# Chapter 38
# Heterotopic Ossification of the Elbow

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## Patient Presentation

The formation of ectopic bone about the elbow commonly presents following elbow trauma, significant neural axis injury, or major burns with symptoms of stiffness or complete ankylosis.[1] By definition, any ossification that forms in tissues which do not typically make bone is considered ectopic or heterotopic. Patients who develop heterotopic ossification about the elbow can present with muscle, nerve, or joint related pain, but most often express frustration due to lack of passive and active motion. Loss of elbow motion leads to dramatic impairment in upper extremity function. For example, a 50% loss of elbow motion will cause up to 80% impairment in upper extremity function.[2]

The pathologic process behind ectopic bone formation has not been fully elucidated. This lack of understanding limits our ability to treat heterotopic bone formation both before and after it occurs. Certainly, the ideal management of any elbow contracture due to heterotopic ossification is prevention. Early and consistent active range of motion exercises,[3-5] medical intervention such as indomethacin and disphosphonates,[6,7] or radiation therapy[8] have all been proposed but remain unproven as potential treatment options for the prevention of heterotopic ossification about the elbow. If it does occur, surgical excision and elbow contracture release are viable options for regaining elbow motion.

There are a few conditions that are associated with spontaneous formation of heterotopic bone about the elbow. Injury to bone, ligament, muscle, tendon, or joint capsule from the distal humerus to the proximal ulna or radius can incite local ectopic bone formation.[7,9-12] Iatrogenic trauma, such as lateral epicondylectomy or elbow arthroscopy, have been reported to cause elbow heterotopic ossification.[13,14] Alternatively, trauma to the central nervous system (including spinal cord injury) and debilitating burns have also been identified as risk factors for spontaneous formation of heterotopic bone about the elbow.[4,5,7,15-17]

## Indications

The primary indication for operative resection of heterotopic bone and elbow contracture release is lack of elbow motion. Once heterotopic ossification has developed and restricted elbow motion, it is nearly impossible to regain the lost motion with conservative measures, such as physical therapy, dynamic splinting, radiation therapy, or medication. Surgical resection of heterotopic bone about the elbow should be considered in patients who present with an unacceptable loss of flexion/extension or pronation/supination. Restoration of a functional arc of motion is the primary goal in active individuals. From a biomechanical perspective, the functional arc of elbow motion has been demonstrated to be from 30° to 130° in the flexion/extension plane and from 55° of pronation to 55° of supination in the plane of forearm rotation.[18] In an otherwise non-functional upper extremity, restoration of extension can even improve daily hygiene and nursing care. When considering the cosmetic appearance of the arm, one group of authors believed that achieving greater extension than 30° of flexion is needed for optimal patient satisfaction.[9]

Historically, surgical excision was delayed until maturity of the heterotopic bone was proven.[19] Guides to assessing the maturity of ectopic bone included normalization of the alkaline phosphatase level, quiescent bone scan, and a solidified appearance on plain radiographs. However, recent reports of outcomes after surgical excision have used only radiographic appearance of the lesion as a determining measure of maturation.[11,20-23] Along with questioning the need for additional tests to ascertain the maturity of the heterotopic bone, there are case series which have investigated early excision of the immature ossification.[20,22-25] We do not believe there is sufficient scientific evidence to suggest that alkaline phosphatase chemistries or nuclear medicine scans are necessary to qualify the maturity (or lack thereof) of elbow heterotopic ossification.

The timing of surgical excision should be dependent on the patient's presentation, the condition of the enveloping soft tissues, and the integrity of the crossing neurovascular structures. It is prudent to obtain sufficient radiographic imaging to understand the extent of heterotopic ossification and elbow ankylosis prior to any definitive procedure. In patients with significant spinal cord or central nervous system trauma, surgical excision should be until maximal motor recovery occurs, which can be as long as 1 to 1.5 years after initial injury.[19,26] If there are burn wounds present about the elbow, these should be entirely healed prior to creating a new incision.[5,23] Neurologic, vascular, and lymphatic systems must be assessed and their status documented and appropriately prioritized.[27] For instance, the ulnar nerve can be encased in heterotopic bone causing cubital tunnel symptoms which may dictate an earlier timing of surgery.[22,27,28] The integrity of the skin and subcutaneous tissues should be evaluated. Lingering soft tissue swelling, edema, or erythema may all point to additional diagnoses that must be dealt with before deciding upon heterotopic bone resection. In a majority of cases, we proceed with surgical resection when the soft tissue envelope is quiescent.

## Relevant Anatomy

It is critical to have a firm understanding of the neurovascular structures that cross this joint, as well as their typical relationships to surrounding structures. Frequently, when ectopic bone is being excised about the elbow, the surgeon is working in a previously scarred area where nerves may have been dissected, mobilized, or even transposed. The proximity of heterotopic ossification to any nerve or blood vessel adds considerable risk to surgical excision. Patients must be aware of the potential for iatrogenic neurovascular injury prior to signing informed consent.

The cutaneous nerves that require diligence are the posterior brachial cutaneous nerve and the medial and lateral antebrachial cutaneous nerves to the forearm. The main peripheral nerves to identify are the median, ulnar, and radial, including the posterior interosseous nerve distally. Lastly, the operating surgeon must always be aware of the location of the brachial artery. The dissection and identification of these anatomic structures will be reviewed within the description of the surgical technique.

Heterotopic bone can occur anywhere about the elbow, but it is typically posterior, deep to the triceps extending from either epicondyle to the olecranon, or anterior, associated with the brachialis (Figures 1, 2). Evans[5] believed that heterotopic bone forms and matures along a line from the olecranon to the medial epicondylar ridge of the humerus at the medial border of the triceps. This has been confirmed as a common location by Tsionos et al.[23] and McAuliffe and Wolfson[22] in more recent studies. Garland[16] states the most common location for heterotopic ossification after a central neurologic injury is either posterolateral (from the posterolateral humeral condyle to the posterolateral olecranon, fixing the elbow at 30° of flexion) or anterior within the brachialis. Another typical location for ectopic bone formation about the elbow is between the radius and the ulna, causing a proximal radioulnar synostosis (Figure 3).

Hastings and Graham[29] proposed a classification system of elbow ectopic bone formation. There are three groups or classes based on functional range of motion which those authors felt would be helpful in both assessment and treatment. Class I includes patients with positive radiographs for heterotopic ossification, but no functional limitations. Class II radiographs demonstrate heterotopic ossification, and there is a functional limitation—either in the flexion/extension axis (Class IIA), the pronation/supination axis (Class IIB), or both (Class IIC). Class III patients have ectopic bone with ankylosis either in flexion/extension (Class IIIA), pronation/supination (Class IIIB), or both (Class IIIC).[1,29]

## Clinical Studies (Outcomes)

The majority of outcome studies on surgical excision are retrospective reviews with small numbers of patients, as this is a relatively uncommon procedure in the realm of orthopaedic surgery. Studies are varied in their operative approaches, as well as in their post-operative protocols. Typically, most cases are treated on an individual basis according to each patient's prior surgery, the condition of the overlying soft tissues, and the surgeon's preference for maintaining motion and preventing the recurrence of heterotopic bone post-operatively.

Viola and Hanel[20] reported on 15 cases of early release (24–78 weeks of initial injury) for post-traumatic elbow contractures with heterotopic ossification. These authors were able to achieve a mean flexion/extension arc of 120° and a mean pronation/supination arc of 152° at an average follow up of 115 weeks. Here, indomethacin and continuous passive motion were used post-operatively in most cases. Morimoto et al.[24] studied nine consecutive patients who underwent early excision (mean 7.7 months from initial injury) of medial-sided heterotopic ossification. Those authors found 112° of flexion and extension at an average follow up of 52 months. Recurrence of elbow stiffness did not occur despite radiographic evidence of spotty heterotopic ossification in five of the nine patients.

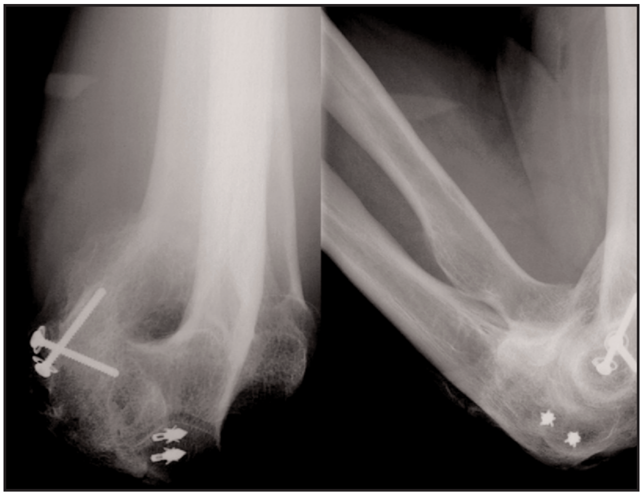

**Figure 1.** Case 1: These anteroposterior and lateral radiographs show complete ankylosis of the elbow at 130° of flexion after prior elbow injury.

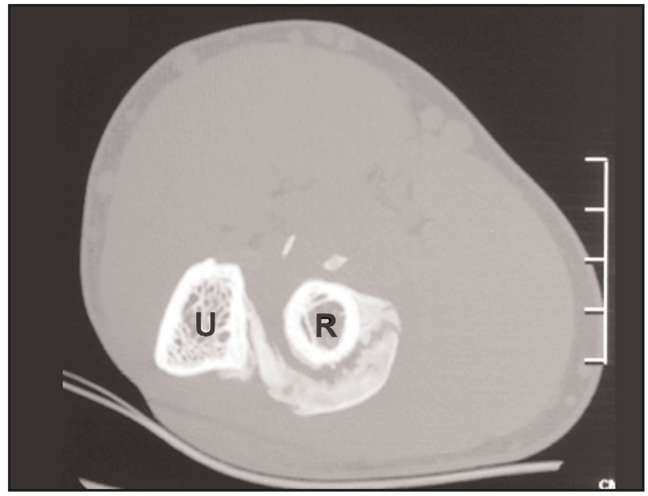


**Figure 3.** Case 3: An axial CT scan image demonstrates a proximal radioulnar synostosis after a two-incision distal biceps tendon repair. The heterotopic bone can be seen extending from the lateral aspect of the ulnar (U), circling around to the lateral aspect of the radius (R).

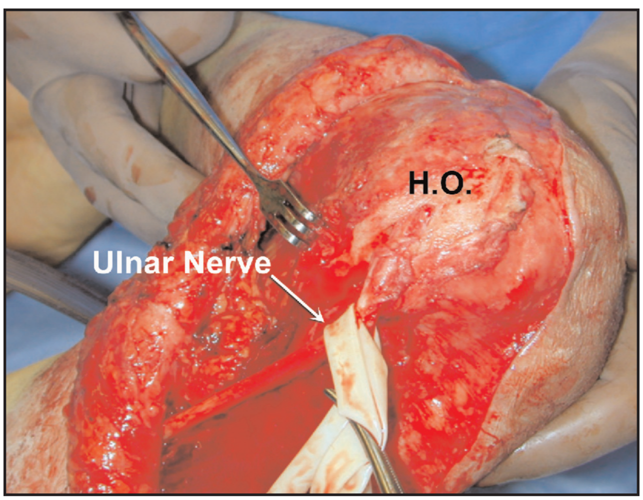


**Figure 2.** Case 1: This is an intra-operative view of the ulnar nerve (marked by a penrose drain) encased in heterotopic ossification (HO) as it courses distally towards the cubital tunnel.

Ring and Jupiter[21] found similar improvements in range of motion with their series of patients which included both post-traumatic and burn patients. However, six of their patients required re-release of their elbow contractures (three post-traumatic and three post-burn). The burn patients demonstrated poorer functional outcomes and frequently were involved with soft tissue coverage problems, requiring either simultaneous or post-operative free flaps. Tsionos et al.[23] had 4 recurrences in their cohort of 35 post-burn patients that had undergone surgical excision despite post-operative indomethacin and continuous passive motion.

With regards to post-operative radiation therapy, McAuliffe and Wolfson[22] used 5 doses of radiation therapy for a total of 1000 cGy and found an average of 103° of flexion and extension at an average follow up of 46 months. This group included eight patients treated with early excision (3–10 months initial injury). Multiple authors have successfully employed single doses of peri-operative radiation (700 cGy) for excision of elbow heterotopic ossification.[9,30,31] None of the above studies noted a clinically significant recurrence of the ectopic ossification.

Studies focused on the release of proximal radioulnar synostosis have examined different types of interposition material as well as the clinical outcomes of the takedown procedure. Failla et al.[32] reported on 20 patients with an average follow up of 40 months and found that approximately half of the achieved intra-operative motion was maintained over time. The interposition material varied in this report, but those authors preferred a synthetic interposition material as outcomes were worse with biologic interpositions. Other authors have refuted these results. Bell and Benger[33] provided a report of three successful cases of proximal radioulnar synostosis takedown followed by interposition of the anconeus. Their operative approach consisted of anterior and posterior capsular release as well as excision of the synostosis. Post-operatively, each patient was treated with single dose radiation therapy (700 cGy), flexion/extension and pronation/supination CPM, and indomethacin.[33] Alternative soft tissue flap interpositions include a pedicled brachioradialis flap,[34] a pedicled adipofascial radial forearm flap,[35] or a free adipofascial flap from the lateral arm.[36]

Jupiter and Ring[11] described 18 cases of post-traumatic proximal radioulnar synostosis that underwent release with no post-operative treatments other than physical therapy. All patients were treated with bone wax at the exposed osseous margins, while eight patients had autologous fat interposition. The authors did not find the fat interposition to have any effect on final outcomes. At final follow up, average forearm rotation was 139° excluding one recurrence, which involved a patient with a head injury. While radiation therapy was not used in their study, Ring and Jupiter[37] have advocated this treatment modality in a more recent technique article.

## Equipment and Implants for the Surgery

The excision of ectopic bone from the elbow is a complex procedure that requires pre-operative planning. For example, while it is not typical to require an implant for the surgery, a total elbow arthroplasty, a radial head arthroplasty, and a hinged external fixator should be available. In addition, soft tissue allografts, such as semitendonosis for ligamentous reconstruction or fascia lata for soft tissue interposition, may be useful. Certain instruments not common to most hand surgery equipment sets can facilitate dissection, retraction, and heterotopic bone removal. Because of the proximity of critical neurovascular structures, instruments should be sharp and in good condition to allow for precision work.

In addition to operative equipment, consideration should be given pre-operatively for planning a patient's post-operative pain control and early rehabilitation. The anesthesia team should be consulted prior to the day of surgery so that they can be prepared to place an axillary or infraclavicular catheter for post-operative pain management while range of motion exercises are initiated. Though anesthesiologists frequently prefer placing a catheter pre-operatively, the nerve block can also be done post-operatively to allow an assessment of neurologic function after the patient has awoken from anesthesia. A continuous or on-demand infusion catheter for post-operative pain control is very helpful in maintaining patient comfort, especially if continuous passive motion is used. A continuous passive motion machine for the elbow often needs to be ordered prior to the day of surgery so that it may be available in the recovery room after surgery. A thorough listing of the equipment and implants for elbow heterotopic bone excision surgery is shown in Table 1.

## Operative Approach

A systematic approach to elbow contracture release with focused goals (Table 2) facilitates excision of heterotopic bone. The specific surgical approach varies according to the underlying pathology (such as the position of orthopaedic hardware, the location of heterotopic bone, or the presence of capsular contracture) and condition of the enveloping soft tissues (previous surgical incisions, muscle and tendon deficiencies, nerve dysfunction, or burn contracture). Pre-operative computed tomography scans can be very helpful in understanding the anatomic location of the heterotopic bone, especially in cases of proximal radioulnar synostosis.

It is our preference to have the patient supine on the operating table with the affected arm on a radiolucent hand table. Certainly if there is a stiff shoulder ipsilaterally, the patient may also be in the lateral position with the affected arm draped over a leg holder for posterior approaches. However, we find that draping the arm draped free on a hand table is simple and straightforward for anesthesia, nursing, and the operating surgeon. The shoulder may be rotated to change the position of the elbow and transition easily from medial to lateral or anterior to posterior. Either position is reasonable, but the chosen position must allow the surgeon to have uncompromised access to both the medial and lateral aspects of the elbow. While it is not our practice to use a tourniquet during excision of heterotopic bone, a sterile tourniquet can be placed on the upper arm prior to skin incision.

Typically, it is prudent to take advantage of prior skin incisions as long as they allow sufficient access to achieve the surgical goals. Fortunately, the skin overlying the elbow is richly perfused, allowing both medial and lateral approaches to be performed through a posterior skin incision, also termed the "global" approach to the elbow.[38] The posterior incision also avoids the medial and lateral antebrachial cutaneous nerves which are susceptible to injury with medial or lateral skin incisions.[39] Patients who have developed heterotopic ossification secondary to a burn injury frequently have a tenuous skin and subcutaneous envelope about the elbow. These patients are at jeopardy for wound healing problems or skin flap necrosis

**Table 1.** Soft Tissue Interpostion Flaps for Elbow HO

**Operative Equipment**

| Standard Equipment | Optional Equipment |
|---|---|
| Preoperative radiographs and CT scan | Fluoroscopy |
| Sterile tourniquet | Fiber optic headlight |
| Retractors, thyroid-type (long & narrow) | Total elbow arthroplasty |
| Lamina spreader | Radial head arthroplasty |
| Vessel loops or Penrose drains | Axillary or infraclavicular catheter |
| Rongeurs (including Kerrison and Pituitary) | Lidocaine infusion pump |
| Osteotomes and curettes | Continuous passive motion machine |
| Screwdrivers for removal of retained implants | Postoperative radiation therapy |
| Suture anchors | Static progressive vs. dynamic splinting |
| Tensor fascia lata and semitendonosis allograft | |
| Hinged elbow external fixation | |
| Closed suction drain | |

which may require free tissue transfer to cover remaining soft tissue defects.[21]

A midline posterior incision begins the procedure. The skin incision is typically straight, passing two centimeters medial or lateral to the tip of the olecranon, but may be curvilinear to incorporate previously placed surgical scars. To preserve the blood supply to the overlying soft tissues, full thickness fasciocutaneous flaps are elevated from investing fascia of the triceps. If ulnar nerve dysfunction is present preoperatively, a medial sided flap should be elevated to expose the medial epicondyle of the distal humerus. From this position, the ulnar nerve can be located proximally as it passes through the medial intermuscular septum. The septum should be released and excised, and an external neurolysis of the ulnar nerve should be performed. Free the nerve distally as it courses around the medial epicondyle and into the proximal aspect of the flexor carpi ulnaris (FCU). Once isolated, the nerve can be tagged with a vessel loop as a reminder of its location. It should be adequately freed to allow anterior transposition after excision of the heterotopic bone (Figures 4, 5, 6).

Occasionally, the ulnar nerve can be found encased in ectopic bone[20] (Figures 1, 2). In these situations, the ulnar nerve should be identified in normal tissue proximally at the level of the intermuscular septum and distally between the

**Table 2.** Key Principles to Operative Release of Elbow Heterotopic Ossification

- Preserve the integrity of the soft tissue envelope, use prior incisions when possible
- Identify crossing neurovascular structures
- Decompress and transpose the ulnar nerve when compressive symptoms exist
- Excise heterotopic ossification from the elbow until normal range of motion is restored
- Release completely the anterior and posterior elbow joint capsules
- Preserve the collateral ligaments whenever possible
- Assess intraoperative range of motion and stability

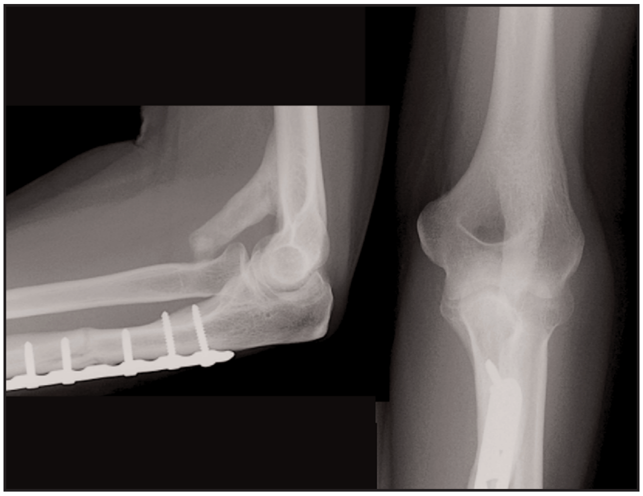

**Figure 4.** Case 2: Anteroposterior and lateral radiographs demonstrate heterotopic ossification anterior to the elbow causing an ankylosed elbow with ulnar nerve dysfunction.

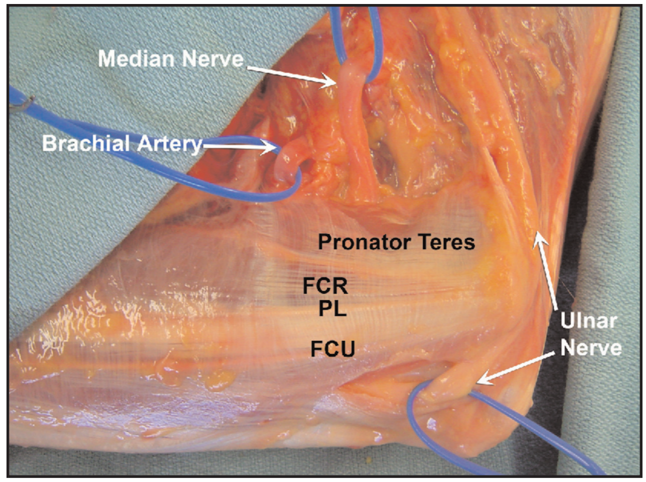


**Figure 5.** Cadaver dissection: The skin and subcutaneous layer has been elevated to expose the medial musculature of the elbow. Blue vessel loops mark the median nerve proximal to the pronator teres and the ulnar nerve distal to the medial epicondyle as it dives between the humeral and ulnar heads of the flexor carpi ulnaris.

ulnar and humeral heads of the flexor carpi ulnaris. Overlying ectopic bone can then be gradually and carefully excised with rongeurs or osteotomes until the nerve is completely free.

If pre-operative radiographs and CT scan imaging demonstrate that the heterotopic bone is limited to the medial side of the elbow then one can proceed to medial anterior capsule exposure and heterotopic bone resection (Figures 6–11). On the other hand, if the heterotopic bone is extensive and primarily involving the lateral column, then we suggest identifying and protecting the radial nerve before proceeding with the heterotopic ossification resection. If hardware is retained about the humeral shaft or distal humerus, then exposing and isolating the radial nerve is a prerequisite to safe hardware removal.

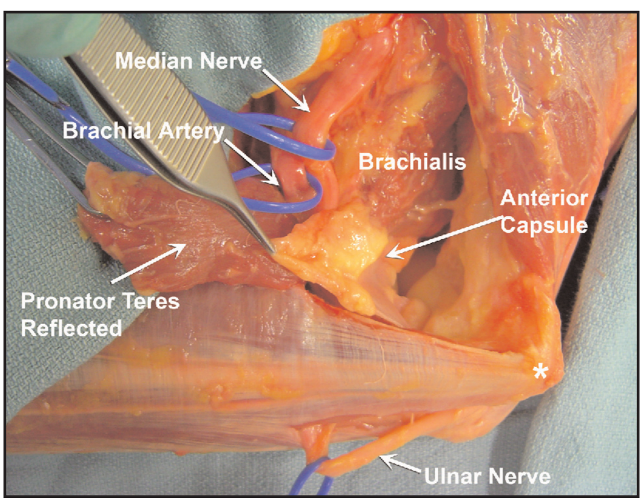


**Figure 6.** Cadaver dissection: The pronator teres is reflected to demonstrate the median nerve, brachialis, and anterior capsule (forceps).

To expose the radial nerve, a lateral fasciocutaneous tissue flap is elevated in the same tissue plane as the medial dissection. Frequently, the lateral branches of the posterior cutaneous nerve of the arm are visible on the undersurface of this flap. These branches can be followed proximally to their take off from the radial nerve proper. If this landmark is not readily available, then our second approach is to dissect the distal portion of the flap towards the lateral epicondyle. Upon reaching this landmark the lateral intermuscular septum is identified and the dissection is directed cephalad. The triceps muscle belly is freed from posterior aspect of the intermuscular septum. Small vessels and nerves seen entering the triceps muscle should be followed proximally; they will lead to the radial nerve proper. If these markers fail to lead to the nerve, then cautiously proceed along the intermuscular septum somewhere between 6 and 10 cm proximal to the tip of the lateral epicondyle; the nerve, surrounded by perineural fat, will be encountered along the spiral groove as it passes through the lateral intermuscular septum to enter the anterior aspect of the arm (Figure 12). Once the radial nerve is identified, the lateral intermuscular septum is removed and

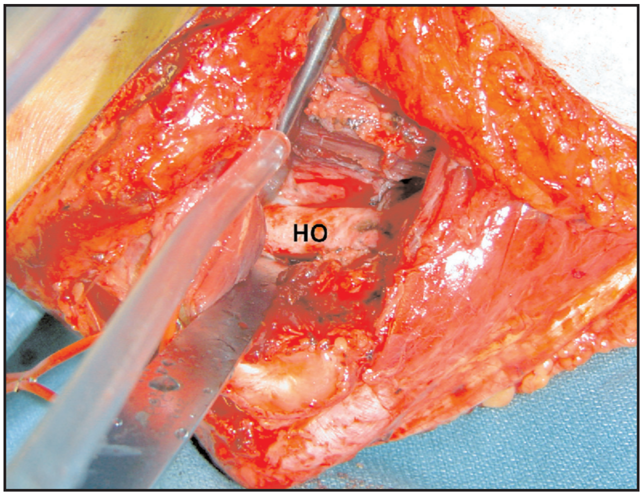


**Figure 7.** Case 2: This intra-operative view shows the same medial approach. The pronator teres and the brachialis are retracted to expose the bridging heterotopic ossification (HO). A medial approach was selected as this patient suffered ulnar nerve distribution paresthesias and weakness. Lateral-sided ossification can be accessed through a medial approach.

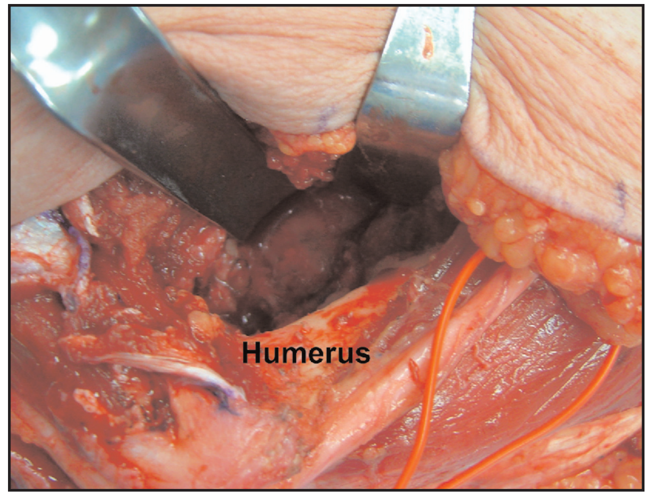


**Figure 9.** Case 2: A close-up intra-operative view reveals an empty space after resection of the heterotopic bone. A full range of elbow motion was achieved intra-operatively.


**Figure 8.** Case 2: This photograph shows the heterotopic ossification after resection.

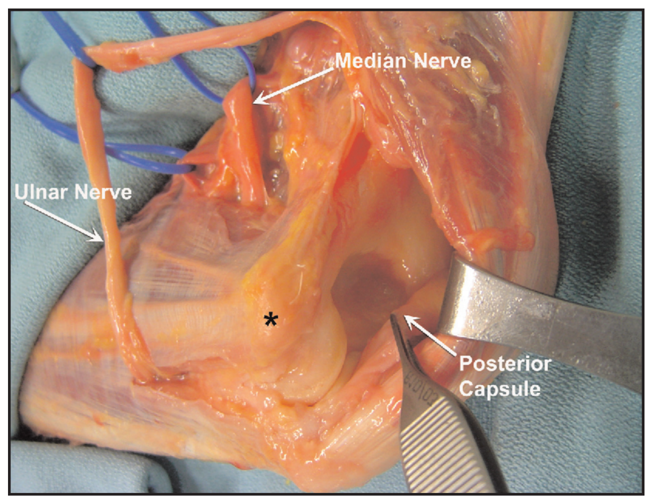


**Figure 10.** Cadaver dissection: The medial triceps is retracted to expose the posterior olecranon fossa.

the nerve followed distally. At the level of the elbow, the nerve can be more easily identified in the internervous plane between the proximal aspect of the brachioradialis and the distal aspect of the brachialis. Blunt dissection between these two muscles, just superior to the joint line, will reveal the radial nerve before it dives under the supinator muscle more distally (Figure 13). Having now identified and protected the vulnerable ulnar and radial nerves, we then proceed with heterotopic ossification resection and release of the elbow contracture.

## Lateral Exposure

The "Column Procedure" described by Morrey[40] for simple release of extraarticular elbow contracture affords exposure of

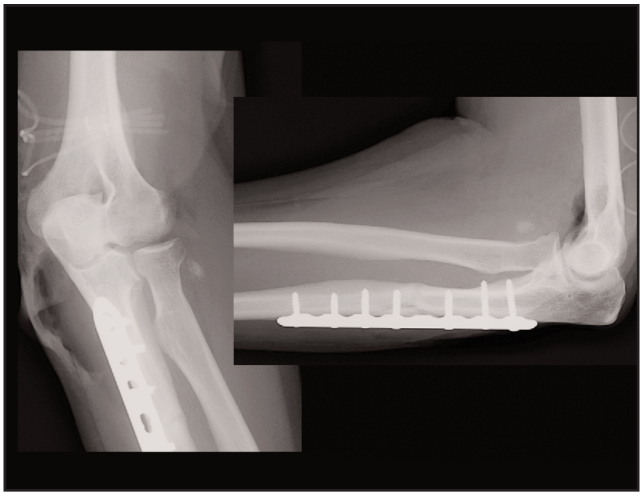

**Figure 11.** Case 2: Intra-operative radiographs show resection of the bridging heterotopic bone.

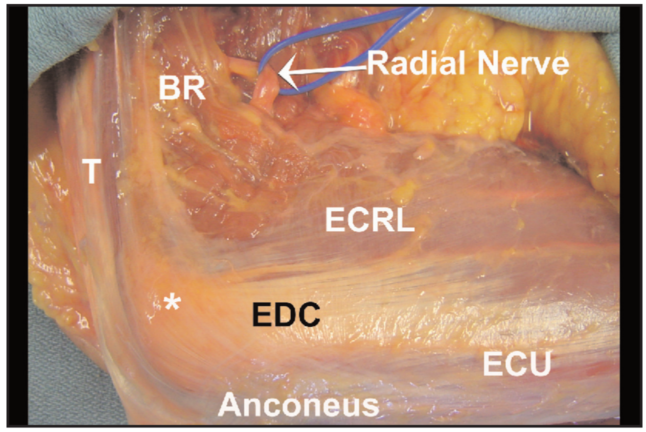


**Figure 12.** Cadaver dissection: Elevation of the skin and subcutaneous tissues reveals the pertinent musculature involved in the lateral approach to the elbow. The radial nerve, coursing between the brachioradialis and brachialis, is identified by a blue vessel loop.

both the posterior and anterior capsules of the elbow joint through either a limited lateral skin incision or an extensile posterior skin incision as previously described (Figures 12, 13). The lateral epicondyle is localized; the lateral edge of the triceps is freed from the lateral intermuscular septum; and the triceps is elevated to expose posterior heterotopic bone and the posterior capsule (Figure 14). Both the heterotopic bone and the capsule should be excised. Redundant synovium and synovial fat within the olecranon fossa should also be debrided. Additionally, any posterior osteophytes or redundant fracture callus that may be causing impingement or preventing full extension must be resected.

Exposure and release of the anterior capsule can be performed by elevating the distal or inferior origin of the brachioradialis and the entire origin of the extensor carpi radialis longus (ECRL) directly off the anterior aspect of the lateral epicondyle. Next, the brachialis can be elevated off of the anterior capsule and retracted anteriorly along with the brachioradialis, ECRL, and extensor carpi radialis brevis (ECRB), if needed. A long narrow thyroid-type retractor is very useful in retracting these laterally-based muscles and the brachialis off the anterior joint capsule to improve exposure. A head light may also improve visualization through this lateral window deep to the medial side of the elbow. This surgical dissection affords access to the anterior elbow capsule (Figure 13) that can be excised under direct vision for contracture release. Anterior heterotopic bone typically forms within the substance of the distal aspect of the brachialis muscle, just anterior to the anterior capsule of the elbow. This lateral exposure allows straightforward excision of anterior heterotopic ossification. The heterotopic bone can be carefully elevated off the distal aspect of the anterior humerus using a combination of osteotomes and rongeurs.

Alternatively, the Kocher approach involves creating an interval distal to the lateral epicondyle between the anconeus and the extensor carpi ulnaris (ECU), or one can exploit the interval between the extensor carpi radialis longus (ECRL) and brevis (ECRB). Proximally, the ECRL is elevated off the lateral epicondyle along with the origin of the brachioradialis. These muscles are retracted superiorly and anteriorly to reveal the anterior capsule. This intermuscular approach between the ECRL and ECRB provides exposure of the joint capsule without taking down the lateral collateral ligament.[41]

## Medial Exposure

In severely contracted elbows this exposure affords uncompromised visualization of the anterior capsule and crossing neurovascular bundles (ulnar nerve, median nerve, and brachial artery). The medial approach begins with exposure of the posterior joint capsule and olecranon fossa from the medial side (Figures 5, 6, 7). The medial border of the triceps is elevated off the intermuscular septum and medial epicondylar ridge of the humerus. The undersurface of the muscle is then retracted to expose posterior heterotopic ossification or the posterior capsule itself (Figure 10).

The anteromedial release takes advantage of the internervous plane between the ulnar innervated flexor carpi ulnaris (FCU) and the median innervated flexor-pronator muscle

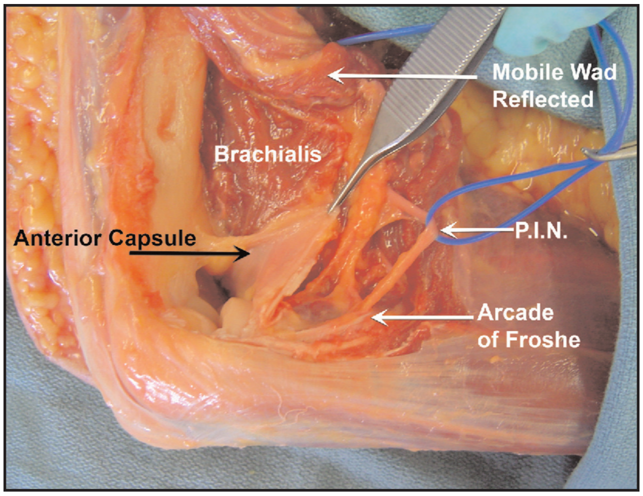


**Figure 13.** Cadaver dissection: The posterior interosseous nerve is marked by the blue vessel loop as it enters the supinator. Deep to the brachialis, the anterior capsule has been incised and is reflected by the hemostat, revealing the anterior aspect of the radiocapitellar joint.

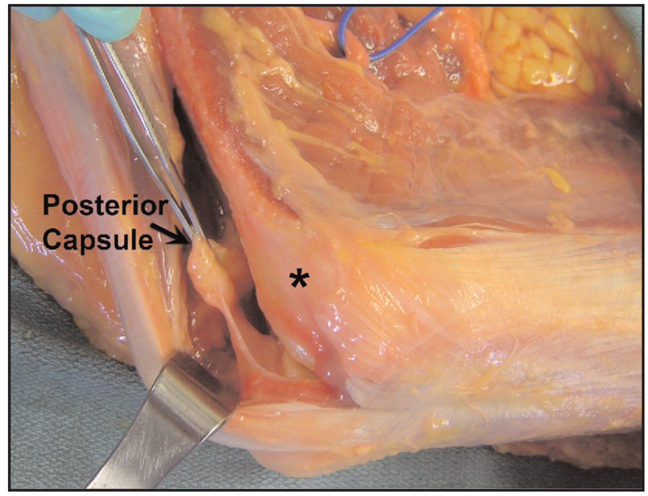


**Figure 14.** Cadaver dissection: The posterior capsule has been incised and is reflected by forceps, exposing the posterior ulnohumeral joint and posterior tip of the olecranon from the lateral side.

group (palmaris longus, flexor carpi radialis [FCR], and pronator teres). Once the plane between the FCU and the flexor-pronator group has been developed and perforating vessels ligated, the common flexor-pronator origin can be elevated to improve exposure to the brachialis and anterior joint capsule. An alternative, more limited intermuscular approach on the medial side is also possible. The pronator teres can be released from the medial epicondyle and dissected from the common flexor origin. After the pronator teres has been elevated, the heterotopic bone can be resected along with the anterior joint capsule (Figures 6, 7, 8, 9). Following contracture release, the flexor-pronator origin can be reattached to the medial epicondyle with multiple suture anchors or sutured down to the epicondyle through bone tunnels. While the medial fascial border of the triceps may be re-approximated to the fascia of the flexor-pronator origin, this step is not necessary. A tight muscle layer closure often limits the motion gained in the contracture release. The ulnar nerve is typically transposed anteriorly in a submuscular or subcutaneous fashion.

With a medial approach using the internervous plane between the FCU and the flexor-pronator origin, care should be taken to leave the origin of the FCU and the underlying anterior band of the MCL undisturbed, maintaining post-operative elbow stability. Unfortunately, there are occasions where the heterotopic bone or elbow contracture is so severe that these structures, too, require release or excision. In such cases, ligamentous reconstruction is necessary to avoid elbow subluxation or dislocation while these patients are mobilized post-operatively. Autograft tendon (e.g., palmaris longus) may be used for ligamentous reconstruction, but it is our preference to use allograft tendon to restore elbow stability either medially or laterally. Ligamentous reconstruction through bone tunnels provides a stable anchor for early elbow motion. The restoration of stability can be augmented with suture anchor reattachment of the flexor-pronator origin to the medial epicondyle, or of the mobile wad origin to the lateral epicondyle for lateral collateral reconstruction. If stability cannot be achieved with ligamentous reconstruction and muscle origin repair, a dynamic external fixator should be applied.

## Proximal Radioulnar Synostosis

Distally, along the posterolateral edge of the proximal ulna, the entire anconeus and extensor carpi ulnaris complex can be elevated subperiosteally from the bone as needed for exposure (Figure 3). The anconeus and extensor carpi ulnaris complex are elevated off the ulna, while leaving the origin of these muscles from the lateral epicondyle (Figure 15). This will prevent vascular injury to these muscles, especially the anconeus. The subperiosteal dissection is carried along the proximal ulna towards the anterolateral surface of the radius and to the base of the synostosis. If dissection continues in a subperiosteal manner, there should be no danger to the posterior interosseous nerve which is protected in the substance of the supinator at the level of the proximal ulna. Consideration

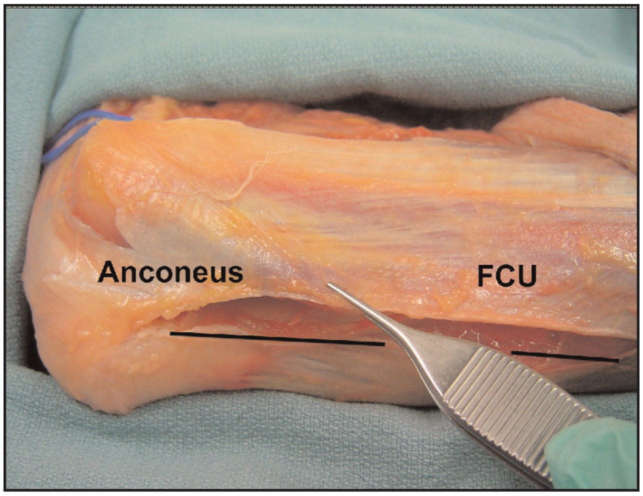


**Figure 15.** Exposure of the proximal radioulnar joint by elevating the anconeus and the flexor carpi ulnaris (FCU) from the subcutaneous border of the ulna (dotted line).

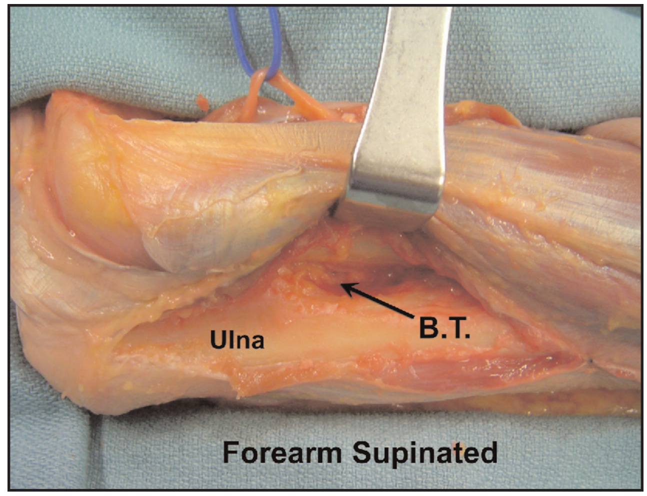


**Figure 16.** The anconeus and FCU are elevated as a unit and the bicipital tuberosity (B.T.) is exposed. In this cadaver dissection the forearm is supinated and the bicipital tuberosity is barely visible. The posterior interosseous nerve is at greater risk of injury in this position.

should be made to locating this nerve in cases where the forearm is fixed in full supination. While pronation will sweep the posterior interosseous nerve anteriorly and medially away from a posterolateral dissection, supination will bring the nerve closer to the field of dissection (Figures 16, 17).

Once localized, the synostosis is resected carefully with a combination of small rongeurs, osteotomes, and Kerrison rongeurs. An appropriately-sized lamina spreader is helpful in retracting and opening up the space between the proximal radius and proximal ulna. Once the synostosis has been released and there is freedom between the two bones, the lamina spreader offers greater direct visualization of any remaining ectopic bone. The synostosis should be excised down to the native cortices of the proximal radius and proximal ulna (Figures 18, 19, 20).

Soft tissue interposition grafts or flaps are a useful adjunct in cases of complete radioulnar synostosis. Two options include a pedicled anconeus myofascial interposition flap or tensor fascia lata interposition. The pedicled anconeus flap is created from the posterolateral aspect of the anconeus fascia and underlying muscle. The flap is elevated from distal to proximal off the proximal ulna up to the lateral epicondyle until there is sufficient freedom to mobilize the anconeus's leading edge to the distal extent of the synostosis. By protecting the proximal origin and the lateral fascial attachments of the triceps, the primary blood supply—the medial collateral artery of the elbow—can be preserved.[42] The distal end of the flap is attached to the biceps tuberosity with the forearm in full pronation using suture anchors. Now, as the forearm is supinated the anconeus will be drawn into the proximal radioulnar space where the synostosis previously lay, creating a thin interposition flap of viable muscle and fascia.

There are certainly cases of heterotopic ossification and radioulnar synostosis where transposing a local muscle flap may be difficult or impossible. In such situations where an alternative "bail-out" option is desired, a tensor fascia lata autograft or allograft may be interposed. The advantage to autograft is donor biocompatibility and minimal infection rate. The disadvantages to autograft are not trivial: donor site morbidity, potential for early pain, hematoma, or superficial nerve injury, and additional site of scarring. Because of these potential complications and the reality that the interposition graft (whether autograft or allograft) is no longer viable after it is harvested, the senior author has abandoned the use of autograft tensor fascia lata in favor of allograft.

The technique is straightforward. Following synostosis exposure and resection, the tensor fascia lata allograft is shaped into a 10–12 cm long and 4–5 cm wide graft. The allograft is then carefully wrapped around either the ulna or the radius and sutured into place using absorbable sutures. The choice of which bone to encase with the graft depends largely on the surgeon's preoperative and intraoperative perceptions concerning the origin of the synostosis. With a complete wrap the graft can simply be sutured to itself or neighboring soft tissues to main-

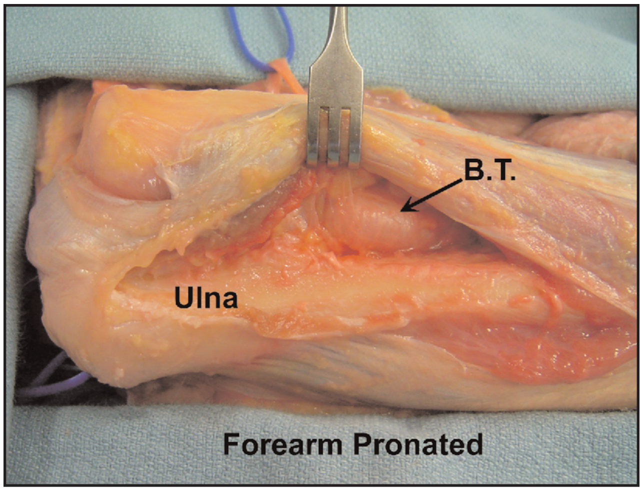


**Figure 17.** With forearm pronation, the Bicipital Tuberosity (B.T.) and the Biceps tendon become prominent. The posterior interosseous nerve is less prone to injury with forearm pronation.

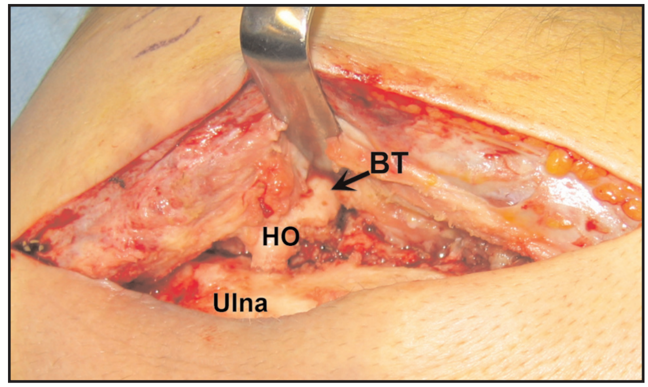


**Figure 18.** Case 3: This intra-operative view reveals the proximal radioulnar synostosis with the heterotopic ossification (HO) marked.

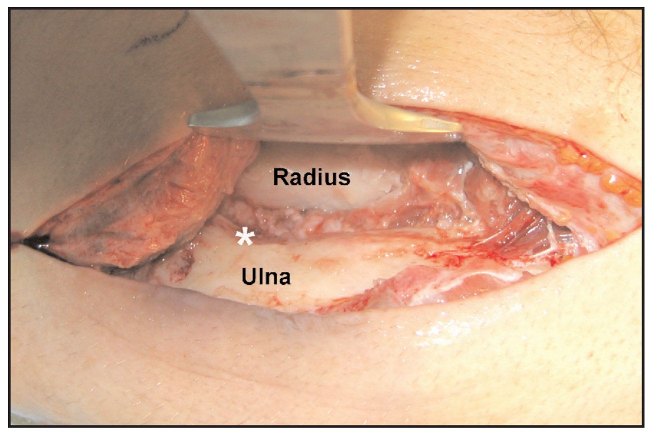


**Figure 19.** Case 3: After the synostosis has been resected, the space between the radius and ulna can be seen.

tain its position. If there is intact muscle about the proximal radius or ulna, preventing a circumferential wrap of the tensor fascia lata graft, suture anchors may be inserted at different locations to maximize the spread of the fascial graft. The goals of this type of fascial interposition are twofold: 1) To provide painless forearm rotation, and 2) To act as a barrier to future bridging heterotopic bone.

## Final Considerations

The excision of ectopic bone and contracture release is complete when normal elbow flexion and extension has been restored. The affected forearm should gain a pronation/supination arc of at least 100°. Motion gained should be documented with intraoperative fluoroscopy or video and in the operative dictation. Documentation of motion is helpful after excision of the heterotopic bone; it serves as a baseline for clinical follow-up in the post-operative period.

Once the heterotopic bone has been adequately excised, a judgment must be made for the removal of indwelling hardware if it exists. Removal of hardware prior to excision of heterotopic bone may result in an unintended intra-operative or post-operative fracture. Internal fixation of the proximal radius is frequently placed through the interval described above for takedown of the synostosis and can be readily removed in those cases. Similarly, hardware about the proximal ulna usually resides on its easily exposed posterior aspect. For removal of internal fixation about the distal humerus, proximal dissection is required. A useful exposure to the distal humerus is the bilateral tricipital or paratricipital approach described by Alonso-Llames which involves opening the intermuscular septi at the lateral and medial edges of the triceps.[43] Through these paratricipital openings medial, lateral, and posterior distal humerus plates and can be removed without violating the triceps insertion on the olecranon.

Upon completion, the surgical field is irrigated with six liters of normal saline. Bleeding points in the soft tissues are coagulated, and bleeding from exposed bone is sealed with bone wax. Routine use of closed suction drains (positioned anterior and posterior to the elbow) helps minimize soft tissue swelling and hematoma formation while the patient begins immediate post-operative range of motion exercises and/or continuous passive motion. Prior to closure of the deep soft

**Figure 20.** Case 3: This lateral radiograph taken one year post-operatively shows some spotty heterotopic bone but no recurrence of the synostosis. The patient maintained a 160° arc of rotation.

tissues, a lidocaine or bupivacaine continuous infusion pump may be placed to help maximize post-operative pain control (in cases where axillary catheters are not used). The catheter for a bupivacaine infusion pump should be placed in a soft tissue layer or location separate from that of the closed suction drains. These pumps will affect the post-operative neurologic examination as they will cause a local nerve block to neighboring peripheral nerves as the local anesthetic is distributed into the soft tissues.

Divisions in the intermuscular septi are never repaired, but anterior muscle attachments to the distal humerus are always repaired. For repairing the origins of these muscles, suture anchors or bone tunnels provide sufficient stability for bony reattachment with nonabsorbable sutures. If the medial, flexor-pronator muscle mass has been elevated, consideration can be made to submuscular transposition of the ulnar nerve. Otherwise, a simple subcutaneous transposition maintained with a wide strip of flexor-pronator fascia frequently will suffice. If desired, the fascial layer may be repaired with an absorbable suture in a running or interrupted fashion. Subcutaneous and skin closure follows. The skin closure should not be under tension, nor should it be watertight such that it would prevent drainage when early motion is initiated.

## Post-operative Management and Rehabilitation

A patient's post-operative rehabilitation has significant influence over the clinical outcome after contracture release and excision of heterotopic bone. The affected upper extremity is immobilized in a soft dressing that applies gentle compression of the soft tissues. A regional anesthetic catheter placed by the anesthesia team can provide substantial pain relief in the immediate post-operative setting. When such a catheter cannot be placed, we have used continuous bupivacaine infusion pumps to supplement intravenous narcotic pain control. With adequate analgesia, continuous passive motion of the elbow can be performed in flexion and extension or, alternatively, in pronation and supination for cases of isolated radioulnar synostosis. It is our preference to use a bed-side continuous passive motion machine for the elbow rather than the more mobile units that are able to provide motion during ambulation. The bedside units tend to maintain a constant position, capitalizing on leverage to impart motion at the patient's elbow (Figure 21).

The passive motion is supplemented with frequent visits by a therapist. As soon as the first post-operative day, a supervised, daily therapy regimen that includes active, active-assisted, and passive-assisted exercises flexion and extension exercises is implemented. In order to prevent loss of forearm rotation, pronation, and supination, exercises are performed while flexing the elbow at 90° and grasping an object in the hand to minimize the contribution of radiocarpal pronation and supination. Static progressive splinting at night is a useful adjunct to preserve the motion gains achieved intraoperatively.[20] In cases of radioulnar synostosis, splints may be alternated nightly between static pronation and static supination.[44]

Radiation treatment of the resected bed of heterotopic ossification or synostosis has been touted to be successful in preventing recurrence of ectopic bone.[22,30,45] However, to our knowledge no prospective randomized trial has shown this modality to be better than resection alone. As this localized radiation procedure comes with some inherent risk of wound breakdown, neuritis, lymphedema, and a remote risk of sarcoma, it should be discussed with patients pre-operatively. A single dose of 700 cGy within the first 24 to 48 hours post-operatively is typically sufficient. In our practice, radiation therapy is limited to patients with involvement of the proximal radioulnar joint.

**Figure 21**. Post-operatively, an elbow continuous passive motion machine is used in conjunction with a regional anesthetic catheter.

Indomethacin and other nonsteroidal anti-inflammatory medicines are also considered useful adjuncts in the prevention of heterotopic ossification.[46] Similar to radiation therapy, the specific agent, dosage, duration, and benefit of treatment are not consistent among published studies.[46] We do not prescribe indomethacin in our patients. We do prescribe intravenous ketorolac during a patient's hospital stay, primarily for pain control.

## Conclusion

Excision of heterotopic bone and release of contracture or ankylosis about the elbow requires a sound knowledge of anatomy. A posterior incision allows a "global" approach to both the medial and lateral sides of the elbow. Anterior and posterior heterotopic bone can be resected using either approach. Substantial improvement in elbow flexion and extension as well as pronation and supination can be obtained with this procedure. Every patient is treated with an aggressive rehabilitation protocol that includes continuous passive motion. Adjuvant treatments such as indomethacin or radiation therapy are utilized on a case-by-case basis. While some motion loss from the significant gains made intra-operatively can be expected, a majority of patients who actively participate in their daily motion exercises will achieve an optimal outcome by preserving a functional arc of motion.

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