Surgical Approaches to the Elbow

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Introduction

Surgical treatment of the unstable elbow requires a thorough understanding of elbow anatomy and the various approaches to the elbow for surgical planning including exposure, repair, and rehabilitation. Often times, multiple superficial or deep approaches are required during the same surgical procedure. Therefore, having knowledge of a variety of approaches will afford the surgeon flexibility during the operation. The close vicinity of neurologic, vascular, and ligamentous structures about the elbow make the various approaches technically challenging. Finally, the surgeon should have a solid understanding of which approaches provide the optimal exposure for each individual pathologic structure in the setting of the unstable elbow to maximize the outcome and minimize surgical morbidity.

Several basic surgical tenets should be followed during any approach to the elbow, but especially in the cases of trauma where the soft-tissue envelope has already been compromised. Full-thickness subcutaneous flaps are preferred to respect skin circulation. Often times minimizing flaps at all may provide the best chance to avoid wound dehiscence or skin edge necrosis especially in patients with poor healing potential. When making multiple incisions, narrow skin bridges should be avoided as well to avoid wound complications. Adhering to internervous anatomic planes will afford improved safety, diminished intraoperative bleeding, and reduced postoperative pain [1]. A sterile tourniquet is routinely recommended and allows ease of removal if more proximal exposure of the humerus becomes necessary. Patient positioning is often dictated by the approach. A posterior or global approach often requires the patient to be lateral, lazy-lateral (bump under ipsilateral shoulder blade with arm across the chest), or prone. Isolated lateral approaches are best treated in the lazy lateral or supine position. Isolated medial approaches are performed in the supine position with abduction and external rotation of the shoulder or prone with abduction and internal rotation of the shoulder.

Approaches to the elbow can be divided into superficial and deep approaches. The three primary superficial approaches in the treatment of elbow instability include posterior, lateral, and medial. Each superficial approach has a variety of deep approaches. The primary deep posterior approaches utilized for elbow instability surgery are the paratricipital approach or triceps reflecting

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Bryan-Morrey approach. The lateral deep approaches include Kocher's interval, Kaplan's interval, and the extensor digitorum communis split. The medial deep approaches include flexor carpi ulnaris split, the Hotchkiss over-the-top, the flexor-pronator split, and Taylor-Scham. Posterior pathology primarily addressed through the paratricipital, triceps splitting, or triceps reflecting approach are olecranon fractures associated with fracture-dislocations, total elbow arthroplasty, or global instability patterns requiring medial and lateral access. Pathologies addressed through deep lateral approaches include radial head fractures, capitellar fractures, and coronoid fractures in the absence of radial head and lateral collateral ligament injury. Medial pathologies addressed through the deep medial approaches include the ulnar nerve, coronoid fractures, and ulnar collateral ligament pathology. The lateral and medial deep approaches can be accessed through either lateral or medial superficial approaches respectively or simultaneously through the superficial posterior approach. Each chapter in this textbook outlining the treatment of various injuries associated with the unstable elbow will describe each author's surgical approach.

Posterior Approaches

Indications for superficial posterior approaches to the elbow include total elbow arthroplasty, open reduction olecranon fracture-dislocations, and global instability requiring medial and lateral simultaneous exposure. The specific deep posterior approaches balance the degree of triceps tendon detachment and the amount of exposure achieved. The three major deep posterior approaches used during the surgical treatment of the unstable elbow are the triceps reflecting, the triceps splitting, and the paratricipital approach. Several other posterior approaches have been described including an olecranon osteotomy or triceps tongue approach but due to the limited use of these approaches during instability surgery, they will not be described in detail.

The standard superficial posterior approach begins with demarcation of the bony landmarks of the elbow including the olecranon and the subcutaneous border of the ulna. Then, a universal posterior skin incision with full-thickness flaps is made. Appropriate management of the ulnar nerve must be considered. The nerve is most easily identified proximally between the medial intermuscular septum and the medial head of the triceps muscle [2]. Iatrogenic nerve injury is not uncommon and may potentially be reduced by leaving the nerve in place therefore limiting the dissection and devascularization of the nerve [3]. Ulnar nerve protection is critical during surgical repair and if ulnar nerve mobilization is deemed necessary for safety, then it should be transposed despite increased dissection in order to prevent injury.

In the triceps-reflecting, or Bryan-Morrey, approach [4] the triceps tendon is sharply detached as a single flap from medial to lateral off the tip of the olecranon (Fig. 3.1). Proximally, the entire extensor mechanism and posterior capsule are reflected as one unit from the distal humerus. As the extensor mechanism is retracted laterally, the elbow is flexed to expose the joint. The ulnar nerve must be monitored closely throughout the procedure to avoid traction injury. Repair of the extensor mechanism to the olecranon at the completion of the procedure is executed with two oblique and one transverse transosseous drill holes. Postoperatively, avoiding active elbow extension against resistance for approximately 6 weeks protects the triceps repair.

For the triceps-splitting approach, a longitudinal incision is made from the proximal triceps muscle to the distal triceps tendon across its insertion on the proximal olecranon [5]. As with the triceps-reflecting approach, ulnar nerve identification and protection is advised prior to the approach. The elbow joint is exposed as the anconeus is reflected subperiostally and laterally, and as the flexor carpi ulnaris (FCU) is reflected medially (Fig. 3.2). The approach may be limited proximally by the location of the radial nerve at the posterior one third of the humeral shaft. The triceps tendon is repaired with nonabsorbable sutures.

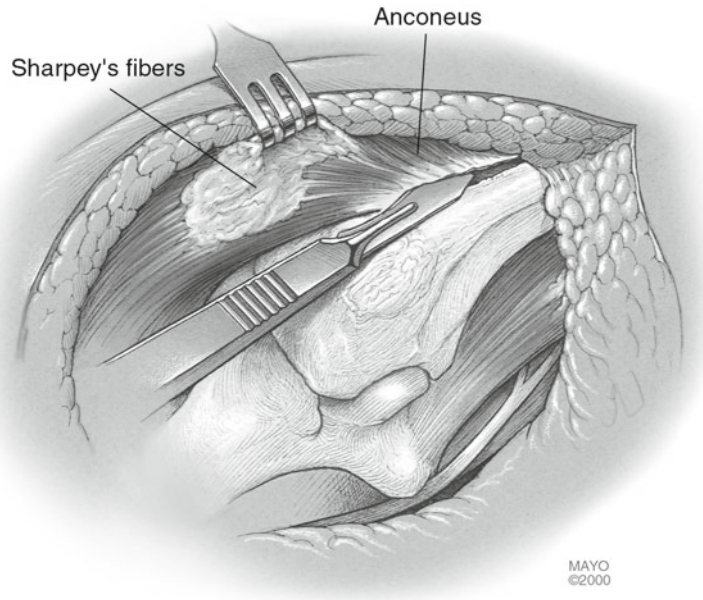

Fig. 3.1 Triceps-reflecting approach. The schematic demonstrates exposure of the distal humerus via subperiosteal reflection of the distal triceps insertion from medial to lateral while maintaining continuity with the forearm fascia and anconeus. Reproduced with permission from © Mayo Foundation for Medical Education and Research. All rights reserved

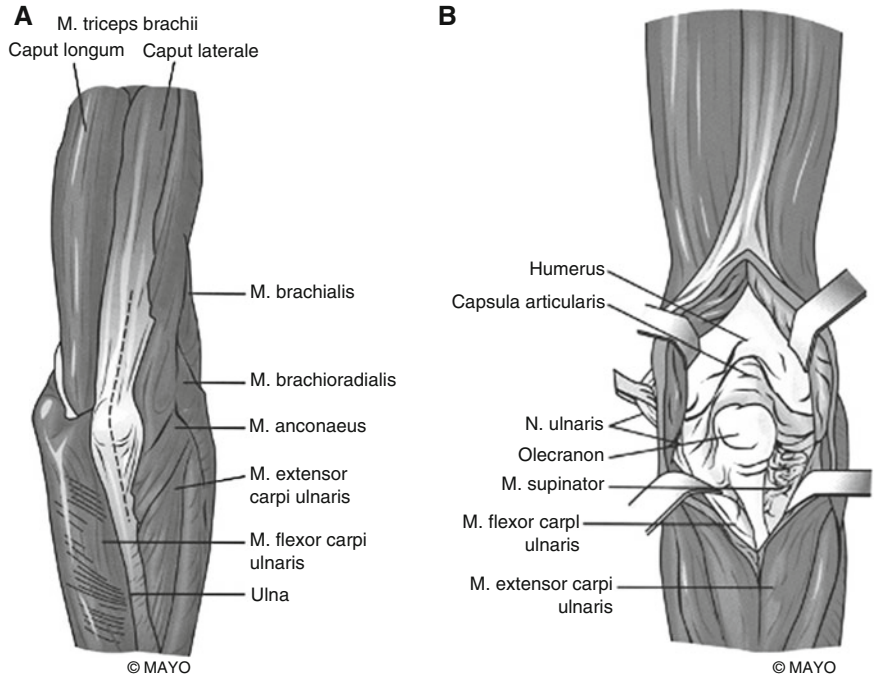

Fig 3.2 Triceps-splitting approach. (**a**, **b**) The illustration depicts exposure of the elbow with distal extension of the incision and retraction of the flexor carpi ulnaris medially and the anconeus laterally (Reproduced with permission from © Mayo Foundation for Medical Education and Research. All rights reserved)

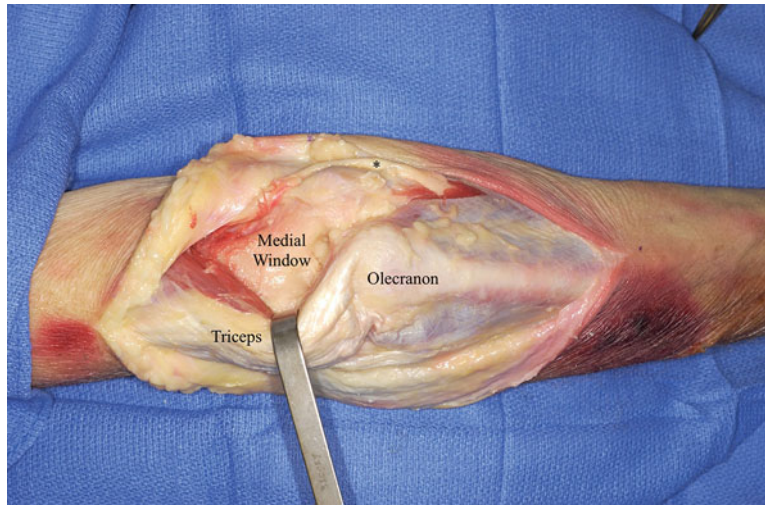

Fig 3.3 Paratricipital approach. Dissecting free the medial and lateral borders of the triceps from the posterior part of the humerus creates medial and lateral windows to visualize the extra-articular distal humerus while preserving the triceps tendon insertion (*=ulnar nerve; lateral window not seen) (Reprinted with permission from Cheung E, Steinmann S. Surgical Approaches to the Elbow. J Am Acad Orthop Surg. 2009; 17(5): 325–33)

Postoperative protection of active extension against resistance and passive stretching in positions of terminal flexion is instituted.

The paratricipital, or Alsonso-Llames, approach [6] maintains the triceps insertions at the olecranon and eliminates risk of postoperative triceps insufficiency while allowing visualization of the extra-articular distal humerus. The tissue plane between the medial intermuscular septum and the medial side of the olecranon and triceps tendon is developed. Ulnar nerve dissection and protection are recommended to avoid traction injuries. On the lateral side, the plane between the lateral intermuscular septum and the anconeus is developed. Joining the medial and lateral tissue planes to release the triceps from the posterior humeral cortex completes the dissection. Medial and lateral windows are created by retracting the triceps tendon laterally and medially respectively (Fig. 3.3). Distal visualization may be compromised with an intact triceps unit; therefore, the approach is typically utilized for elbow arthroplasty after release of the collateral ligaments or during olecranon fracture dislocations where the distal extent of the approach around the proximal olecranon is utilized. Visualization may be improved by placing the elbow into an extended position to relax the triceps unit.

Lateral Approaches

Lateral exposures allow access to the lateral column of the distal humerus, radial head, capitellum, and lateral collateral ligament complex. The coronoid process can also be accessed through a lateral approach if the radial head has been fractured or resected. Access to the lateral aspect of the elbow can be achieved through a direct lateral superficial approach or with a posterior superficial approach and elevation of a thick flap until the lateral epicondyle is reached. The presence of associated injuries guides the approach. If medial sided structures (coronoid process, ulnar collateral ligament complex) are likely to require exposure, then a posterior superficial approach is used. If this is unlikely, then a lateral superficial approach can be used. The three primary deep lateral approaches include the Kaplan approach, the Kocher approach, and the extensor digitorum communis split approach.

The Kaplan approach allows for excellent exposure of the radial head without interruption of the lateral ulnar collateral ligament (LUCL) [7] (Fig. 3.4). A skin incision is made with the elbow flexed at 90° from the tip of the lateral epicondyle and extended distally approximately 3–4 cm towards Lister's tubercle of the distal

radius. The superficial interval lies between the extensor digitorum communis (EDC) and extensor carpi radialis brevis (ECRB). Special care must be taken to avoid injuring the lateral antebrachial cutaneous nerve, which travels within the adipose tissue at the distal aspect of the incision. The nerve pierces the brachial fascia approximately 3 cm proximal to the lateral epicondyle, and then passes 4.5 cm medial to the lateral epicondyle [8]. Deeper, the approach divides the annular ligament complex but remains anterior to the LUCL along the axis of the radiocapitellar joint.

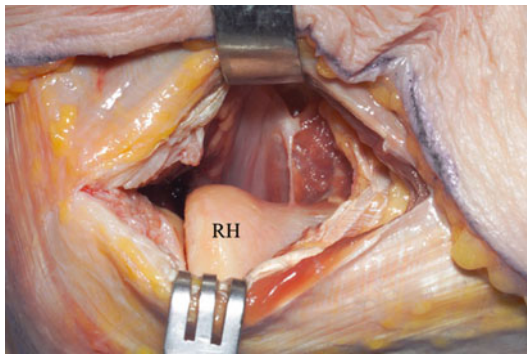

Fig 3.4 Kaplan approach. The interval between the extensor digitorum communis and extensor carpi radialis brevis provides access to the radial head (RH). Forearm pronation during the approach protects the posterior interosseous nerve (Reprinted with permission from Cheung E, Steinmann S. Surgical Approaches to the Elbow. J Am Acad Orthop Surg. 2009; 17(5): 325–33)

The interval for the Kocher approach is between the anconeus and the extensor carpi ulnaris (ECU) [9]. A fat stripe, often seen, defines the interval. The ECU is retracted anteriorly and the anconeus is retracted posteriorly to allow access to the lateral capsule and ligaments (Fig. 3.5). The capsule is incised along the anterior border of the LUCL. The fibers of the LUCL, if intact, must be recognized and protected to avoid destabilizing the elbow [2]. The Kocher approach may be extended both proximally and distally for LUCL reconstruction and complex radial head fractures, or to the coronoid process in terrible triad injuries primarily if the radial head fragments are removed. Caution must be exercised to avoid injury to the radial nerve. The radial nerve crosses the lateral intermuscular septum from the spiral groove 8–10 cm proximal to the lateral epicondyle [8].

The EDC splitting approach is a direct lateral and alternative safe approach that can provide excellent visualization of the proximal radius (Fig. 3.6). The approach offers more reliable exposure of the anterior half of the radial head while minimizing soft-tissue destruction and reducing the risk of iatrogenic injury to the LUCL compared to the Kocher approach [10]. The EDC splitting approach also reduces risk of iatrogenic injury to the deep branch of the radial nerve. In a cadaveric study, the distance of the deep branch of the radial nerve to the radial head was 20 mm

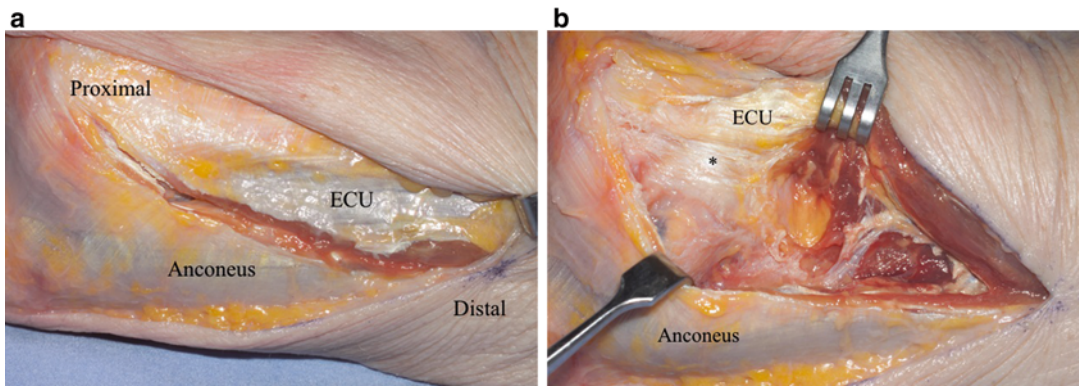

Fig 3.5 Kocher approach. (**a**) The plane between the anconeus and the extensor carpi ulnaris (ECU) is developed. (**b**) Anterior retraction of the ECU and posterior retraction of the anconeus provides visualization of the lateral capsule (*) and ligaments. The capsule is incised anterior to the equator of the radial head to avoid iatrogenic injury to the lateral ulnar collateral ligament complex (Reprinted with permission from Cheung E, Steinmann S. Surgical Approaches to the Elbow. J Am Acad Orthop Surg. 2009; 17(5): 325–33)

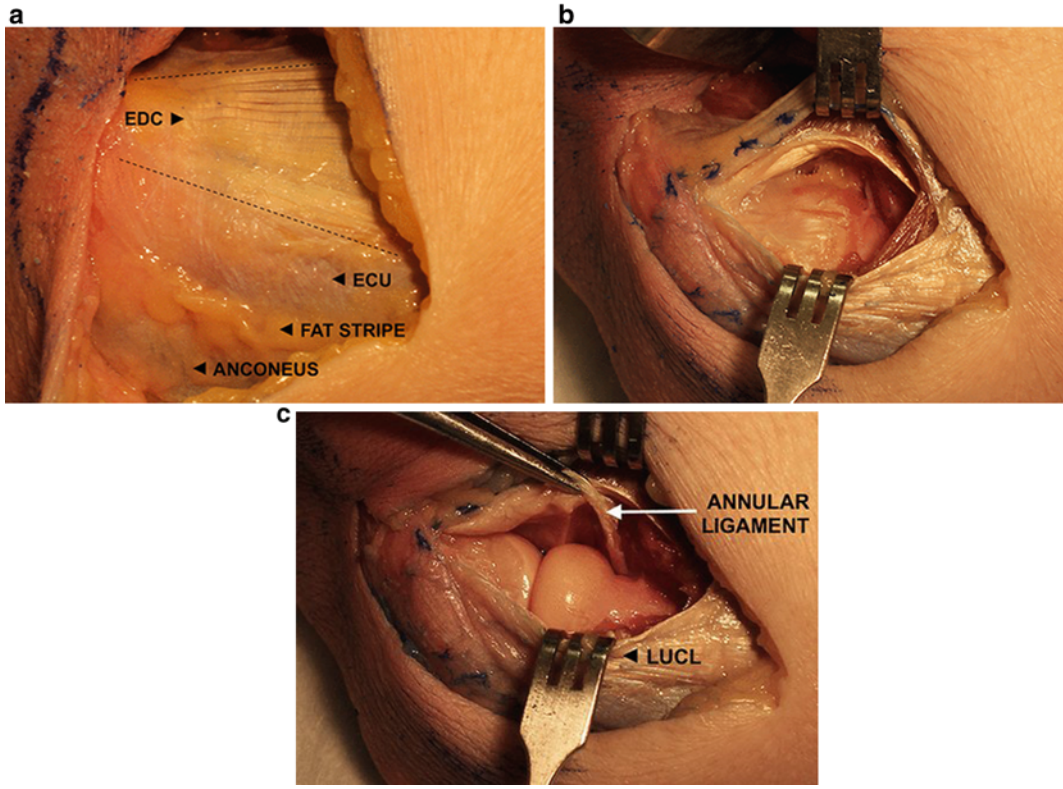

Fig 3.6 Extensor digitorum communis (EDC) split approach. (**a**) The EDC tendon is identified by its characteristic white tendinous appearance. The borders of the tendon are represented by the dotted lines. (**b**) A longitudinal split of the EDC tendon exposes the lateral radiocapitellar joint capsule. (**c**) The lateral elbow capsulotomy performed anterior to the equator of the capitellum and in line with the EDC split exposes the radiocapitellar joint (ECU = extensor carpi ulnaris, LUCL = lateral ulnar collateral ligament) (Reprinted with permission from Berdusco et al. Lateral elbow exposures: The extensor digitorum communis split compared with the kocher approach. JBJS Essential Surgical Techniques 2015:5(4):e30)

in the EDC splitting approach compared to 7 mm in the Kaplan approach [11]. Once the EDC tendon is identified, the tendon is bisected longitudinally, starting proximally at the lateral epicondylar ridge and extending 25 mm distally from the radiocapitellar joint [10]. After muscle splitting, the capsule and annular ligament are incised anterior to the equator of the capitellum to avoid injury to the LUCL posteriorly and resultant posterolateral rotatory instability. If greater exposure is needed, the anterior half of the EDC and ECRB tendons are detached proximally from the lateral epicondyle. Subsequently, the extensor carpi radialis longus and brachioradialis origins from the supracondylar ridge are detached. The extensile approach allows sufficient access to the ulnar coronoid process, which can be used to treat terrible triad injuries [12].

One of the major pitfalls of the deep lateral approaches is iatrogenic injury to the posterior interosseous nerve (PIN). The distance where the PIN crosses the radius distal to the radiocapitellar joint varies with forearm rotation and alters the surgical safe zone [13–15]. In a cadaveric study utilizing the Kaplan approach, the PIN crossed the radius 4.2 cm distal to the radiocapitellar joint with the forearm in neutral rotation [13]. Supination decreased the distance to 3.2 cm whereas pronation increased the distance to 5.6 cm. Another study utilizing the Kocher approach found pronation of the forearm to safely expose at least 38 mm of the lateral aspect of the

radius; supination dwindled the proximal safe zone to as little as 22 mm [14]. In contrast, another study found limited PIN distal translation with pronation and recommended limiting dissection to 4.0 cm from the radiocapitellar joint regardless of forearm rotation during a lateral approach [16]. During the EDC splitting approach, the PIN is generally safe when dissecting up to 29 mm from the radiocapitellar joint and up to 42 mm from the lateral epicondyle with the forearm in pronation [15]. A useful landmark for intraoperative orientation may be the radial tuberosity during a lateral Kocher approach. One study showed the PIN is located a minimum of 2.1 cm distal to the radial tuberosity in pronation at the lateral aspect of the radius and as closed as 7 mm distal to the tuberosity in supination [17]. In general for most lateral approaches if the forearm is kept in pronation, a proximal safe zone of about 4 cm is present from the articular surface of the radial head distally before the PIN is at significant risk for injury.

Medial Approaches

For the unstable elbow, medial approaches are useful for reconstruction of the ulnar collateral ligament (UCL) complex or coronoid fracture fixation. They may be performed by either a long posterior elbow skin incision, elevating a medial flap, or by a medial incision halfway between the medial epicondyle and the olecranon. The ulnar nerve must be identified and generously mobilized both proximally and distally for protection. A posterior midline skin incision may be preferred to reduce the risk of injury to the medial antebrachial cutaneous nerve [1]. The nerve commonly lies on the fascia anterior to the medial intermuscular septum. Identification of the nerve and protection may prevent formation of a postoperative neuroma. At an average of 14.5 cm proximal to the medial epicondyle, the medial antebrachial cutaneous nerve divides into anterior and posterior branches [8]. The anterior branch crosses the elbow between the medial epicondyle and the biceps tendon. The posterior branch has two or three additional divisions, which typically cross the elbow proximal to the medial epicondyle.

In the FCU split approach, the humeral and ulnar heads of the FCU are divided to expose the coronoid process for visualization of coronoid tip or anteromedial coronoid facet fractures (Fig. 3.7). The exposure is kept anterior to the sublime tubercle and, thus, the UCL so as not to detach the ligament and potentially destabilize the elbow. The capsule is incised parallel and anterior to the UCL, exposing the ulnohumeral joint. Proximal extension is achieved by elevating

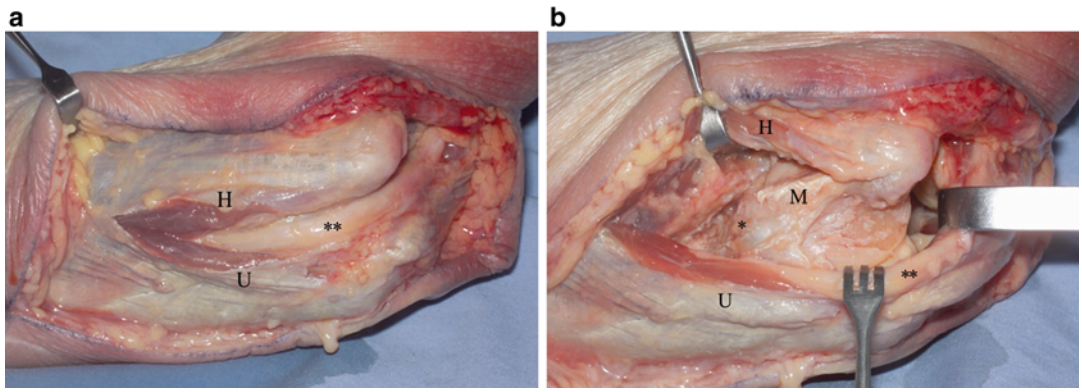

Fig 3.7 Flexor carpi ulnaris (FCU) split approach. (**a**) The humeral (H) and ulnar (U) heads are divided to enable in situ release of the ulnar nerve (**). (**b**) As the humeral head of the FCU is reflected superolaterally and the ulnar nerve is gently retracted posteriorly, the anterior band of the medial collateral ligament (M) and the coronoid process (*) are exposed (Reprinted with permission from Cheung E, Steinmann S. Surgical Approaches to the Elbow. J Am Acad Orthop Surg. 2009; 17(5): 325–33)

the capsule up to the medial epicondyle. Additional exposure distally is achieved by dissecting the brachialis and the FCU from the ulna, while protecting the ulnar nerve. Transposition of the ulnar nerve may minimize postoperative or posttraumatic ulnar neuritis.

The extended medial, or Hotchkiss, approach [18] provides excellent exposure of the anterior capsule and coronoid process through an approach over the top of the humeral origin portion of the common flexor pronator muscle mass with safe distal extension to the medial ulna. Once the medial intermuscular septum is identified along with the medial supracondylar ridge, the brachial fascia is then incised along the anterior aspect of the septum, and the flexor-pronator group is released from the supracondylar ridge [2]. The flexor group is split longitudinally at the distal aspect. The posterior aspect of the FCU origin is left intact on the medial aspect of the distal humerus to facilitate repair at the end of the procedure. Elevation of the brachialis, flexor carpi radialis, and pronator teres muscles off the anterior capsule allows visualization to the lateral aspect of the anterior elbow joint (Fig. 3.8). The brachialis is released in continuity with the flexor-pronator mass along the medial supracondylar ridge to protect the median nerve, brachial artery, and brachial vein, which lie superficial to the brachialis. The anterior band of the ulnar collateral ligament is preserved beneath the FCU.

The FCU split and the Hotchkiss over-the-top approaches are the two most commonly used surgical techniques to expose medial elbow structures. In one cadaveric study, both were found to provide a comparable area of greater than 800 mm^2 of proximal ulna exposure [19]. However, another study using calibrated digital images showed that the FCU split approach may provide enhanced exposure of the osseous and ligamentous structures of the medial elbow [20]. The FCU split approach exposed 13.3 cm^2 of average surface area. During the Hotchkiss over-the-top approach, the average surface are exposed was three times less (4.4 cm^2) and visualization of the sublime tubercle as well as the anterior and posterior bundles of the UCL was not consistently obtainable [20].

In the throwing athlete, the flexor pronator split approach allows UCL reconstruction with decreased soft tissue trauma in a safe and simple manner. The site of the muscle-split is through the posterior one-third of the common flexor bundle, within the most anterior fibers of the FCU [21, 22]. The anterior bundle of the UCL lies directly deep to this region of the common flexor mass. Additionally, the muscle-split utilizes an internervous plane, as the anterior portion of the

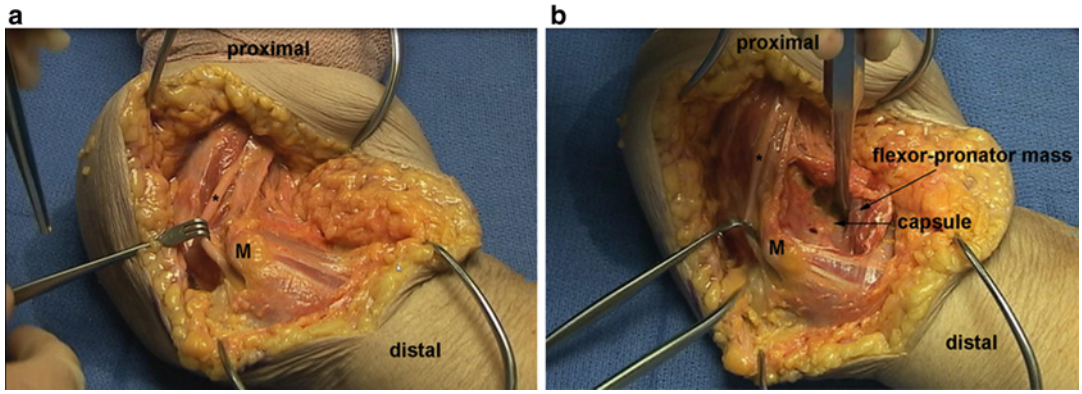

Fig 3.8 Hotchkiss over-the-top approach. (**a**) The medial intermuscular septum, medial supracondylar ridge of the humerus, and the origin of the flexor-pronator mass are identified while mobilizing and protecting the ulnar nerve. (**b**) Release of the flexor-pronator mass and brachialis from the medial supracondylar ridge allows exposure of the joint (M = medial epicondyle, * = ulnar nerve) (Reprinted with permission from Olson et al. Surgical Approaches to the Elbow. Orthopedic Knowledge Online Journal 2013;11(7))

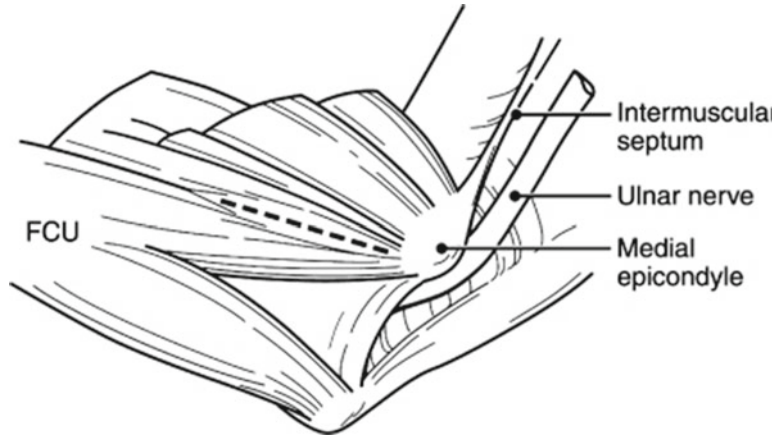

Fig 3.9 Flexor-pronator split approach. The flexor-pronator mass is split by incising the raphe from the medial epicondyle to the sublime tubercle to expose the ulnar collateral ligament (Reprinted with permission from Conway JE. The DANE TJ procedure for elbow medial ulnar collateral ligament insufficiency. Techniques in Shoulder and Elbow Surgery 2006;7(1):36–43)

flexor bundle is innervated by the median nerve and the posterior portion is innervated by the ulnar nerve (Fig. 3.9). Following the fascial incision from the medial humeral epicondyle to the sublime tubercle approximately 3–4 cm distally, the muscle is bluntly split to the level of the UCL [21]. Safe extension may be performed 1 cm distal to the UCL's insertion on the sublime tubercle. Subperiosteal dissection allows complete exposure of the proximal ulna for placement of bone tunnels, while retractors protect the underlying ulnar nerve [21, 22]. In athletes with medial elbow instability, the muscle-splitting approach without transposition of the ulnar nerve allows excellent results with return to sport and reduced postoperative neurologic complications compared with similar procedures [23].

Fractures of the anteromedial coronoid facet resulting from a varus posteromedial rotational injury force may be repaired via a Taylor-Scham approach. An incision along the subcutaneous border of the ulna is made followed by subperiosteal dissection medially and elevation of the ulnar and deep heads of the flexor digitorum superficialis and pronator teres, respectively (Fig. 3.10). The muscular origin of the flexor digitorum profundus is subsequently elevated, with dissection carried anteriorly until the margin of the coronoid and sublime tubercle are delineated [24, 25]. A variation of this approach has been described using a limited skin incision and elevation of enough of the flexor-pronator mass such that adequate visualization of the anteromedial coronoid facet is achieved [26]. The approach can be extended proximally by transposing the ulnar nerve and then detaching the FCU and part of the flexor-pronator mass as needed creating an L-shaped exposure between the ulnar head of the FCU and the ulna and then proximally up the humeral shaft. A stump of FCU and flexor mass should be left on the humerus for repair at the end of the procedure.

Preferred Approaches

To expose the different compartments of the elbow, we prefer to utilize separate skin incisions, rather than one large incision. This minimizes the chance of developing a subcutaneous hematoma collection or seroma formation. Traction injuries to the skin are also minimized, which may compromise healthy primary wound healing. For complex elbow fractures and total elbow arthroplasty, we regularly transpose the ulnar nerve anteriorly into a subcutaneous pocket. In contrast, the nerve is preferentially left in situ after decompressing the cubital tunnel retinaculum in the

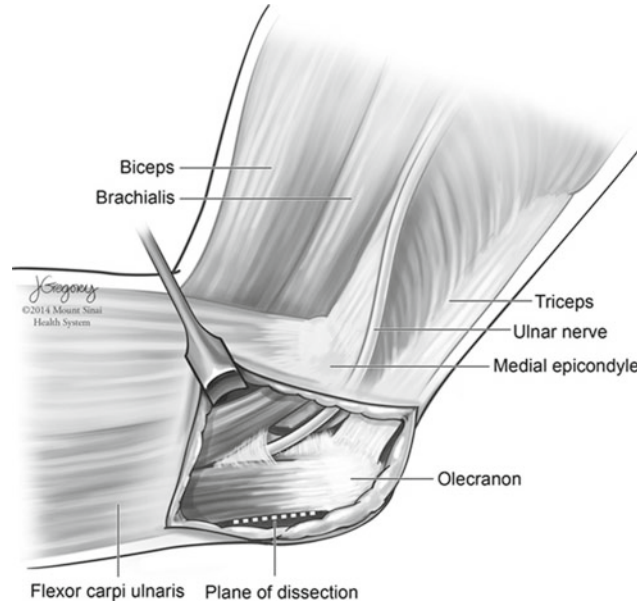

Fig 3.10 Taylor-Scham approach. Following an incision along the subcutaneous border of the ulna, subperiosteal dissection medially and elevation of the flexor-pronator mass allows access to the anteromedial coronoid facet and sublime tubercle (Reprinted with permission from Shukla et al. A novel approach for coronoid fractures. Techniques in Hand & Upper Extremity Surgery. 2014;18(4):189–193)

setting of posttraumatic contracture release or in some cases of UCL repair or reconstruction.

For terrible triad injuries, we prefer an extended EDC split approach. This provides adequate visualization of the radial head and neck. Often times, the LUCL avulsion is apparent upon entry of the fascia, and the LUCL can be fixed primarily to a suture anchor placed at the isometric point near the lateral epicondyle. Care should be taken to not extend past the radial neck due to the location of the PIN. Proximally, the common extensor group, ECRB and ECRL may also be released along the lateral column such that one may visualize the tip of the coronoid. If the coronoid fracture is small, then suture fixation may be performed through the lateral incision, and transosseous drill holes can be made to secure the suture fixation through the base of the fracture. If, however, the coronoid fracture is large, then an additional medial incision may be made to perform the coronoid fixation through a flexor pronator split approach, making care to avoid injury to the ulnar nerve.

We prefer a flexor pronator split approach for UCL reconstruction. Either retraction of the ulnar nerve posteriorly or anterior transposition minimizes the risk of iatrogenic injury, since the ulnar nerve lies in very close proximity during the approach. Due to the need to place drill holes along the sublime tubercle as well as at the inferior aspect of the medial epicondyle, one must ensure that there is adequate visualization of anchorage of the graft while avoiding injury to the ulnar nerve.

In cases of chronic lateral instability of the elbow requiring LUCL reconstruction, we prefer a Kocher approach, which extends parallel to the course of the LUCL. The approach affords clear visualization of the supinator crest for drilling and fixation of the distal aspect of the graft. The entirety of the lateral epicondyle is also easily visualized through this approach such that the ligament graft may be secured to the most isometric point determined intraoperatively.

Conclusion

Several surgical approaches exist for addressing elbow instability. The three primary superficial approaches in the treatment of elbow instability include posterior, lateral, and medial. Each superficial approach has a variety of deep approaches. Deep posterior approaches utilized for elbow

instability are the triceps reflecting, paratricipital, or triceps splitting. These approaches allow for simultaneous medial and lateral exposure in the setting of global instability. Additionally, the deep posterior approaches are indicated for total elbow arthroplasty and olecranon fracture associated with dislocation. The deep lateral approaches are the Kocher, Kaplan, and the EDC split. Pathology addressed through these approaches include radial head fractures, capitellar fractures, and coronoid fractures in the absence of radial head and LUCL trauma. Deep medial approaches include the FCU-split, the Hotchkiss over-the-top, the flexor-pronator split, and Taylor-Scham. Coronoid fractures and UCL injuries may be addressed through deep medial approaches. Access to deep lateral and medial approaches may be achieved via either lateral or medial superficial approaches respectively, or simultaneously through the superficial posterior approach. Regardless of the approach, a thorough understanding of the anatomy is necessary to determine compromised osseous and ligamentous structures in the unstable elbow for preoperative planning and safe execution of the particular surgical technique.

References

1. Barco R, Antuña S. Management of elbow trauma: anatomy and exposures. Hand Clin. 2015;31(4):l 509–19.
2. Cheung EV, Steinmann SP. Surgical approaches to the elbow. J Am Acad Orthop Surg. 2009;17(5):325–33.
3. Vazquez O, Rutgers M, Ring DC, Walsh M, Egol KA. Fate of the ulnar nerve after operative fixation of distal humerus fractures. J Orthop Trauma. 2010;24(7):395–9.
4. Bryan RS, Morrey BF. Extensive posterior exposure of the elbow. A triceps-sparing approach. Clin Orthop Relat Res. 1982;166:188–92.
5. Morrey BF, Sanchez-Sotelo J. Approaches for elbow arthroplasty: how to handle the triceps. J Shoulder Elbow Surg. 2011;20(2 Suppl):S90–6.
6. Alonso-Llames M. Bilaterotricipital approach to the elbow. Its application in the osteosynthesis of supracondylar fractures of the humerus in children. Acta Orthop Scand. 1972;43(6):479–90.
7. Kaplan E. Surgical approaches to the proximal end of the radius and its use in fractures of the head and neck of the radius. J Bone Joint Surg. 1941;23(1):86.
8. Adams JE, Steinmann SP. Nerve injuries about the elbow. J Hand Surg Am. 2006;31(2):303–13.
9. Kocher T. Textbook of operative surgery. 3rd ed. London: Adam and Charles Black; 1911.
10. Desloges W, Louati H, Papp SR, Pollock JW. Objective analysis of lateral elbow exposure with the extensor digitorum communis split compared with the Kocher interval. J Bone Joint Surg Am. 2014;96(5):387–93.
11. Han F, Lim CT, Lim JC, Tan BH, Shen L, Kumar VP. Deep branch of the radial nerve in lateral surgical approaches to the radial head - a cadaveric study. Orthop Traumatol Surg Res. 2016;102(4):453–8.
12. Sukegawa K, Suzuki T, Ogawa Y, Ueno K, Kiuchi H, Kanazuka A, et al. Anatomic cadaveric study of the extensile extensor digitorum communis splitting approach for exposing the ulnar coronoid process. J Shoulder Elbow Surg. 2016;25:1268.
13. Calfee RP, Wilson JM, Wong AH. Variations in the anatomic relations of the posterior interosseous nerve associated with proximal forearm trauma. J Bone Joint Surg Am. 2011;93(1):81–90.
14. Diliberti T, Botte MJ, Abrams RA. Anatomical considerations regarding the posterior interosseous nerve during posterolateral approaches to the proximal part of the radius. J Bone Joint Surg Am. 2000;82(6): 809–13.
15. Schimizzi A, MacLennan A, Meier KM, Chia B, Catalano 3rd LW, Glickel SZ. Defining a safe zone of dissection during the extensor digitorum communis splitting approach to the proximal radius and forearm: an anatomic study. J Hand Surg Am. 2009;34(7): 1252–5.
16. Lawton JN, Cameron-Donaldson M, Blazar PE, Moore JR. Anatomic considerations regarding the posterior interosseous nerve at the elbow. J Shoulder Elbow Surg. 2007;16(4):502–7.
17. Hackl M, Wegmann K, Lappen S, Helf C, Burkhart KJ, Muller LP. The course of the posterior interosseous nerve in relation to the proximal radius: is there a reliable landmark? Injury. 2015;46(4):687–92.
18. Kasparyan NG, Hotchkiss RN. Dynamic skeletal fixation in the upper extremity. Hand Clin. 1997;13(4): 643–63.
19. Jost B, Benninger E, Erhardt JB, Kulling FA, Zdravkovic V, Spross C. The extended medial elbow approach-a cadaveric study. J Shoulder Elbow Surg. 2015;24(7):1074–80.
20. Huh J, Krueger CA, Medvecky MJ, Hsu JR. Medial elbow exposure for coronoid fractures: FCU-split versus over-the-top. J Orthop Trauma. 2013;27(12): 730–4.
21. Smith GR, Altchek DW, Pagnani MJ, Keeley JR. A muscle-splitting approach to the ulnar collateral ligament of the elbow. Neuroanatomy and operative technique. Am J Sports Med. 1996;24(5):575–80.
22. Rohrbough JT, Altchek DW, Hyman J, Williams 3rd RJ, Botts JD. Medial collateral ligament reconstruction of the elbow using the docking technique. Am J Sports Med. 2002;30(4):541–8.

23. Thompson WH, Jobe FW, Yocum LA, Pink MM. Ulnar collateral ligament reconstruction in athletes: muscle-splitting approach without transposition of the ulnar nerve. J Shoulder Elbow Surg. 2001;10(2):152–7.
24. Taylor TK, Scham SM. A posteromedial approach to the proximal end of the ulna for the internal fixation of olecranon fractures. J Trauma. 1969;9(7):594–602.
25. Doornberg JN, Ring DC. Fracture of the anteromedial facet of the coronoid process. J Bone Joint Surg Am. 2006;88(10):2216–24.
26. Shukla DR, Koehler SM, Guerra SM, Hausman MR. A novel approach for coronoid fractures. Tech Hand Up Extrem Surg. 2014;18(4):189–93.