Surgical Approaches to the Elbow

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The recent explosion of interest in the elbow and the need for better surgical approaches, has produced numerous new approaches and the modification of other approaches, the result of which is a much shorter but more useful list of surgical approaches. Surgeons who perform a large number of elbow procedures have found that these approaches permit them to perform the majority of elbow procedures with only one skin incision, usually a straight posterior midline incision. Knowledge of the deep intermuscular and internervous intervals allows the surgeon to expose the elbow circumferentially through one skin incision. This approach has been associated with fewer wound complications and has allowed immediate active motion of the elbow.

Surgical approaches to the elbow can be classified according to the aspect of the joint exposed, as anterior, lateral, medial and global (Tables 1, 2). The current study reports on the operative approaches to the elbow which are used in the authors’ practice and which the authors have found to be safe and predictable when performing reconstructive elbow surgery. It is not the authors’ intention to provide an exhaustive list of approaches. The approaches the authors have chosen to describe will allow surgeons to perform virtually all major elbow reconstructive procedures. Simple, direct approaches, such as those used for lateral epicondylitis or one of a kind procedures, will not be addressed. The authors have few, if any, indications for procedures that require a straight lateral or medial approach and these will not be discussed.

The aim of a surgical approach to the elbow is to provide an adequate extensile exposure with preservation of the neurovascular structures while permitting early mobilization of a stable joint, which heals without a joint contracture.

Modern surgical approaches to the elbow began with the lateral approach to the elbow described by Kocher. Subsequently, many authors have described approaches to the elbow with the intention of providing improved visualization, primarily of the anterior elbow, without compromising the surgical outcome. Henry described the generally followed principle as “extensile exposure”. The majority of these exposures use internervous or intermuscular intervals. Therefore, it is useful to review some of the pertinent anatomy common to these approaches.
### TABLE 1. Summary of Surgical Approaches to the Elbow

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\( \pm \) = with or without; ECRB = extensor carpi radialis brevis; ECRL = extensor carpi radialis longus; ECU = extensor carpi ulnaris; EDC = extensor digitorum communis; FCR = flexor carpi radialis; FCU = flexor carpi ulnaris; FDP = flexor digitorum profundus; FDS = flexor digitorum superficialis; PL = palmaris longus; PT = pronator teres.

### TABLE 2. Indication and Recommended or Alternate Surgical Approaches

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<th>Indication</th>
<th>Recommended Approach</th>
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APPLIED SURGICAL ANATOMY

Exposure of the elbow potentially is difficult because of multiple neurovascular structures that cross the joint. The neurovascular structures are at risk when the joint is approached from any direction; however, the approaches to the anterior joint structures have given surgeons the most difficulty. In addition, the propensity for stiffness or instability to develop after surgery has led many surgeons to avoid complex or extensive approaches to the elbow. However, this anxiety can be tempered by becoming familiar with a small number of anatomic relationships.

NERVES

Many of the described skin incisions are placed in areas where named cutaneous nerves lie and when injured, may produce painful neuromata or paresthesia.\(^7,9,10,17,54\) The lateral antebrachial cutaneous nerve is at risk during surgery on the lateral aspect of the elbow.\(^17\) It pierces the brachial fascia 3 cm proximal to the lateral epicondyle and passes 4.5 cm medial to the lateral epicondyle. The anterior and posterior branches supply the anterolateral and posterolateral surfaces of the forearm.

The medial antebrachial cutaneous nerve is at risk of injury during surgery on the medial aspect of the elbow.\(^9,10,36,54\) The posterior branch divides into two or three branches that cross anywhere from 6 cm proximal to 6 cm distal to the medial epicondyle.\(^9\) These cutaneous nerves lie just superficial to the deep fascia and are protected if full thickness fasciocutaneous flaps are created.\(^11\) In addition, the posterior midline of the elbow has relatively few cutaneous nerves crossing it, and when they do, they usually are small in diameter.\(^11\) Given these relationships, when indicated, the authors advocate the use of a midline longitudinal posterior skin incision to minimize the risk of cutaneous nerve injury.\(^11\)

Distal to the insertion of the deltoid, the deep investing fascia of the brachium thickens on each side to form strong intermuscular septae, which stabilize the fascia to the respective supracondylar ridge and epicondyle. The radial nerve and the anterior descending branch of the profunda brachii artery, perforate the lateral intermuscular septum 10 to 12 cm proximal to the lateral epicondyle. The ulnar nerve and collateral artery perforate the medial intermuscular septum. Excision of this septum is recommended whenever an anterior transposition of the ulnar nerve is performed.\(^10,31\)

The ulnar nerve passes posteriorly through the medial intermuscular septum and continues distally along the medial margin of the triceps with the superior ulnar collateral artery. The arcade of Struthers is formed by a band of fascia extending from the medial intermuscular septum to the medial head of the triceps and is present in 68% of the population.\(^2\) The ulnar nerve has no branches in the arm. The cubital tunnel is a fibroosseous tunnel beneath the cubital tunnel retinaculum that bridges the medial epicondyle and olecranon.\(^45\) The ulnar nerve enters the cubital tunnel posterior to the medial epicondyle and grooves the posterior portion of the medial collateral ligament. A few small branches supply the elbow.\(^30\) The ulnar nerve supplies motor branches to the two heads of flexor carpi ulnaris, before passing beneath the arcade of Osborne, or cubital tunnel retinaculum, which is a thickened aponeurotic band bridging the two heads.\(^45\) It then passes between the two heads, to enter the forearm to supply the ulnar half of the flexor digitorum profundus.

The radial nerve courses through the lateral intermuscular septum 10 to 12 cm proximal to the lateral epicondyle.\(^65\) In the anterior compartment, the radial nerve lies between the brachialis and brachioradialis, supplying motor branches to each (only the lateral portion of the brachialis). The radial tunnel is approximately 5 cm long and extends from the level of the radiocapitellar joint to the proximal edge of the superficial head of the supinator muscle.\(^32,58\) The superficial cutaneous branch of the radial nerve exits the tunnel proximally, whereas the posterior interosseous nerve diverges posterolaterally to pass beneath the
proximal edge of the superficial head of the supinator muscle.  

**MUSCLES**

Beneath the deep fascia lies the muscular layer, which is interspersed by the major neurovascular structures. An understanding of the various intermuscular intervals is critical to perform safe surgery about the elbow. There are a few muscles that are of particular surgical importance and are described in detail.

The triceps brachii constitutes the entire musculature of the posterior compartment of the arm. The long head originates from the infraglenoid tuberosity of the scapula. The lateral head has a linear origin proximal and lateral to the spiral groove, which separates it from the long head. The medial head is deep to the other two heads and originates from below and medial to the spiral groove and widens to include the adjacent intermuscular septae. Each head takes origin distal to the other, with progressively larger areas of origin. The long and lateral heads are superficial and blend in the midline to form a common superficial tendon, which inserts into the posterior surface of the proximal olecranon and the adjacent deep fascia. The deep medial head is fleshy and inserts mainly into the deep surface of the common tendon, with the remainder inserting into the olecranon and joint capsule, to prevent the capsule from being "nipped" in extension. With pronation of the forearm, the posterior interosseous nerve is translated approximately 1 cm anteromedially. This concept is important when performing lateral approaches to the elbow, because pronation will increase the zone of safety for the posterior interosseous nerve.

The pronator teres muscle is the most proximal of the flexor pronator group and forms the medial border of the cubital fossa. The large humeral head arises from the medial supracondylar ridge and the anterosuperior aspect of the medial epicondyle. The small ulnar head arises from the coronoid process of the ulna and is absent in 10% of individuals. A fibrous arch connects the two heads and may entrap the median nerve that passes beneath it. The median nerve supplies a branch to each of the heads before it passes beneath them into the forearm.

**LIGAMENTS**

The ligamentous complexes that stabilize the joint are thickenings of the capsule on the medial and lateral aspects. The medial collateral ligament complex consists of three components: the anterior, posterior, and transverse bundles. The anterior bundle is structurally and biomechanically the most significant
component of the medial collateral ligament complex. The anterior bundle attaches to the sublime tubercle on the medial aspect of the coronoid process. The posterior bundle of the medial collateral ligament is fan shaped and attaches inferiorly and posteriorly to the axis of rotation on the medial epicondyle. It attaches to the middle of the medial margin of the trochlear notch and is taut during flexion. The transverse bundle is not always well-defined and does not significantly contribute to stability.

The lateral collateral ligament complex consists of three components: the radial collateral ligament, the annular ligament, and the lateral ulnar collateral ligament. The radial collateral ligament attaches to the lateral epicondyle and merges indistinguishably with the annular ligament. The annular ligament attaches to the anterior and posterior margins of the lesser sigmoid notch of the proximal ulna, encircling the radius but not attaching to it. The lateral ulnar collateral ligament attaches proximally to the lateral epicondyle and distally to the tubercle of the crista supinatoris of the ulna. The humeral attachment of the lateral ulnar collateral ligament is at the isometric point on the lateral side of the elbow. It is the primary lateral stabilizer of the ulnohumeral joint, and its deficiency produces posterolateral rotatory instability.

SURGICAL APPROACHES

The authors perform major elbow surgery with the patient in the lateral decubitus position or supine position. A sterile tourniquet is applied to the most proximal arm. In the lateral position, the arm is positioned on a cushioned support, so that the elbow is extended and flexed easily. In the supine position, a bolster or padded Mayo stand is used to support the extremity over the chest. When exposure of the anterior joint is required, for example a capsulectomy or internal fixation of a capitellum fracture, the supine position is favored. One author (SDP) has reverted to using the supine position for patients with T-intercondylar fractures of the distal humerus, and patients requiring intraarticular osteotomies of the distal humerus, because this provides better visualization of the anterior joint at the expense of the need to have an assistant support the extremity.

GLOBAL APPROACH

The global approach was developed conceptually to provide a reproducible and consistent surgical approach for treatment of complex reconstructive and traumatic conditions of the elbow, especially fracture-dislocations and contractures. Through one skin incision and various previously described intermuscular approaches, the surgeon is able to obtain circumferential exposure of the elbow, including the collateral ligament complexes, anterior joint capsule, and coronoid process. It is versatile and extensible, without precipitating instability or increasing the risk to neurovascular structures. This skin incision avoids the need to place more incisions around the elbow (Figs 1–8).

Skin Incision

The authors recommend a straight posterior midline longitudinal skin incision for almost all major elbow surgery. The front door to the elbow is at the back, and the entire elbow, including the anterior aspect, can be exposed through this incision, and none of the authors’ patients had skin necrosis using this approach. It is critically important that the skin incision be taken directly down through the deep fascia to the triceps tendon and subcutaneous border of the ulna and that full thickness medial or lateral fasciocutaneous flaps are elevated, preserving the subcutaneous arterial plexus and cutaneous nerves in the full thickness flaps. When performing procedures on the medial aspect of the elbow, the authors always isolate the ulnar nerve and place a 1.5-inch Penrose drain around the ulnar nerve, to act as a constant reminder of its location. The Penrose drain is not clamped so that traction is not inadvertently placed on the drain. If the posteromedial joint
Fig 1. The normal lateral anatomy of the elbow is shown. ECRB = extensor carpi radialis brevis; ECRL = extensor carpi radialis longus; EDC = extensor digitorum communis; ECU = extensor carpi ulnaris.

Fig 2. The limited Kocher approach between anconeus and extensor carpi ulnaris is shown. ECRB = extensor carpi radialis brevis; ECRL = extensor carpi radialis longus; EDC = extensor digitorum communis; ECU = extensor carpi ulnaris.

Fig 3. The extended Kocher approach is shown. The common extensor origin is reflected from the lateral humerus, and the anconeus and triceps are reflected from the posterior humerus. ECRL = extensor carpi radialis brevis; EDC = extensor digitorum communis; ECU = extensor carpi ulnaris; ECRB = extensor carpi radialis brevis.
Fig 4. The column approach is shown. The combined Kocher and Kaplan muscle splitting approaches, which leave the extensor digitorum communis and extensor carpi ulnaris attached to the humerus can be seen. ECRB = extensor carpi radialis brevis; ECRL = extensor carpi radialis longus; EDC = extensor digitorum communis; ECU = extensor carpi ulnaris.

Fig 5. The Kaplan approach is shown between extensor digitorum communis and extensor carpi radialis longus and brevis. ECRB = extensor carpi radialis brevis; ECRL = extensor carpi radialis longus; EDC = extensor digitorum communis; ECU = extensor carpi ulnaris.

requires exposure, then an anterior transposition of the ulnar nerve is performed. In this situation the medial intermuscular septum must be excised and the cubital tunnel retinaculum must be released completely to allow the ulnar nerve to be mobilized anteriorly without compression or kinking.31

The Posteromedial Approach
To expose the anterior bundle of the medial collateral ligament, coronoid process, or anterior joint capsule, the posteromedial muscles of the proximal ulna are released subperiosteally only from the ulna and are retracted anteriorly.60 The flexor carpi ulnaris fascia is left attached to the subcutaneous border of the ulna for later repair (Figs 6, 8).

When this approach is undertaken for repair of anterior structures after a fracture-dislocation, excellent exposure of the fractured coronoid process,55 avulsed medial collateral ligament, and anterior joint capsule is provided, allowing placement of either a suture or screw into the coronoid from the posterior aspect of the ulna. In reconstructive procedures, if a capsulotomy is required, it is made anterior to the anterior bundle of the medial collateral ligament. The common flexor and pronator origin and medial collateral ligament attachments to the medial epicondyle are left intact. This approach is extensile proximally along the medial humeral supracondylar ridge and distally, by reflecting the flexor carpi ulnaris from the ulna.50,60
The Posterolateral Approach

Access to the radial head, capitellum, and lateral ulnar collateral ligament is obtained through Kocher’s interval.29 Posterolaterally, the interval between the anconeus and the extensor carpi ulnaris is visualized as a thin white line along the deep fascia. The overlapping deep fascia is divided and the interval between the anconeus and extensor carpi ulnaris is separated to expose the joint capsule proximally and the supinator distally (Figs 1, 2).

To expose the olecranon fossa and posterior aspect of the humerus, the anconeus and triceps are reflected medially from the lateral side of the distal humerus.23 To expose the radial head, the common extensor origin is elevated anteriorly from the underlying capsule, lateral collateral ligament complex, and lateral humeral epicondyle. An arthrotomy then is made along the anterior border of the lateral ulnar collateral ligament, dividing the annular ligament, but preserving the integrity of the lateral ulnar collateral ligament. If additional exposure is required for osteosynthesis of the radial head, especially a comminuted radial head and neck fracture, a lateral epicondyle chevron osteotomy can be performed.20 The most lateral edge of the capitellum is identified to ensure that the distal limb of the osteotomy does not violate it. A chevron osteotomy is marked on the posterior aspect of the humerus with the apex directed medially. The epicondyle is predrilled and tapped to accept one or two 4-mm cancellous or 3.5-mm cortical screws. Either a small sagittal saw or osteotome is used to perform the cut. The muscles of the supracondylar ridge are elevated.

Fig 6. The normal medial anatomy of the elbow is shown. FCR = flexor carpi radialis; PL = palmaris longus; FCU = flexor carpi ulnaris.

Fig 7. The Hotchkiss approach between flexor pronator origin and brachialis and flexor carpi ulnaris and triceps is shown. FCR = flexor carpi radialis; PL = palmaris longus; FCU = flexor carpi ulnaris.

Fig 8. The Taylor and Scham approach is shown. The flexor carpi ulnaris and flexor digitorum profundus are reflected from the medial aspect of the proximal ulna, to the level of the coronoid and brachialis insertion. FCR = flexor carpi radialis; PL = palmaris longus; FCU = flexor carpi ulnaris; MCL = medial collateral ligament.
subperiosteally, so that they remain in continuity with the epicondyle and the common extensor origin. The lateral ulnar collateral ligament is not violated and remains in continuity with the epicondyle. If this does not allow adequate anterior joint visualization, Kaplan’s interval between extensor digitorum communis and extensor carpi radialis longus and brevis can be developed to the level of the posterior interosseous nerve, where it enters the supinator at the Arcade of Frohse \(^{28}\) (Fig 5). This allows the common extensor origin (extensor carpi ulnaris and extensor digitorum communis) and lateral ulnar collateral ligament, with the attached lateral epicondyle to be reflected anteriorly and distally.

On the lateral aspect the exposure is extensile proximally to where the radial nerve perforates the lateral intermuscular septum. Distally, the exposure is extensile along the proximal third of the radius, to the ulna. If the neck and shaft of the proximal radius require exposure, division of the annular ligament, and supinator are required, respectively. The forearm is pronated to translate the posterior interosseous nerve anteriorly to increase the zone of safety. \(^{59}\) The annular ligament is divided at least 5 mm from the edge of the lesser sigmoid notch, so that it can be repaired anatomically. The supinator muscle is released from the supinator crest and retracted with the posterior interosseous nerve, thereby exposing the radius. At the time of closure, close attention is given to the repair of the lateral ulnar collateral ligament complex.

In some situations, exposure of the anterior elbow is required through alternative or additional anterior intermuscular approaches. In the authors’ practices, this is especially true for release of complex elbow contractures \(^{34}\) or osteosynthesis of anterior shear fractures of the capitellum or trochlea. \(^{26,37}\) These exposures may be performed in isolation, or more commonly, in conjunction with one or more of the previously described approaches. These additional exposures are performed by additional anterior elevation of the posteromedial and posterolateral fasciocutaneous flaps. It is important when undertaking this degree of exposure, to ensure that the tissues are not allowed to desiccate, because this will increase the risk of complications, especially necrosis and infection.

The Anteromedial Approach

This intermuscular interval has been popularized by Hotchkiss \(^{22}\) (Figs 6, 7). The authors have used this approach alone, when the injury is predominantly on the medial aspect of the joint. However, for severe contractures, the authors usually combine the anteromedial approach with the intermuscular lateral approaches.

The anteromedial approach is performed between the flexor carpi ulnaris and flexor carpi radialis or palmaris longus, when present. This places the incision in an internervous plane, minimizing the risk to the ulnar nerve innervated flexor carpi ulnaris and the median nerve innervated flexor carpi radialis, palmaris longus, and pronator teres muscles. By identifying the vessels that perforate the fascia between the two muscles, the interval is recognized. The medial supracondylar ridge of the humerus is identified and the dissection is begun proximally by dividing the investing fascia over the brachialis on the anterior aspect of the ridge. The brachialis is elevated subperiosteally from the anterior humerus and joint capsule. The interval between the flexor carpi ulnaris and the palmaris longus with the flexor carpi radialis then is developed and taken down to the joint capsule, where the anterior margin of the medial collateral ligament is identified. The palmaris longus, flexor carpi radialis, and pronator teres then are divided 2 cm from their origin on the medial epicondyle and carefully are reflected anterolaterally from the medial epicondyle and capsule, along with the adjacent brachialis. This serves to protect the median nerve and brachial artery, which also are retracted laterally. By performing this incision anterior to the flexor carpi ulnaris, the anterior bundle of the medial collateral ligament is preserved beneath the flexor carpi ulnaris, along with the
origin of the flexor carpi ulnaris, which maintains elbow stability. The anterior capsule can be opened or excised, heterotopic bone removed, or a trochlea fracture repaired. This approach also can be used to reconstruct the deficient medial collateral ligament.

The Anterolateral Approach
Kaplan\(^2\) described this intermuscular approach. The anterolateral approach lies between the extensor digitorum communis and extensor carpi radialis longus muscles superficially. The authors commonly use the anterolateral approach for release of elbow contractures, exposure of the posterior interosseous nerve, and internal fixation of displaced capitellar or lateral condyle fractures\(^26,37\) (Fig 5).

The intermuscular interval is best found by observing where along the anterior margin of the extensor digitorum communis aponeurosis, vessels penetrate the fascia. The fascia is split longitudinally and the extensor carpi radialis longus separated from the extensor digitorum communis. As the dissection is carried deep to the extensor carpi radialis longus, the extensor carpi radialis brevis is encountered. Deep to the extensor carpi radialis brevis the transversely oriented fibers of the supinator are encountered, along with the posterior interosseous nerve, which usually is surrounded by fat. The posterior interosseous nerve is protected and defines the distal extent of the exposure. If required, proximal dissection with elevation of the extensor carpi radialis longus, extensor carpi radialis brevis, and brachioradialis anteriorly from the lateral supracondylar ridge of the humerus provides exposure of the anterior joint capsule. When the Kaplan approach is extended proximally along the lateral supracondylar ridge of the humerus, it is referred to as the extended lateral approach\(^37\).

If the Kaplan and Kocher approaches are used together, (which the authors commonly do, when releasing contractures from the lateral side), the extensor digitorum communis, extensor carpi ulnaris, and the lateral ulnar collateral ligament remain attached to the lateral epicondyle preserving stability.\(^18\) This recently has been redescribed as the “column procedure”\(^34\) (Fig 4).

POSTERIOR APPROACHES
Specific isolated posterior approaches usually are used for distal humerus\(^24,25,63\) and olecranon fractures,\(^50\) repair of triceps tendon avulsions, elbow arthroplasty,\(^5,12,39,43,53\) ulnar nerve transposition, removal of loose bodies, and posterior capsulectomies.

Campbell’s Posterior Approach
Campbell’s posterior approach is used for fractures of the distal humerus and can be used for elbow arthroplasty.\(^8\) The triceps aponeurosis and the deep medial head are split in the midline. The other muscles around the elbow (anconeus, extensor carpi ulnaris, and flexor carpi ulnaris) are released subperiosteally from the humerus and proximal ulna and retracted laterally and medially, respectively. The joint capsule and the periosteum of the humerus are divided sharply in the midline to expose the distal humerus. Gschwend et al\(^19\) modified this approach by elevating osteoperiosteal flaps with the bone.

Campbell\(^8\) and others\(^62-64\) have modified this basic approach. A tongue of triceps aponeurosis, left attached to the olecranon, is elevated with division of the deep head in the midline. Campbell\(^6\) recommended using the triceps tongue approach only if there was a triceps contracture, for example a chronic elbow dislocation, and that closure should be performed using a V-Y lengthening technique. This technique can increase elbow flexion by as much as 40°, but will produce triceps weakness. The current authors limit the triceps tongue approach to those indications originally recommended by Campbell.\(^6\)

Alonso-Llames Approach
The Alonso-Llames approach primarily was described for treatment of supracondylar fractures in children, and was termed the “bi-laterotricipital approach”.\(^1\) Through a midline skin incision, the triceps muscle is approached
from the medial and lateral aspects and elevated from each intermuscular septum. The authors have used this approach for the treatment of patients with extraarticular supracondylar humeral fractures. Patients with noncomminuted T-intercondylar distal humeral fractures also can be treated with this approach. In patients with noncomminuted T-intercondylar distal humeral fractures, the medial and lateral joint capsule are opened as one would do in preparation for an olecranon osteotomy, and distraction is applied to the olecranon, allowing visualization of the distal humerus articular surface.

Bryan and Morrey Approach
The Bryan and Morrey approach was developed to preserve the continuity of the triceps, after total elbow arthroplasty. By doing this, the elbow can be actively mobilized immediately.

The deep incision is placed along the medial aspect of the triceps, extending distally through the posterior bundle of the medial collateral ligament and joint capsule and then obliquely across the fascia over the flexor carpi ulnaris, crossing the subcutaneous border of the ulna to the extensor carpi ulnaris, where it ends. This mandates that the ulnar nerve be transposed anteriorly. The triceps and fascia are elevated as one flap from medial to lateral, ‘skeletonizing’ the olecranon and subcutaneous border of the ulna. This should be performed at 20° to 30° flexion to relieve tension on the flap, thereby facilitating its dissection. The flap is thin over the proximal subcutaneous border of the ulna, and it is common for a ‘buttonhole’ to be created at this point. Consequently, to avoid this, the flap can be raised as an osteoperiosteal flap. A small osteotome is used to elevate the fascia with petals of bone. The flap is mobilized laterally, elevating the anconeus origin from the distal humerus until it can be folded over the lateral humeral condyle. At this point the radial head can be visualized. The tip of the olecranon can be excised to help expose the trochlea. The anterior medial collateral ligament is reflected by sharp dissection from the humerus, allowing the elbow to dislocate and providing the exposure required for a linked total elbow arthroplasty.

The authors have used this approach almost exclusively for placement of linked total elbow arthroplasties or interposition arthroplasties when an articulated external fixator is used. The authors also have used it for open reduction and internal fixation of distal humeral fractures, including selected intraarticular fractures. However, in this situation, the medial collateral ligament is left intact. Nevertheless, the authors prefer the Alonso-Llames approach for these fractures, as it still allows an olecranon osteotomy to be done if the bilaterotricipital approach is inadequate.

Morrey and Adams recommend that the periosteum and triceps insertion be reattached to the proximal ulna with a nonabsorbable braided Number 5 transosseous suture. An additional transverse suture secures the triceps to the olecranon. Using Morrey’s technique, one author (SDP) has observed occult loss of fixation of the triceps from the olecranon and now places two Number 5 nonabsorbable longitudinal grasping sutures through the triceps and into the olecranon.

Boyd Approach
The Boyd approach was developed to provide a safe exposure of the proximal third of the radius, by avoiding injury to the posterior interosseous nerve. Surgeons have used this approach for Monteggia fracture-dislocations, distal biceps brachii tendon avulsions, and contracture releases. Boyd recommended this approach for Monteggia fracture-dislocations, radial head fractures, and reconstruction of the annular ligament.

The muscles on the lateral side of the ulna (anconeus and supinator) are elevated in the subperiosteal plane from the ulna. Retraction of anconeus and supinator exposes the joint capsule overlying the radial head and neck. This lateral capsule contains the lateral ligamentous complex and its division can lead to posterolateral rotatory instability.
supinator muscle protects the posterior interosseous nerve. To expose the radial shaft, the incision may be continued along the subcutaneous ulna border, elevating the muscles off the lateral aspect of the ulna (extensor carpi ulnaris, abductor pollicis longus, and extensor pollicis longus). The posterior interosseous and recurrent interosseous arteries may need ligation. The authors strongly recommend that the lateral ligamentous complex be reattached to the supinator crest to avoid posterolateral rotatory instability.

Radioulnar synostosis may occur as the proximal radius and ulna are exposed subperiosteally. The authors have seen posterolateral rotatory instability and radioulnar synostosis from the Boyd approach and recommend that its use be reserved for excision of a radioulnar synostosis. Gordon recommended that for the Monteggia fracture-dislocation, the ulna should be exposed with subperiosteal dissection and that the radial head should be exposed through the Kocher interval between anconeus and extensor carpi ulnaris. Gordon preferred this technique because it preserves the vascularity of the proximal ulnar fragment and reduces the risk of a radioulnar synostosis. The current authors recommend the Gordon modification for the treatment of a Monteggia fracture-dislocation because of the potential dangers of the Boyd approach.

**MacAusland Transolecranon Approach**

The primary indication for the MacAusland transolecranon approach, is a T-intercondylar fracture of the distal humerus. The authors also have used the transolecranon approach for reconstruction of capitellum and trochlea fractures, and intraarticular osteotomies of the distal humerus after intraarticular malunions.

The olecranon is exposed and predrilled if a 6.5-mm cannulated screw is to be used. The anconeus is elevated from the olecranon laterally and the flexor carpi ulnaris is elevated from the medial aspect of the olecranon. A bone holding forceps is used to distract the joint so that the nonarticular area of the olecranon can be identified. A chevron osteotomy then is performed with a thin oscillating saw blade up to the anterior cortex and then the osteotomy is completed with a small osteotome. The point of the chevron faces distally so that the collateral ligaments remain attached to the distal ulna. The olecranon and the triceps mechanism are elevated proximally to expose the distal humerus. The advantage of the chevron osteotomy is that it increases the area for healing and provides some intrinsic rotational control. The olecranon is reattached with a large 6.5-mm cannulated cancellous screw and tension band wire, a Kirschner (K) wire tension band construct, or a 3.5-mm pelvic reconstruction plate. One author (GIB) uses a cannulated screw, because this helps to align the olecranon. A bone holding forceps is used to provide rotational control as compression is applied across the osteotomy.

**LATERAL APPROACHES**

There have been numerous surgical approaches described for the lateral aspect of the joint (Fig 1). The best known is that via the interval between the extensor carpi ulnaris and anconeus, which Kocher described. Another lateral approach has been described between the extensor carpi radialis brevis and the extensor digitorum communis. This lateral approach was described in the section on the global approach.

The position of the posterior interosseous nerve is important when performing any lateral approach to the elbow. Kaplan stressed the importance of performing the procedure with the forearm in pronation, which translates the nerve anteriorly and thereby increases the zone of safety. The posterior interosseous nerve moves approximately 1 cm medially on pronation of the forearm.

**Kocher’s Lateral Approach**

This approach alone, frequently is used for the insertion of unlinked total elbow arthroplasties or contracture releases. The authors use it as a component of the global approach, as discussed previously (Fig 3).
Kocher\textsuperscript{29} recommended a J shaped skin incision from the lateral supracondylar ridge to the subcutaneous ulna. The authors prefer the posterior midline skin incision.\textsuperscript{11} The intermuscular plane between the extensor carpi ulnaris and the anconeus is identified and each muscle is retracted to expose the lateral joint capsule, annular ligament, and supinator muscle.

The triceps is reflected from the posterior aspect of the humerus to expose the olecranon fossa. The muscles of the lateral epicondyle are released to expose the radial head. The common extensor origin and the muscles of the supracondylar ridge (brachioradialis and extensor carpi radialis longus) are reflected anteriorly to expose the anterior aspect of the joint. Kocher\textsuperscript{29} recommended that a shell of bone be removed with the lateral epicondyle to preserve the attachment to periosteum, that the lateral capsule be released subperiosteally from the humerus, and that the annular ligament be released from the ulna.

The exposure can be extended proximally or distally as required to provide greater exposure of the humerus and ulna respectively. A triceps-anconeus flap can be raised from the olecranon and displaced medially to allow the elbow to dislocate, while hinging on the intact medial collateral ligament.\textsuperscript{12,29} The authors recommend that the lateral collateral ligament complex and common extensor origin be repaired carefully with Number 1 or 2 transosseous nonabsorbable grasping sutures to prevent posterolateral rotatory instability.\textsuperscript{23}

One author (GIB) uses a modification that includes a step cut Z incision of the annular ligament anterior to the lateral ulnar collateral ligament. This preserves the lateral ulnar collateral ligament and ensures that the annular ligament can be repaired easily without tension.

The ulnar nerve may be injured during manipulation by a small bony spur, which is commonly present in patients with rheumatoid arthritis, at the ulnar attachment of the medial collateral ligament.\textsuperscript{19} One author (SDP) had this experience during the insertion of a non-linked total elbow arthroplasty done using this approach. This author routinely now transposes the ulnar nerve anteriorly when performing a total elbow arthroplasty through a posterolateral approach.

Pankovich\textsuperscript{49} exposed the posterolateral compartment of the elbow by developing the Kocher\textsuperscript{29} interval and then reflecting the insertion of the anconeus subperiosteally from the ulna.

**ANTERIOR APPROACH**

**Henry Approach**

In the authors’ practice the Henry approach\textsuperscript{21} to the elbow is used almost exclusively for the spastic elbow contracture, although, this also can be performed through a posterior global approach. This approach has been used for the release of isolated anterior capsular contractures.\textsuperscript{15,40,56,57,61,67} The approach commences a hands breadth proximal to the elbow flexion crease, a finger breadth lateral to the biceps, and curves across the elbow crease and distally along the ulnar border of the extensor mobile wad.\textsuperscript{21} The cephalic vein and the medial and lateral cutaneous nerves of the forearm must be protected.

The tendon of the biceps is an important landmark and acts as a vertical partition that divides the proximal ante cubital fossa into a dangerous medial side, and a safe lateral side.\textsuperscript{21} However, the lateral antebrachial cutaneous nerve is at risk on the lateral side of the biceps tendon and should be identified and protected. The deep fascia on the lateral side of the biceps tendon is divided. Henry\textsuperscript{21} recommends that the surgeon pass a finger through “the swamp of fat” along the lateral edge of the guiding biceps tendon until the resistance of the recurrent vascular loop is encountered. This loop is only the proximal rib of a fanlike spread of vessels that lie in several layers, each of which is divided and ligated. If additional exposure is required, the muscular branches of the radial artery are divided and ligated. The mobile wad of three muscles is mobilized and the elbow is flexed to 90° to allow exposure of the supinator muscle. The ra-
dial nerve only gives branches laterally; therefore, it can be safely retracted laterally with the brachioradialis.

The dissection then follows the course of the biceps tendon to the radial tuberosity and the bicpital bursa. The bursa is divided and the supinatator muscle is elevated in the subperiosteal plane sandwiching within its substance the posterior interosseous nerve.

If an anterior capsular release is to be performed, the radial nerve laterally and the median nerve and brachial artery medially are identified. The interval between the biceps tendon and pronator teres is developed. The brachialis muscle is dissected off the anterior joint capsule. The lateral dissection is between the radial nerve and the brachialis. The entire anterior soft tissue was, consisting of the median nerve, the brachial artery, the brachialis, and the biceps then are elevated off the anterior capsule. The entire anterior capsule can be visualized and released.

A sound knowledge of the surgical anatomy and approaches to the elbow is critical for the safe and competent execution of elbow surgery. Having reviewed the pertinent surgical anatomy and approaches, it is hoped that this will advance the scientific practice of the art of elbow surgery.

References

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