approach depends on site, extension (elbow joint or proximal radioulnar joint), severity of the initial articular surface, and periarticular tissue injury.
- The posterolateral approach is indicated for synostoses: at or distal to the bicipital tuberosity, at the level of the radial head and proximal radioulnar joint.
- The posterior global approach is recommended when the forearm synostosis is associated with complete bony ankylosis of the elbow involving the distal aspect of the humerus.

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INTRODUCTION

In the forearm, posttraumatic heterotopic ossification (HO) usually forms as a proximal radioulnar synostosis. The incidence of posttraumatic radioulnar cross-union ranges from 1.2% [1] to 18% [2]. HO may arise after plate fixation of forearm fractures and has been reported in approximately 6.6% of fractures of the proximal third of the radius and ulna [1–3]. It can occur after soft tissue injury involving the interosseous membrane (IOM) [2] or after surgery involving the radius and ulna, such as distal biceps tendon repair [4]. It can also be induced by radial head (RH) dislocation or fracture.

Thompson and Garcia [5] have found a 3% incidence in a series of isolated elbow dislocations, but when dislocation was combined with RH fracture or with an additional elbow fracture, the incidence rose to 15% and 20%, respectively.

The incidence of HO formation increases about fivefold when elbow dislocation is associated with a radial fracture [5].

McLaughlin has reported a series of RH fractures where the rate of HO formation was 12% if RH resection was performed within 24 h and 38% in case of delayed resection [6]. He devised some recommendations to reduce the risk of HO formation: RH excision within 24 h of injury, removal of the RH and all fracture fragments, prevention of bone dust formation, careful hemostasis, and prevention of hematoma formation.

A 9% incidence has been described by Bromberg and Morrey [7] in patients with elbow fracture-dislocation and delayed RH resection. The rates reported in the review by Vince and Miller [8] are 2.0% (range, 0–9.37%) in 2381 adults with forearm fractures and 18% in patients with brain lesions. Their study suggests that patients with a Monteggia lesion may be at higher risk of developing cross-union (2%–4%).

The surgical approach is dictated by the extension and site of the synostosis. There may be elbow ankylosis due to posttraumatic distortion of joint surface anatomy or to the formation of a bone bridge across the radial-capitellar joint (RCJ). The decision to remove the synostosis is made by evaluating its anatomy, size, and location and the state of the humeroulnar joint and proximal radioulnar joint (PRUJ) on computed tomography (CT) scans.

CLINICAL PRESENTATIONS

Radioulnar cross-union commonly forms as a result of musculoskeletal injury, burns, or RH injuries. Its type and location in the forearm vary with the underlying condition. Risk factors for HO formation around the elbow and forearm include initial injury: complex elbow instability with intra-articular fracture, RH fracture treated by surgery more than a week from injury, Monteggia lesions, especially when radius and ulna are fractured at the same level, forearm fractures with extensive IOM damage, comminuted fractures of the radius and ulna result in HO formation, especially if they are at the same level in the proximal forearm, where the two bones are very close to one another [1,3], severe high-energy traumas associated with radial and ulnar shaft fracture and severe soft tissue injury, and open fractures with extensive IOM damage. Previous surgical treatment includes distal biceps tendon repair, delayed surgical management, repeat surgical procedure 2–3 weeks after the injury, and hardware protruding into the interosseous space. Central nervous system injury includes brain injury and forearm and elbow trauma in patients with traumatic brain injury. Garland and Dowling [9] have reported an incidence of 33% in 50 patients, where a synostosis arose after plaster immobilization or surgical fixation. Burns: extensive burns over 20% of the total body surface area [10] and joint immobility in patients requiring prolonged bed confinement.

The diagnosis of synostosis is based on the total loss of passive and active pronation and supination on clinical examination. The radiocarpal joint may show very limited pronation and supination. The patient feels no pain, but in incomplete synostosis, the limited range of motion (ROM) may be painful. When the HO extends to the distal aspect of the humerus, it results in complete humeroulnar joint ankylosis, usually in 20–90° of elbow flexion [9].

CLASSIFICATION OF FOREARM SYNOSTOSIS BASED ON ANATOMICAL LOCATION

Vince and Miller [8] have classified forearm synostosis into three types based on location (Fig. 1): type 1 – distal third, type 2 – middle third, and type 3 – proximal third. This classification has subsequently been modified by Hastings and Graham [11], who identified six forearm regions that can be involved by the synostosis and the surgical procedures that can be performed in each region. They describe elbow involvement as a bony bridge extending from the forearm to the lateral humeral condyle or posterolateral olecranon and almost reaching the lateral collateral ligament (LCL). Anterior HO may also extend from the humerus to the radius and ulna at the level of the bicipital tuberosity. The bony bridge is often associated with proximal radioulnar synostosis with bony encasement of the biceps tendon [12]. Jupiter and Ring [12] have divided the type 3 synostosis of Vince and Miller into three subgroups (Fig. 2A–I): type 3A: synostosis at or distal to the bicipital tuberosity, type 3B: synostosis at the level of the RH and the PRUJ, type 3C: synostosis contiguous to or associated with HO extending to the distal aspect of the humerus (complete bony ankylosis of the elbow).

To improve the surgical excision of HO involving the PRUJ, Viola and Hastings [13] distinguish the following features on preoperative radiographs: type 1 lesion: PRUJ synostosis involving the intra-articular

![Image](518x494 to 346x97)

**Fig. 1.** Classification of radioulnar synostosis. Vince and Miller [8] identified three sites for therapeutic and prognostic purposes: type 1: distal intra-articular radius and ulna; type 2: extra-articular sites; type 3: proximal radioulnar synostosis.
surfaces, type II lesion: PRUJ synostosis extending distally to the bicipital tuberosity and involving the joint surfaces, type III lesion: synostosis distal to the PRUJ involving the neck and the bicipital tuberosity. In turn, type I includes bony involvement: 1A anterior to the PRUJ, 2B posterior to the PRUJ, and 3C affecting the whole PRUJ.

CLASSIFICATION OF FOREARM SYNOSTOSIS BASED ON FUNCTIONAL LIMITATION

This is a useful system to guide the surgeon in the preoperative clinical assessment and in setting treatment goals. Hastings and Graham [11] have developed a three-part classification system: class I: no functional limitation; Class II: II A limited flexion-extension, II B limited pronation-supination, III C limited flexion-extension and pronation-supination; and Class III: ankylosis.

Vince and Miller [8] rated the outcomes of their patients based on the amount of forearm rotation recovered after surgical excision of the synostosis: excellent 80°-140°, good 30°-80°, fair <30°, failure no movement. Failla et al. [4] evaluated postoperative forearm rotation based on a biomechanical study of the functional elbow motion that is needed to perform 15 key tasks [14]. Postoperative pronation and supination are rated out of a total of 100° as excellent >50°, rotation needed to perform all 15 tasks, good >30°, rotation needed for six tasks, poor <30°, and rotation sufficient to perform three tasks.

DIAGNOSTIC TESTS

In the radiological studies conducted at the Mayo Clinic [15,16], HO have been classified based on their appearance, size, and functional implications, as follows: “hazy or granular immature,” where HO lack corticocancellous definition, “mature limited,” where corticocancellous definition is visible, but the area is small to moderate, “mature extensive,” where two separate bones are almost in contact, and “bone bridge,” where the separate bones are connected. The early phase of synostosis formation is clearly depicted on radiographs, although the bone margin separating the HO from surrounding soft tissue may be indistinct. Screening radiography can be used to select the appropriate time for excision [17]. The synostosis can be resected when the ectopic bone margin and trabeculation appear mature on radiographs. CT scans can be useful to map the location of lamellar bone formation and the extent of the bony involvement and assist in the evaluation of HO geometry. Magnetic resonance imaging is rarely needed.

SURGICAL TECHNIQUE

The timing of surgical treatment is considered critical. An interval of 6-12 months from the injury is generally recommended based on ectopic bone maturity.
Jupiter and Ring [12] have suggested early resection to reduce the risk of progressive soft tissue contracture and articular cartilage destruction and to limit the duration of severe disability. The rate of recurrence after primary resection ranges from 6% to 35% depending on the degree of soft tissue and bone trauma and on whether the patient has an associated traumatic brain injury [9,12]. After surgical resection of a proximal radioulnar synostosis, the exposed bone surfaces can be covered with interposition material to minimize recurrence. Materials include nonbiological materials: silicone [18–20], bone wax [4,12], polyethylene [10], and cellophane membrane [20].

Biological soft tissue includes fascia lata (autograft or allograft) [21], vascularized anconeus muscle [22], free fat flap [23,24], vascularized adipofascial flap [25,26], and pedicle muscle flaps (wrapped around the exposed bone surfaces) [27].

Morrey and Harter [28] have suggested these recommendations: resect HO if all movements are limited, avoid articular cartilage damage, ensure atraumatic tissue handling, perform accurate hemostasis, accurately drain the surgical field, minimize bone dust production, perform meticulous lavage, avoid neurological injury, and ensure early postoperative motion.

Selection of the surgical approach depends on site, extension (elbow joint or PRUJ), severity of the initial articular surface, and periarticular tissue injury.

The Jupiter and Ring classification [12] may be useful to guide in the choice between the limited posterolateral approach and the extensile posterior (global) approach with or without RH excision. The posterolateral approach is indicated for synostoses: at or distal to the bicapital tuberosity (type 3A) [12] and at the level of the RH and PRUJ (type 3B) [12].

The posterior global approach is recommended when the forearm synostosis is associated with complete bony ankylosis of the elbow involving the distal aspect of the humerus (type 3C) [12].

The procedure is performed under locoregional or general anesthesia with the patient supine and the arm on a hand table. A tourniquet is applied to achieve a bloodless field.
POSTEROLATERAL APPROACH

The posterolateral skin incision allows exposing the Kocher interval between the anconeus and the extensor carpi ulnaris (ECU) muscles. The entire anconeus and the ulnar origin of the ECU are raised from the posterolateral edge of the proximal ulna to expose the synostosis and the proximal third of the radius (Fig. 3A and B). The ankylosed position of the forearm may involve posterior interosseous nerve (PIN) damage when the synostosis is resected: when the forearm is pronated, the PIN lies more anterior and medial, and proximal radius exposure should pose no risk; when the forearm is supinated, the PIN is near the operative field and is at risk of injury; in such cases, it should be localized before resecting the synostosis [29].

The proximal and distal margins of the synostosis are identified and dissected free of any bony entrapment. The surrounding soft tissues are protected; the entire synostosis must be resected to restore forearm rotation. The radius and ulna must be debrided to a smooth surface without sharp edges. After synostosis resection, if the radioulnar joint surfaces are intact (type 3A) [12], we recommend interposing between the bones a free fat layer of the patient's subcutaneous tissue (upper limb or buttock) or the common extensor tendon aponeurotic fascia. In patients where the synostosis involves the PRUJ (type 3B) [12], Kamineni et al. have proposed proximal radial resection as an alternative procedure [30]. The indications for this procedure include extensive synostosis not amenable to safe resection, articular surface involvement, and associated anatomical deformity.

The proximal radial shaft is exposed with the Kocher approach, and 1–1.5 cm resected about 1 cm distal to the synostosis and to the bicipital tuberosity to mobilize the forearm. The remaining resected bone, proximal and distal, is covered by interposing a layer of free fat or a pedicle anconeus muscle flap [30].

RH resection is performed in patients with elbow stiffness secondary to RH malunion or posttraumatic RCJ degeneration with incongruence. After RH resection, full passive forearm pronation-supination and elbow flexion-extension can be recovered, provided that posterolateral elbow stability is preserved or has been restored.

When the bicipital tuberosity is involved, the bicipital tendon is detached; at the end of the procedure, it is securely reattached to the radial tuberosity, usually with bone anchors.

POSTERIOR GLOBAL APPROACH

The posterior approach is used when the radioulnar synostosis is contiguous or associated with the bone extending across the elbow (type 3C) [12].

The global approach can be used to access the posterior, anterior, medial, and lateral joint compartment (Fig. 4A and B). On the lateral side of the elbow, the radial nerve is isolated between the brachioradialis and brachialis muscle proximal to its division into a superficial and a deep branch (PIN). The PIN is isolated distally, and its relationship with the supinator muscle explored under the arcade of Fröhse [31]. In the

Fig. 3. (A,B) The posterolateral approach.
proximal half of the deep posterolateral dissection (Kocher approach),
the insertion of the brachioradialis, extensor carpi radialis longus, and
brachialis muscle is elevated from the anterolateral aspect of the hu-
merus. A Hohmann retractor can be used to pull back the anterolateral
muscles and nerves to expose the HO and the joint capsule. In the distal
half of the deep approach, the Kocher interval is dissected, the common
extensor tendon insertion is released from the lateral epicondyle of the
humerus, and the ectopic bone is encountered. The distal dissection is
continued until the entire forearm synostosis has been cleared. If the HO
extends posteriorly, triceps elevation allows visualizing the posterior
aspect of the humerus, the olecranon, and the HO. After excision of
the anterior and posterior capsule, the extent of the HO resection is de-
termined under direct vision and with intraoperative fluoroscopy.

The bone resection proceeds proximal to distal until passive elbow
motion and forearm movement are restored. At the time of bone resec-
tion, if the patient suffers from posterolateral elbow instability, the LCL
must be reconstructed, and a hinged elbow distractor applied [32].

If, after proximal HO resection and restoration of elbow flexion and
extension, the distal resection is not safe, proximal radial resection [3]
may be useful to improve forearm rotation and preserve RCJ integrity,
especially when the PRUJ exhibits degenerative or anatomical changes.

At the end of the procedure, a suction drain is applied to minimize
hematoma formation, which may support bone growth.

CONCLUSION

The incidence of posttraumatic radioulnar cross-union ranges from
1.2% [1] to 18% [2]. Radioulnar cross-union commonly forms as a result
of musculoskeletal injury after soft tissue injury involving the IOM [2] or
after surgery involving the radio and ulna, such as distal biceps tendon
repair [4] or by RH dislocation or fracture. Its type and location in the
forearm vary with the underlying condition. The classification of forearm
synostosis is based on the anatomical locations [8] or on the functional
limitations [11]. Screening radiography can be used to select the appro-
priate time for excision. The synostosis can be resected when the
ectopic bone margin and trabeculation appear mature on radiographs. An
interval of 6–12 months from the injury is generally recommended based
on ectopic bone maturity. Selection of the surgical approach depends on
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[12], at the level of the RH and PRUJ (type 3B) [12]. The posterior global
approach is recommended when the forearm synostosis is associated
with complete bony ankylosis of the elbow involving the distal aspect of
the humerus (type 3C) [12]. After surgical resection of a proximal radi-
oulnar synostosis, the exposed bone surfaces can be covered with inter-
position material to minimize recurrence.

Declaration of competing interest

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