

Elbow Trauma: Rehabilitative Evaluation and Treatment

PDH Academy Course #OT-19xx
6 CE HOURS

AOTA LOGO

This course is offered for 0.6 CEUs (Intermediate level; Category 2 – Occupational Therapy Process: Evaluation; Category 2 – Occupational Therapy Process: Intervention; Category 2 – Occupational Therapy Process: Outcomes).

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Course Abstract

This course addresses the rehabilitation of patients with elbow trauma. It begins with a review of relevant terminology and anatomy, next discusses injuries to the elbow with attention to medical interventions, and then examines the role of therapy as it pertains to evaluation and rehabilitation.

Target audience: Occupational Therapists, Occupational Therapy Assistants, Physical Therapists, Physical Therapist Assistants (no prerequisites).

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Learning Objectives

At the end of this course, learners will be able to:

- Differentiate between definitions and terminology pertaining to elbow trauma
- Recall the normal anatomy and kinesiology of the elbow
- Identify elbow injuries, with attention to their medical diagnosis and treatment
- Recognize roles of therapy as it pertains to the evaluation and rehabilitation of elbow trauma

Timed Topic Outline

- I. Introduction & Definitions (30 minutes)
- II. Provocative Testing at the Elbow (10 minutes)
- III. Elbow Anatomy (50 minutes)
 - Bones of the Elbow, Soft Tissue Structures of the Elbow, Ligaments of the Elbow, Nerves of the Elbow, Kinematics of the Elbow
- IV. Elbow Fractures (90 minutes)

- Classifications, Non-Operative Treatment vs. Surgical Treatment, Generalized Healing Time for Fractures as Related to Rehabilitation, Fractures to the Elbow, Terrible Triad Injuries, Essex-Lopresti Injuries
- V. Elbow Instability and Throwing Injuries (60 minutes)
Elbow Dislocation, Elbow Instability, Throwing Injuries, Other Athletic Injuries
- VI. Considerations for Elbow Evaluation (60 minutes)
Gathering History, Objective Measurements
- VII. Considerations for Elbow Treatment (30 minutes)
Therapeutic Modalities, Physical Agent Modalities, Strengthening
- VIII. Conclusion, References, and Exam (30 minutes)

Delivery & Instructional Method

Distance Learning – Independent. Correspondence/internet text-based self-study, including a provider-graded multiple choice final exam.

To earn continuing education credit for this course, you must achieve a passing score of 80% on the final exam.

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Course Author Bio & Disclosure

Amy L. Paulson, OTR, CHT, is a certified hand therapist with over 20 years of experience in outpatient upper extremity care. She has been a licensed occupational therapist for more than 20 years, has experience in home health, skilled nursing, and acute care, and is a member of the American Society of Hand Therapists.

Amy has led multiple community-based classes on arthritis care, energy conservation and work simplification, and she taught as an adjunct professor at Palm Beach Community College in the OTA program. She designs and instructs hands-on continuing education courses in splinting and upper extremity treatment, and enjoys providing clinical instruction to students interested in specializing in hand therapy. She is also involved in coordinating and overseeing therapy programs in Gulu, Uganda by volunteering with the Medical Missions Foundation of Overland

Park, KS, and is co-founder of the Gulu Project, a non-profit organization that is building an outpatient village for the burn patients of Northern Uganda.

Amy currently owns and operates her private practice in outpatient hands, where she provides patient care, clinical instruction to Level II students, community education, marketing, and insurance billing.

DISCLOSURES: Financial – Amy Paulson received a stipend as the author of this course.
Nonfinancial – No relevant nonfinancial relationship exists.

Introduction

The elbow is a complicated joint complex that plays a very important role in the function of the arm and hand. When elbow motion and strength are limited, the function of the upper extremity is profoundly impacted. Functional elbow health is vital to provide power for stability during close-chained activities such as pushing a door open or using a power tool. Elbow stability also provides a solid base for open-chained, precision activities such as throwing a ball or brushing your teeth. Elbow flexion is necessary to feed yourself. Elbow extension is necessary to tie your shoes, do yoga, or use a drive-thru ATM. Pronation is essential in typing, reaching items on a high shelf, and putting on earrings. Supination is vital for carrying a tray or safely lifting a casserole dish. You can't swing a bat or throw a ball without at least some elbow motion and stability. Simply put, a person's independence can be greatly affected by elbow health.

Although the elbow joint is one of the most congruous in the body, it is at great risk for contracture after major elbow trauma for several reasons. Capsular and ligamentous tightening and adhesions, adhesions of the musculotendinous structures of the elbow such as the brachialis on the anterior portion and the triceps insertion on the posterior portion of the elbow, and intra-articular adhesions are all risk factors with elbow trauma such as complex fractures and ligamentous injury. Due to all of the structures in and around the elbow, this joint is also at prime risk to develop heterotopic ossification.

In this course, we will review many of the structures that reside in the elbow complex including the three articulation surfaces of the elbow, their ligamentous support, the joint capsule itself, and the surrounding musculature. Various elbow fractures and ligament injuries will be discussed, with focus on how the anatomy is affected and what that means for treatment, both surgical and rehabilitation. We will consider generalized timelines and suggestions for developing a treatment plan. Finally, we will review some of the common soft tissue complications that can arise following elbow injury, such as prolonged stiffness and contractures, lateral and medial epicondylagia, and nerve damage, and consider how therapy can assist with a patient's return to function.

Amy's note: My primary goal for any readers of this course is to keep up with the latest research while learning practical information that they can use immediately in a clinic setting. In addition, occasionally I will toss in more personal musings, indicated by italicized writing. Text in italicized print is based in large part on my opinions, generated by 24 years of practical experience as a hand therapist – not solely science and research. This is what I like to call “evidence-based practice with a side dish of clinical experience (or old age).” For as we all know, and Albert Einstein so aptly stated, “In theory, theory and practice are the same. In practice, they are not.”

Definitions

Anconeus: Originates on the posterior aspect of the lateral epicondyle of the humerus and inserts onto the lateral aspect of the olecranon process, extending to the lateral surface of the body of the ulna. Its primary action is posterior elbow joint stability; it plays a small role in elbow extension. Innervated by the radial nerve (C7, C8).

Annular ligament: This ligament provides stability to the proximal radioulnar joint. It wraps around the radial head and inserts onto the ulna.

Avascular necrosis: Death of bone tissue due to lack of blood supply to the tissue. If blood flow is cut off from a section of fractured bone, the fragment is at risk for tissue death.

Biceps: Originates on the tip of the coracoid process of the scapula (short head) and the supraglenoid tubercle of the scapula (long head) and inserts onto the tuberosity of the radius and fascia of the forearm via the bicipital aponeurosis. Innervated by the musculocutaneous nerve (C5, C6).

Brachial artery: Main blood supply to the elbow. It is located medially in the upper arm along the path of the median artery superficial to the brachialis, enters the cubital fossa laterally, and then splits into the radial and ulnar arteries at the level of the elbow. The brachial artery sits medial to the biceps tendon and lateral to the median nerve in the cubital fossa.

Brachialis: Originates on the distal half of the anterior surface of the humerus and inserts onto the coronoid process of the ulna. Its primary action is to flex the elbow. It's more isolated with the forearm in pronation. Innervated by the musculocutaneous nerve (C5, C6).

Closed fracture: Any fracture that does not puncture the skin. These may or may not require surgery depending on the degree of displacement or comminution.

Comminuted fracture: Any fracture that results in many bone fragments, such as those that can occur with a crush injury or high-velocity fall.

Complex regional pain syndrome (CRPS): Formerly known as reflex sympathetic dystrophy (RSD), this is a complication that can occur after upper extremity trauma where the brain has a loss of pain inhibitory mechanisms and a hyper-activation of ascending pain pathways which results in excruciating pain, changes in sleep patterns, increased swelling, stiffness, and loss of function to the hand. CRPS can occur due to any injury, but is often seen after high velocity falls and elbow injury and will greatly impact function.

Cubital fossa: The anterior hollow of the elbow. The lateral border is the brachioradialis, the medial border is the pronator teres, and the proximal border is the distal humerus.

Displaced fracture: A fracture that results in movement of the bony fragment away from its proper alignment. Technically any fracture that is displaced more than 2 mm in any plane on x-ray is considered displaced. Displaced fractures can be manually or surgically reduced depending on the severity.

Essex-Lopresti injury: The fracture of the radial head (proximal radius) with dislocation of the distal radioulnar joint and disruption of the interosseous membrane. X-rays reveal dorsal subluxation of the distal ulna on a lateral view of the pronated wrist. This is a result of a fall from height or high energy forearm trauma. Treatment is typically open reduction and internal fixation (ORIF) of the radial head to regain position (Edwards & Jupiter, 1988).

Extra-articular fracture: This refers to a fracture that does not extend into the articular surface of the joint. One of the most important descriptors of a fracture, extra-articular fractures tend to be less complicated and have better functional outcomes than intra-articular fractures unless they are comminuted.

Interosseous membrane: A large fibrous membrane traveling between the radius and ulna extending the length both bones. This membrane provides stability in the forearm and also serves to compartmentalize the volar and dorsal portions of the forearm.

Intra-articular fracture: This refers to a fracture that extends to the articular surface of the bone, causing damage to the cartilage and potentially the ligament attachments as well. These types of injuries may result in degenerative arthritis and tend to have more complicated recoveries than extra-articular fractures.

Lateral collateral ligament complex (LCL): Consists of the radial collateral ligament (RCL) and the lateral ulnar collateral ligament (LUCL). Its primary function is to provide stability during varus stress and restrain against posterolateral rotatory instability. The LCL originates on the posterior lateral epicondyle and inserts on the supinator crest of the proximal ulna (lesser sigmoid notch). The LUCL portion of the LCL is most important for stability.

Median nerve: Branching from the medial and lateral cords of the brachial plexus, it runs from lateral to medial superficial to the brachialis muscle and deep to the biceps muscle. It extends distally across the elbow joint on the anterior and lateral side. It innervates the lateral aspect of the elbow joint itself. It innervates muscles that originate at the elbow joint, but the nerve does not actually branch until it is located distal to the elbow.

Mobile wad: Also known as the “mobile wad of Henry,” the mobile wad refers to a group of three muscle bellies in the posterior compartment. These are the extensor carpi radialis longus (ECRL), the extensor carpi radialis brevis (ECRB), and the brachioradialis. As a group, they work to flex the elbow as a secondary action. The primary job of the ECRB and ECRL is to extend the wrist.

Musculocutaneous nerve: Branching from the lateral cord of the brachial plexus from roots C5, C6, the musculocutaneous nerve innervates the brachialis and a portion of the biceps and runs between these two muscles. At the elbow, the musculocutaneous nerve exits laterally, distal to the biceps tendon.

Non-displaced fracture: A full or partial fracture of the bone that does not move away from its proper alignment. Non-displaced fractures are typically treated with conservative casting or splinting to allow time for healing and have fewer complications.

Posterior interosseous nerve (PIN): A more common name for the deep branch of the radial nerve, this is the portion of the radial nerve that provides motor function to several muscles in the forearm, wrist, and hand. The posterior interosseous nerve crosses the proximal radius from anterior to posterior within the supinator muscle, 4 cm distal to the radial head. The PIN innervates the extensor carpi radialis brevis, the extensor digitorum (including the digiti minimi and indicis proprius), the supinator, the abductor pollicis longus, the extensor pollicis longus and brevis, and the extensor carpi ulnaris. The PIN pierces through the supinator muscle, and runs close to the proximal radius. It is at risk of being damaged during a radial head replacement if not protected.

Open fracture: Any fracture that punctures the skin. These fractures must be fixed with surgery.

Open reduction and internal fixation (ORIF): An operative technique of opening the patient in surgery to apply suture anchors, pins, plates, or screws, or a combination thereof.

Radial nerve: Branching from the posterior cord of the brachial plexus from roots C7, C8; innervates the anconeus, triceps. At the elbow it leaves the triangular interval of the teres major, long head of the triceps, and the humerus. It extends down through the spiral groove which is found about 13 cm above the trochlea (just distal to the deltoid insertion), and pierces the lateral intermuscular septum about halfway to the trochlea, between the middle and distal third of the humerus. It lies between the brachialis and the brachioradialis. It then runs superficial to the joint capsule of the radiocapitellar joint of the elbow. In the forearm, the radial nerve dives into the supinator muscle approximately 3-4 cm distal to the lateral epicondyle and innervates the posterior compartment muscles.

Terrible triad: Severe injury to the elbow involving a coronoid fracture, an elbow dislocation with lateral collateral ligament injury, and radial head or neck fracture.

Triceps brachii: Originates on the infra-glenoid tubercle of the scapula (long head), the posterior aspect of the humerus, superior to the radial groove (lateral head), and inferior to the radial groove on the posterior humerus (medial head), and inserts into the olecranon process of the ulna and fascia of the forearm. Innervated by the radial nerve (C6, C7, C8). The triceps brachii is the main elbow extensor.

Ulnar collateral ligament (UCL): Also known as the medial collateral ligament (or MCL), the ulnar collateral ligament provides medial stability from valgus stress to the elbow, extending from the posterior medial epicondyle of the humerus to the medial coronoid process of the ulna.

Ulnar nerve: The ulnar nerve branches from the medial cord of the brachial plexus, runs medial to the brachial artery, pierces the medial intermuscular septum at the level of the arcade of Struthers, and enters the posterior compartment. It traverses posterior to the medial epicondyle through the cubital tunnel and innervates the medial elbow joint. It innervates muscles that originate at the elbow joint, but the nerve does not actually branch until it is located distal to the elbow. The ulnar nerve is palpable at the ulnar groove of the elbow, commonly known as the “funny bone.”

Ulnar shortening osteotomy: This is a type of procedure to shorten the ulna in cases where it is impacting on the proximal carpal row. The surgeon will cut a predetermined length of the shaft of the ulna and use a locking plate and screws to regain bony alignment. The goal is to allow about 2 mm of room for the ulna to translate on the proximal carpal row. This procedure is used to reduce symptoms of wrist pain after elbow or forearm injuries.

Ulnar translation: With pronation, the ulna actually translates slightly in the sigmoid notch of the radius. That is to say, with pronation, the ulna slides distally about 2 mm in relation to the radius. With a fracture of the proximal radius or ulna, the ability of the ulna to translate may be affected, which can cause pain or stiffness in the wrist with forearm rotation.

Valgus extension overload (VEO): Also known as pitcher's elbow, valgus extension overload is a valgus instability due to overuse specifically from throwing sports.

Valgus instability: Caused by medial or ulnar collateral ligament injury allowing more movement medially in the elbow joint than the joint can manage safely. When placing pressure medially on the lateral aspect of the elbow, the medial elbow is not stable enough to withstand the pressure, causing increased valgus stress.

Valgus posterolateral rotatory instability (VPLRI): Involves a radial head fracture and less than 15% coronoid fracture; the anterior band of the medial collateral ligament is ruptured and the lateral collateral complex including the lateral ulnar collateral ligament is avulsed from the bone. Provocative testing for VPLRI includes the varus stress test, chair rise, and lateral pivot shift.

Varus posteromedial rotatory instability (VPMRI): The posterior band of the medial collateral ligament is ruptured; the anterior band is intact; the lateral collateral ligament including the lateral ulnar collateral ligament is avulsed. Provocative testing for VPMRI includes a valgus stress test, moving valgus stress test, and milking maneuver. A varus posteromedial rotatory instability does not involve a radial head fracture, but does involve a more than 15% coronoid fracture.

Varus stress: Caused by lateral ulnar collateral ligament injury allowing more movement laterally in the elbow joint. When placing pressure laterally on the medial aspect of the elbow, the lateral elbow is not stable enough to withstand the pressure, causing increased varus stress.

Provocative Testing at the Elbow

Cozen's test: Also known as the resisted wrist extension test, this is a provocative test to rule out lateral epicondylalgia, or tennis elbow. The examiner places one hand (and more specifically the thumb of one hand) over the painful area of the lateral epicondyle as reported by the patient, with the patient's elbow in 90 degrees of flexion and forearm in pronation. Then the examiner asks the patient to hold their wrist in radial extension with the hand in a full fist, and hold that position while the therapist is providing manual resistance on the dorsal radial aspect of the hand. If the patient experiences pain at the lateral epicondyle, then test is positive. Having the thumb on the tender spot on the lateral epicondyle can give the therapist more awareness of the specific treatment area to be addressed (Valdes & LaStayo, 2013).

Gripping Rotary Impaction (GRIT) test: Measures the amount of ulnar impaction present in the wrist. Perform a grip strength test in neutral, pronation, and supinated. The strength ratio of supination to pronation is calculated and compared to the contralateral side. A ratio of greater than one is indicative of ulnar impaction (LaStayo & Weiss, 2001).

Lateral Pivot Shift test: This test is performed by a physician and tests the integrity of the lateral ulnar collateral ligament (LUCL), checking for posterior elbow rotatory instability. The patient lies down with the affected arm over her head. The examiner provides forearm supination with valgus stress and axial load, while bringing the elbow from full extension to 40 degrees of flexion. With a positive test, the radial head will sublux through the first part of the motion, and will suddenly shift at about 40 degrees of elbow flexion due to the triceps force on reducing the radial head.

Maudsley's test: This is a provocative test to rule out lateral epidondylalgia, or tennis elbow. The examiner places one thumb over the painful area of the lateral epicondyle as reported by the patient. The patient's forearm is resting on the table, with fingers resting on the table in extension. The examiner resists extension of the third digit (middle finger), placing specific stress to the extensor digitorum. This test is positive if the patient reports pain over the lateral epicondyle. This rules out radial nerve compression or involvement of the extensor carpi radialis brevis (Saroja et al., 2014).

Milking Maneuver: The patient is placed in about 70 degrees of shoulder flexion, maximum external rotation, and supination. The patient can support their elbow with the other hand. Create a valgus stress by pulling on the patient's thumb with the forearm fully supinated and elbow flexed at 70 degrees. A positive test is a subjective apprehension, instability, or medial joint pain at the origin of the medial collateral ligament on the antero-inferior surface of the medial epicondyle.

Mills test: This is a provocative test to rule out lateral epicondylgia, or tennis elbow. The examiner places one hand (and more specifically the thumb of one hand) over the painful area of the lateral epicondyle as reported by the patient, with the patient's elbow in 90 degrees of flexion and forearm in neutral. The examiner's other hand is holding the patient at the wrist, with the wrist in a neutral position. The examiner then passively moves the patient into forearm pronation, wrist flexion, and then elbow extension to monitor for a pain response at the lateral epicondyle. If the patient feels pain at the lateral epicondyle, the test is positive. Having the thumb on the tender spot on the lateral epicondyle can give the therapist more awareness of the specific treatment area to be addressed.

Moving Valgus Stress test: Place the elbow in the same position as the milking maneuver (pulling on the patient's thumb with the forearm supinated and elbow flexed at 70 degrees). Apply a valgus stress while the elbow is passively ranged through full flexion and extension. The test is positive with subjective apprehension, instability, or medial joint pain at the MCL origin between 70-120 degrees of elbow flexion.

Posterior Drawer test: The patient lies supine with the arm overhead with the forearm in supination. The examiner will palpate the radial head with the index finger on the posterior surface and the thumb on the volar surface. The examiner will then provide a posterior force with the thumb on the radial head. If the radial head subluxes posteriorly, this is a positive posterior drawer test. This suggests disruption of the LUCL and posterior elbow rotatory instability.

Radial tunnel compression: The radial tunnel can be compressed in five different areas, but is most commonly compressed at the Arcade of Frohse, which is the proximal edge of the superficial layer of the supinator muscle. Common provocative testing for radial tunnel compression include resisted wrist extension (with pain located about 3-4 cm distal to the lateral epicondyle), and pain with resisted long finger extension. Electromyography (EMG) and nerve conduction velocity (NCV) studies tend to be normal in patients with radial tunnel compression, so are not helpful in identifying this condition (Dang & Rodner, 2009).

Radius Pull test: Also called the Radius Axial Interosseous Load (RAIL) test, this is an intra-operative test for Essex-Lopresti type injuries to identify proximal radio-ulnar joint instability. The surgeon will measure and provide 20 pounds of in-line traction to the radial neck while examining the wrist using a fluoroscope, monitoring for a change in ulnar variance. Ulnar variance with this test confirms the presence of instability between the radius and the ulna.

Rule of Nine test: This is a provocative test to rule out radial nerve compression. The anterior proximal forearm just below the elbow crease is divided into nine small circular sections about the size of a half dollar each. The circles are arranged in a 3x3 grid. The examiner palpates each area, checking for tenderness. The three medial circles are control circles and should be pain free. The proximal two circles of the lateral side of the grid will be painful with radial nerve irritation. Tenderness over the distal two circles of the middle row is indicative of medial nerve irritation (Moradi et al., 2015).

Valgus Stress test: This test is performed to test the integrity of the medial collateral ligament. Flex the elbow to 20-30 degrees to unlock the olecranon, externally rotate the humerus, and apply valgus stress (stress applied from the lateral elbow in a medial direction) to the elbow joint.

Elbow Anatomy

Bones of the Elbow

Three bones make up the anatomy of the elbow joint, making it a complex hinge joint. The distal end of the humerus articulates with the proximal ends of the radius and the ulna. The joint is actually made up of several different articulating surfaces, including the ulnohumeral joint, the proximal radioulnar joint (PRUJ), and the radiocapitellar joint. Each surface plays a different role in the balance between joint stability and mobility.

IMAGE 1

Humerus

The distal end of the humerus flares out into two bony processes – the trochlea on the medial side and the capitulum on the lateral side. The concave capitulum on the lateral side is covered in cartilage and articulates with the convex proximal end of the radius, also known as the radial head. This articulation is actually very loose, allowing the radius to articulate and move in relationship to the ulna as well. This will be discussed in more detail below. Immediately superior to the capitulum is the lateral epicondyle, which is the bony origin for the radial collateral ligament and for the common extensor tendon. The common extensor tendon is the origin to the extensor carpi radialis longus, extensor digitorum, extensor digiti minimi, and the extensor carpi ulnaris that act on the wrist and hand as primary extensors.

The trochlea makes up the medial portion of the elbow joint at the distal humerus, and it articulates with the trochlear notch of the ulna. It is located just medial to the capitulum and is also covered with cartilage. Just medial to the trochlea is the medial epicondyle, which is the bony origin for the ulnar collateral ligament, the pronator teres, and the flexor wad of muscles including the flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, and the palmaris longus. The ulnar nerve runs through a groove on the posterior aspect of the medial epicondyle and will be discussed below.

Due to the shape of the humerus, when the arm is in full extension, the long axis of the forearm (radius and ulna) is offset by roughly 11-16 degrees compared to the long axis of the humerus. In other words, the long axis of the forearm has a lateral inclination or valgus at the elbow of 11-16 degrees. This is often referred to as the “carrying angle” of the elbow, and does not change with elbow flexion. It can vary slightly from person to person, so it is best to compare to the uninvolved extremity when determining valgus position. Carrying angle does vary slightly between genders, with women averaging 1-2 degrees more lateral inclination than men, and varying by about 1 degree more on the dominant side than the non-dominant side (Moore & Dalley, 2006).

Amy's note: Valgus and varus are the terms that describe the position of the distal bones of a joint in comparison to the proximal bone. We use these terms for the elbows and the knees.

I think I remember about four things from college: one of them is how to recall which direction is valgus and which direction is varus. My professor taught us to remember that “valgus” is like “valgum”, and gum sticks everything together. So a valgus position in the arm means that the elbow joint is close to the person’s side, and the forearm is protruding out laterally. A valgus position for the knees would describe someone who is knock-kneed and varus describes someone who is bow-legged. (The other thing I remember is that the vending machine in the upstairs hallway of our allied health building would steal folding money. Always bring change!)

Radius

The radius is the lateral bone on the anatomical forearm. The cartilage covered, concave end of the radial head articulates with the capitulum of the humerus as noted above, allowing flexion and extension at the elbow. The sides of the radial head are covered in cartilage in an arc of about 240 degrees, allowing it to articulate with the ulna at the ulnar notch, which is the articulation that allows pronation and supination. The remaining arc of the radial head is free of cartilage, making it amenable to open reduction and internal fixation under the right circumstances. The radiocapitellar joint is actually a very loose articulation which is what allows both radioulnar pronation and supination while also functioning as part of elbow flexion and extension. The annular ligament of the radius arises from the margin of the trochlear notch of the ulna and encircles the radial head, keeping it in the radial notch of the ulna for stable articulation. This articulation is further supported by the radial collateral ligament that feeds into the annular ligament and the joint capsule of the entire elbow.

The radial head narrows significantly distal to the articulating surface into the radial neck. Just below this area, the radial protuberance is found on the medial aspect of the radius and is the insertion point for the biceps brachii. The biceps brachii acts to flex the elbow and is a supinator of the forearm as well. The radius also gives rise to a portion of the flexor digitorum superficialis and the flexor pollicis longus.

The radius is actually the shorter of the two forearm bones, but it fans out at the distal end and is the main articulating surface to the proximal carpal row in the wrist. The distal end articulates with the scaphoid and lunate. The radius also articulates with the ulna again at their distal ends, providing distal stability to the forearm. In pronation and supination, the radius actually rotates around the ulna.

The radius and the ulna are also attached between their two articulating surfaces by an interosseous membrane. The interosseous membrane separates the forearm into volar and dorsal compartments, and runs obliquely from the radius to the ulna in a downward, medial direction. The interosseous membrane becomes taut in the mid-prone position. It also becomes taut with an axial load to the forearm bones during weight bearing. It is crucial in transferring some of the load of weight bearing over the hand from the radius into the ulna. In normal wrist loading, the radius bears 80% of the load coming through the carpal bones. This helps to understand why the radius is most commonly the insulted bone with a fall, as it is taking most of the load. The radius also bears 80% of the load with active gripping, which may affect a patient’s functional tolerance after a change in radial length due to trauma.

Understanding the role of the radius in normal elbow function is crucial as we prepare to learn the importance of its role in hand function. Not only does the radius have three distinct articulating points that contribute to motion, it also is an anchor point for muscles that act on the elbow, wrist, and hand, and acts as the primary absorber of weightbearing stress. When discussing elbow injury and trauma, the health and proper position of the radial head specifically

is paramount in allowing strong and pain-free function at the wrist and hand. We will discuss how changes in radial length are detrimental to long-term function after elbow trauma.

Ulna

The third bone that makes up the elbow joint is the ulna. At the proximal end, the olecranon is the end of the ulna which articulates with the posterior humerus in the olecranon fossa and forms the “point” or “tip” of the elbow. The olecranon is the largest part of what is considered the posterior elbow joint and prevents the elbow from extending past neutral in most people. The proximal end of the ulna is called the trochlear notch, as it is concave (anterior to posterior) and seats itself in the trochlea of the humerus. The distal lip of the trochlear notch protrudes anteriorly to form the coronoid process, which fits into the coronoid fossa on the anterior part of the humerus. On the lateral edge of the coronoid process of the ulna, there is the small radial notch that forms the proximal radioulnar joint with the radius, allowing the radius to rotate in the notch for pronation and supination. A long ridge on the anterior side of the coronoid process known as the ulnar tuberosity extends down the shaft of the ulna as a muscle attachment point for a portion of the brachialis muscle. Other muscles that arise from the ulna are a portion of the flexor digitorum superficialis, a portion of the flexor digitorum profundus, the anconeus, and the pronator teres.

As the ulna extends down toward this wrist, it gives rise to other muscles of the hand (extensor pollicis longus and indicis proprius) and receives the fibers of the interosseous membrane. The distal ulna does not actually articulate with the carpal bones of the proximal row, but is protected from the weight of the carpal impact by the triangular fibrocartilage complex (TFCC). With movement, the radius rotates longitudinally around the head of the ulna at the radial notch, allowing for pronation and supination of the forearm. The head of the ulna covers 80% of the surface of the distal radioulnar joint and articulates with the sigmoid notch of the distal radius and with the inferior surface of the TFCC. The ulna bears only 20% of a weight bearing load, and that load is transferred through the TFCC and the interosseous membrane. The ulna slightly translates distally during pronation against the radius, which can cause pain and difficulty after injury.

Soft Tissue Structures of the Elbow

Joint Capsule and Bursae

The elbow joint is a synovial joint whose sides are thickened by the fibers of the radial or lateral collateral ligament and the ulnar collateral ligament. The front portion of the joint capsule is thickened by fibers from the brachialis muscle. All three articulations of the joint share a common synovial membrane, so the radioulnar joint that provides pronation and supination directly shares the lubrication of the joint surfaces that provide elbow flexion and extension. Therefore, if joint fluid is lacking, it will affect all joints of the elbow equally. All articulating surfaces of the three bones of the elbow joint are covered in hyaline cartilage for smooth articulation.

Within the joint capsule there are as many as seven different bursae, but there are three main bursa sacs found in most people that help cushion the joint and reduce friction during movement. The three main bursae are the intratendinous bursa, which is within the tendon of the triceps brachii, the subtendinous bursa, which is between the olecranon and the triceps brachii tendon, and the subcutaneous bursa, which is between the olecranon and the overlying connective tissue. Smaller bursae are typically present as well, surrounding most of the tendons that cross over the elbow.

Muscles

Just outside the joint capsule, several muscle groups cross over the elbow joint, providing dynamic stabilization. The anconeus, brachialis, brachioradialis, supinator, triceps brachii, and biceps brachii muscles all originate proximal to the joint and insert distal to the joint, providing compressive stability to the elbow. The common extensor tendon and common flexor tendon on the lateral and medial epicondyles respectively also cross over from the distal humerus to locations in the forearm, wrist and hand.

IMAGE 2

Anconeus

The anconeus muscle is a small, under-appreciated muscle on the posterior elbow that is actually a joint stabilizer for the elbow, keeping the posterior capsule of the joint from being pinched in full extension. It originates on the posterior aspect of the lateral epicondyle and the fascia of the triceps and inserts on the lateral posterior surface of the proximal ulna, supporting the annular ligament. It can play an important role in reconstructing the lateral elbow in the event of trauma. It is innervated by a branch from the radial nerve and can be palpated just lateral to the olecranon process of the ulna.

Biceps brachii

The biceps brachii sits just superior to the brachialis muscle. It originates in two separate heads. The long head of the biceps originates on the supraglenoid tubercle of the scapula and the short head originates on the coracoid tubercle of the scapula. As the biceps travels distally down the anterior humerus, it runs over the median nerve and brachial artery, the brachialis, and the anterior elbow joint, and inserts onto the radial tuberosity of the radius. At the level of the elbow joint, the biceps has converged into a large tendon to insert into the bone. The biceps brachii has a relatively poor mechanical advantage as it travels close to the axis of rotation of the elbow joint as well, but is a major flexor of the elbow. It is also a strong supinator of the forearm when the forearm is in full pronation. The biceps also has several bursae running its entire length to protect it and the structures around it from friction during movement. Because the biceps brachii inserts close to the center of rotation of the elbow resulting in short and inefficient lever arms around the elbow, there are large joint reaction forces which can contribute to degenerative changes at the elbow.

Brachialis

The brachialis muscle has the most “square footage” when crossing over the elbow joint, but it has a poor mechanical advantage in elbow flexion due to being so close to the axis of rotation. The origin of the brachialis is the entire anterior distal half of the humerus; it crosses just anterior to the joint capsule (the deepest elbow flexor), and inserts into the coronoid process. Some of its fibers attach to the joint capsule itself, and assist in retracting the anterior joint capsule during elbow flexion. The brachialis is innervated by the musculocutaneous nerve. Due to the proximity of this muscle to the actual joint itself, the brachialis is most at risk for injury in cases of elbow dislocation. The radial nerve runs deep to the brachialis, while both the median nerve and brachial artery run superficial to the brachialis, between it and the biceps brachii.

Brachioradialis

The brachioradialis originates on the lateral supracondylar ridge of the distal humerus, travels across the elbow joint into the forearm, and inserts distally into the radial styloid process of the distal radius. It has the most mechanical advantage of any of the elbow flexors. The brachioradialis is innervated by the radial nerve.

Supinator

The supinator muscle has several points of origin above and below the elbow joint itself. It originates on the lateral aspect of the lateral epicondyle of the humerus, the lateral collateral ligament, and the anterior crest of the ulna. It runs obliquely, distally, and radially and wraps around the proximal and middle shaft of the radius. It is innervated by the radial nerve. The radial nerve actually pierces through the supinator from the anterior compartment into the posterior compartment of the forearm. This area is a common location of irritation for the radial nerve and is located approximately 3-4 centimeters distal to the lateral epicondyle. The supinator acts to supinate the forearm along with the biceps brachii. The supinator is actually a weaker supinator than the biceps, but it is equally as effective in supinating regardless of elbow position, unlike the function of the biceps.

Triceps brachii

The triceps brachii is the major extensor of the elbow and is situated on the posterior aspect of the humerus. The three heads of the triceps are the long head, the lateral head, and the medial head. The long head originates from the infraglenoid tuberosity of the scapula, the lateral head originates off the proximal intramuscular septum located on the posterior proximal humerus, and the medial head originates off the posterior distal half of the humerus. The three heads converge into a large muscle belly and then taper into its insertion on the tip of the olecranon of the ulna. There is a large bursa that runs under the triceps insertion, keeping it from creating friction on the olecranon. All three heads of the triceps are innervated by the radial nerve.

Name	Origin	Insertion	Innervation	Action	Nearby Structures
Anconeus	Posterior lateral epicondyle	Dorsal aspect of the ulna	Radial n.	Supports elbow joint in extension	Annular ligament Joint capsule
Biceps Brachii	Supraglenoid and coracoid process of scapula	Radial tuberosity of the radius	Median n.	Strong elbow flexor Supinator	Median n. Brachial a. Brachialis
Brachialis	Anterior distal half of humerus	Coronoid Process	Musculo-cutaneous n.	Weak elbow flexor	Radial n. Median n. Joint capsule
Brachio-radialis	Distal humerus	Distal radius (radial styloid)	Radial n.	Strong elbow flexor	Radial n.
Supinator	Lateral epicondyle	Proximal and middle radius	Radial n.	Supinates the forearm	Radial n. Lateral epicondyle
Triceps Brachii	Scapula and proximal humerus	Olecranon	Radial n.	Extends elbow	Radial n. Anconeus m.

Ligaments of the Elbow

Ulnar Collateral Ligament (Medial Collateral Ligament)

The ulnar collateral ligament (UCL), also known as the medial collateral ligament (MCL), arises from the medial epicondyle of the humerus. The UCL is divided into three components. The first portion, the anterior oblique ligament, is the strongest and most significant stabilizer to valgus and distractive stress. It inserts onto the medial surface of the coronoid process of the ulna. Its anterior and posterior bands give reciprocal function through elbow flexion and extension: that is to say, the anterior band is tight with elbow extension, and the posterior band is tight with elbow flexion. The second portion of the UCL is the posterior oblique ligament. It actually forms from the floor of the cubital tunnel and inserts onto the medial coronoid process of the ulna. This portion of the ligament is most taut in flexion, and the most slack in flexion. If it becomes contracted, flexion may be limited. The third portion of the UCL is the transverse ligament, which does not actually contribute to stability.

IMAGE 3

Lateral Collateral Ligament Complex

The lateral collateral ligament complex (LCL) consists of three components as well. The radial collateral ligament (RCL) attaches the anterior portion of the lateral epicondyle to the annular ligament (another portion of the complex) and the fascia of the supinator muscle of the forearm. The annular ligament forms a sling around the radial head of the radius, and spans from the sigmoid notch to the supinator crest of the ulna. The lateral ulnar collateral ligament (LUCL) spans from the lateral epicondyle to the supinator crest of the ulna. The primary function of the lateral collateral ligament complex as a whole is to provide stability during varus stress to restrain against posterolateral rotatory instability (PLRI) of the elbow and to maintain the continuity of the proximal radioulnar joint during pronation and supination. Along with the bony articulation of the radial head in the radial notch of the ulnar and the radiocapitellar joint, the LUCL portion of the LCL is most responsible for preventing PLRI of the elbow and provides stabilization to varus stress and external rotation stress.

IMAGE 4

The primary static stabilizers of the elbow are the ulnohumeral joint, and the medial and lateral collateral ligaments. Secondary stabilizers of the elbow include the radiocapitellar joint, and the joint capsule itself. The radiocapitellar joint provides approximately 30% of the valgus stability, and is most important when the elbow is in 0-30 degrees of flexion/pronation. The capsule is in a closed chained position in full elbow extension, providing secondary stability in that position. These are important things to understand when discussing the position a patient was in when he fell, what structures were damaged, and how that will impact stability, mobility, and function of the joint moving forward.

Nerves of the Elbow

All three major peripheral nerves of the forearm and hand have bifurcated before reaching the elbow joint. We will briefly discuss the paths each of these nerves takes as it relates to the anatomy of the elbow, so that when we discuss injury, the vulnerability of nerve damage is evident. Without function of the radial, median, and ulnar nerves, hand function will suffer.

IMAGE 5

Radial Nerve

The radial nerve originates from the posterior cord of the brachial plexus from the ventral roots of C5, C6, C7, C8, and T1. In the arm, it runs through the radial groove of the back of the humerus and then travels to the lateral side of the arm at 5 cm below the deltoid tuberosity (where the deltoid inserts into the lateral humerus), where it provides motor innervation to the triceps brachii and anconeus which are responsible for extending the elbow (and straightening the arm).

The radial nerve then pierces the lateral intermuscular septum to reach the anterior compartment of the arm, providing motor innervation to the brachialis and the brachioradialis – both elbow flexors and secondary pronator/supinators. At the elbow joint, it travels down to cross the lateral epicondyle of the humerus, and then separates into a superficial and a deep branch which continues into the cubital fossa and then into the forearm.

The superficial branch of the radial nerve (SBRN) provides sensation to the dorsal aspect of hand, dorsal aspect of thumb, index finger, middle finger and lateral side of ring finger except the nail beds (which are supplied by the median nerve).

The posterior branch of the radial nerve is also called the posterior interosseous nerve (PIN), as it pierces through the supinator muscle four centimeters distal to the radial head. The PIN innervates the extensor carpi radialis brevis, the extensor digitorum (including the digiti minimi and indicis proprius), the supinator, the abductor pollicis longus, the extensor pollicis longus and brevis, and the extensor carpi ulnaris. The radial nerve can suffer damage with lateral elbow trauma, severe posterolateral instability, and with subsequent repair such as a radial head replacement if not protected.

Injury to the radial nerve will result in sensory changes to the dorsal forearm, wrist, hand, and fingers, and weakness or loss of extension at the elbow, wrist, and fingers depending on the location of the injury. The tell-tale sign of radial nerve motor loss is wrist drop. The nerve can be palpated just below the deltoid tuberosity (to check for irritation compared to the other arm), just superior to the lateral epicondyle, and at the radial snuff box – the sulcus on the radial aspect of the wrist at the intersection of the base of the first and second metacarpals. Palpation in these areas does not lead to any specific diagnosis or condition, but can be noted by the therapist as a risk factor for radial nerve irritation, adhesions, or involvement of some sort.

Ulnar Nerve

The ulnar nerve arises from the medial cord of the brachial plexus, originating at C8 and T1 of the spinal cord. The ulnar nerve does not innervate anything in the upper arm, but travels down the medial aspect of the humerus and through the ulnar groove of the medial epicondyle of the humerus. A small branch supplies the elbow joint itself, but the primary job of the ulnar nerve is in the forearm, wrist, and fingers. After the ulnar nerve passes the elbow joint, it pierces through the two heads of the flexor carpi ulnaris in the anterior compartment of the forearm on the ulnar side and branches into three smaller branches. The muscular branch gives motor innervation to the flexor carpi ulnaris and the flexor digitorum profundus of the ring and small fingers. The other two branches are sensory branches that innervate the skin of the ulnar half of the volar hand, the small finger (volar and dorsal surfaces) and the ulnar aspect of the ring finger (volar and dorsal surfaces). As the nerve enters into the wrist through Guyon's canal, it branches into smaller branches, innervating the intrinsic muscles of the hand: the adductor pollicis, the hypothenar muscles including the abductor digiti minimi and opponens digiti minimi, the ulnar two lumbricals, the palmaris brevis, and the volar and dorsal interossei of the hand.

Ulnar nerve injury can be a result of damage to the medial aspect of the elbow, or can be due to the complications of soft tissue injury or chronic swelling to this area. The nerve can also become adhered to surrounding tissue, specifically in areas where it pierces through other soft tissue. Complaints of numbness, tingling, or nerve irritation can almost always be traced back to soft tissue adhesions along the course of the nerve. We will discuss how to assess for this as it relates to elbow trauma in the "Considerations for Elbow Treatment" section.

The ulnar nerve can be palpated in the ulnar groove at the medial epicondyle, commonly known as the "funny bone." Most people are slightly uncomfortable with palpation to this area as the ulnar nerve is relatively exposed. Make sure to compare the patient's complaints from side to side to determine if the ulnar nerve is more sensitive on the affected side. Cardinal signs of motor loss of the ulnar nerve are a "claw hand" – hyperextension of the MP joints of the ring and small fingers with a flexed posture of the same digits, wasting of the hypothenar eminence, a positive Wartenburg's sign – chronic abduction of the small finger with the inability to adduct, and weak pinch strength due to poor adductor strength of the thumb.

Median Nerve

The median nerve originates from the medial and lateral cords of the brachial plexus originating at C6, C7, C8, and T1. It does not innervate any muscles in the upper arm, but travels distally and medially towards the elbow, crossing the elbow at the cubital fossa, and then enters the anterior compartment of the forearm. It gives off two major branches in the forearm: the anterior interosseous nerve and the palmar cutaneous nerve. The palmar cutaneous nerve gives sensation to the volar radial aspect of the hand, specifically the volar aspect of the thumb, index, middle, and half the ring finger and the dorsal tips to those corresponding fingers. The anterior interosseous nerve is a motor nerve that innervates the pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis, flexor pollicis longus, pronator quadratus, and the lateral half of the flexor digitorum profundus.

The cardinal sign of median nerve damage is an "ape hand," or noted thenar atrophy. Other common complaints are numbness and tingling to the radial aspect of the hand, pain at night, and a positive Phalen's maneuver (prolonged wrist flexion causes numbness). These signs can be indicative of carpal tunnel syndrome which is located at the base of the hand, but proximal median nerve health should be considered if the patient has sustained an elbow injury.

Amy's note: If you are having trouble picturing the anatomy of the elbow joint or explaining it to a patient, check out <https://www.innerbody.com/image/skel14.html>. You can roll over each structure of the elbow, and when you click on it, it zooms in on the structure and gives you basic information about it. I think this is much easier than trying to picture these structures in your mind or even viewing them on paper. Another great resource is YouTube videos that animate the structures for you. I find these extremely helpful in educating patients to their injuries.

Kinematics of the Elbow

Extensive studies have been completed over the years on the intricacies of elbow kinematics. It is important to understand the bony stability of the elbow joint in various positions, as elbow flexion and extension, and pronation and supination, can be combined in a multitude of ways during functional use. To be clearer, a person does not simply flex and supinate, or extend and pronate. He does a combination of all of these movements in a fluid and coordinated manner. If the bony stability of the elbow joint is in question, this can lead soft tissue damage, joint damage, and joint pain. In order to problem solve, we need a good understanding of exactly how the joint functions with each particular motion.

At the ulnohumeral joint, the axis of rotation is found at the center of the trochlea of the humerus. The trochlea remains stable as the trochlear notch of the ulna moves anterior to posterior for elbow flexion and extension. There is no deviation to the medial or lateral side, and the trochlear notch maintains constant contact with the humerus throughout the range of motion. The close-packed position (or position of greatest joint tightness) of the ulnohumeral joint is full extension. The loose-packed position is 70-90 degrees of elbow flexion combined with 10 degrees of supination of the forearm.

With regards to the radiocapitellar joint, the concave radial head maintains full contact with the capitulum as well during flexion and extension. The close-packed position of the radiocapitellar joint is 90 degrees of elbow flexion combined with 50 degrees of supination. The loose-packed position for this part of the joint is full elbow extension combined with full supination. The radius and the ulna move together around the trochlea and capitulum of the humerus respectively for pure elbow flexion and extension. The arc of this motion is described as 0 degrees for full extension, and 140 degrees for end range flexion. Functionally, a person needs 30-130 degrees of motion in the flexion/extension arc to perform most personal hygiene and sedentary tasks (Morrey, 2006).

For pure pronation and supination, the axis of motion is found at the humeral capitulum, as the radial head pivots in place on the capitulum. With regards to the proximal radioulnar joint (PRUJ), the head of the radius slides and rolls within the radial notch of the ulna during pronation and supination. The close packed position for the PRUJ is 5 degrees of supination, and the loose packed position is 70 degrees of elbow flexion and 35 degrees of supination.

Joint congruity refers to the position where the two bones making up the joint have the most contact, thereby offering the most stability. The radial head actually migrates proximally into the capitulum in full pronation, making this the most congruent position for the radiocapitellar joint. The proximal radioulnar joint is most congruent in full supination. The ulnohumeral joint congruity is not affected by forearm rotation. Joint congruity refers to the articulation itself, while the close packed position refers to the joint capsule fiber tightness (Omori et al., 2016).

Elbow position and motion also affect the kinematics of the distal radioulnar joint. The kinematics of the distal radioulnar joint are primarily affected by forearm rotation and secondarily by elbow flexion. As the forearm goes into pronation, the radius typically migrates proximally. This is normal joint kinematics and can vary widely. In cases of elbow trauma, this migration may increase or decrease depending on the injury. Due to the radius' attachment to the ulna through the interosseous membrane and forearm muscles, changes in migration patterns can increase the weight bearing stress over the distal ulna, which can lead to the wrist complex being at risk for impaction, joint derangement, and increased pain (Fu & Li, 2009).

Elbow Fractures

Most elbow fractures occur due to a high velocity fall on an elbow or a direct blow to the elbow such as a car crash or getting hit with a baseball or a baseball bat. The most common elbow fracture is to the olecranon, and occurs from falling directly on an elbow bent to more than ninety degrees.

In this section, we will be reviewing the physician classification systems for fractures in order to understand the plan of care ordered by our referring physicians. We will discuss non-operative

care vs. surgical care involved, generalized healing time for fractures, and finally we will review the specific fractures that can occur at the elbow and how they are treated differently by the therapist. We will also discuss what structures are closest to each fracture so that we can anticipate and circumvent the soft tissue complications that arise with fracture healing and immobilization.

Classifications

There are several classification systems for understanding the severity of fractures that allow physicians to determine how they will treat a fracture. Some of the more commonly used systems are the Mayo Classification, the Colton Classification, the Schatzker Classification, the Horne and Tanzer Classification of olecranon fractures, and the AO Classification. All fractures fall somewhere on the spectrum between simple fracture dislocation to comminuted and displaced, intra-articular to extra-articular.

Physicians have protocols that correspond to each of these levels of classification and they use these tables to determine the best course of action to take for a fracture based on the current base of evidence. As the therapist, we don't typically need to have these classifications memorized, but they are helpful to understand and recognize, especially when communicating with the physician. An overview of four of these systems can be seen on the tables below (an overview of the Horne and Tanzer Classification of olecranon fractures appears in conjunction with the discussion of these specific fractures, later in the course).

Mayo Classification

Type I	Non-displaced fx
Type II	Displaced stable A - Non-comminuted B - Comminuted
Type III	Unstable A - Non-comminuted B - Comminuted

Colton Classification

Non-displaced (or less than 2 mm displacement)	Displacement does not increase with elbow flexion Elbow extensor mechanism remains intact
Displaced	A - Avulsion fx B - Oblique or transverse fx C - Comminuted D - Fracture Dislocations

Schatzker Classification

Type A	Simple transverse fx
Type B	Transverse impacted fx

Type C	Oblique fx
Type D	Comminuted fx
Type E	More distal fx, extra-articular
Type F	Fracture-dislocation

AO Classification

Type A	Extra-articular
Type B	Intra-articular, unicondylar fx
Type C	Intra-articular, bicondylar Subgroups: Simple T or Y fx Extra-articular comminution Intra-articular comminution

Non-Operative Treatment vs. Surgical Treatment

In general, casting is the treatment of choice for fractures that are non-displaced. This is also the treatment of choice in low demand elderly individuals: they tend to tolerate casting better than more aggressive forms of treatment and they tend to have lower expectations for outcome. With casting (or any type of prolonged immobilization), the fracture site will go through several phases of healing before it is stable enough to withstand active motion and eventually strengthening.

The first seven days after the fracture, the site enters the inflammatory, or reaction, phase of healing where the body forms a hematoma to provide early fracture stabilization and extra blood supply. When the fracture takes place, several small blood vessels will tear, leaking small amounts of blood which will then clot to form the hematoma. Part of that inflammatory stage is the influx of cytokines, prostaglandins, and growth fractures which are the basis of healing, but do promote inflammation of the tissue. As this organizes itself over the first few days after injury, it creates a primary callus.

The next phase is the repair phase, where the damaged cells are removed from the site and replaced with callus bone. This begins around the end of the first week and can continue for several weeks to months following the injury. The primary callus that was formed in the inflammatory stage begins to harden into harder callus, and this is when we see the bone becoming relatively stable again. You will hear physicians describe this hardening as the "clinical union" of the bone, meaning that it is healing into one piece (as seen on x-ray), but is not necessarily strong enough to withstand stress. The body continues to provide extra vascularization during this time in order to repair the bony matrix as well as remove the damaged debris from the accident. The repair phase can last between 6 weeks and 4 months depending on the site of injury, but, as a very general rule, most non-displaced fractures are healed within 6-8 weeks.

The callus continues to harden throughout this time, and eventually the body begins the remodeling phase in order to return the bone to its original strength. Beginning at the end of the

reparation phase as described above, the body will spend time remodeling the union over the next several months to several years, remodeling the tissue surrounding the callus to mimic its original structure. This means that the excess callus will eventually be removed and the bony union will smooth out its surface. In an ideal scenario, the bone is as strong as it was prior to the injury and can withstand external forces as well as before the fracture. Unfortunately, the rate of remodeling is inversely proportional to age. So, the older a patient is, the slower this rate of remodeling occurs, leaving more room for soft tissue complications to occur as the bone heals.

It is also relevant to note that fractures to the end of long bones heal more quickly than fractures at mid shaft. Furthermore, each long bone actually heals quicker at one end than the other. Unfortunately, the proximal humerus heals more quickly than the distal humerus, and the distal radius and ulna heal more quickly than the proximal end of either of those bones. This means that in the arm, the elbow heals much slower than either the wrist or the shoulder.

Surgical Treatment

Surgical intervention is required for fractures that are displaced, or when several fragments of the bone have occurred. Fixation can potentially speed up the course of treatment as it provides the support that the body creates using callus formation, essentially bypassing the need for this system. If the surgeon is able to realign the fragments with adequate compression and stability, and the fragments have good blood supply, the body will avoid the callus formation stage and move into the final stages of healing. This helps reduce edema and allows for earlier initiation of motion, which helps avoid other soft tissue complications from prolonged immobilization and gets the patient back to functional activities sooner. This is an excellent option for patients who tolerate surgery well (i.e. younger patients in good health), and can drastically reduce the healing time following injury. Surgical options are divided into closed reduction with external fixation and open reduction with internal fixation.

Closed Reduction with Internal Fixation

Closed reduction with internal fixation is the term used when a physician is able to reduce the fracture without surgical intervention. Sometimes the patient must be anesthetized in order for the doctor to regain alignment, but no opening of the skin is needed. The surgeon will anesthetize the patient, provide traction to realign the fracture, and then cast the patient to maintain the proper alignment.

Closed Reduction with External Fixation

Closed reduction of a fracture involves anesthetizing the patient and placing external pins or fixators through the skin and into the bone in order to provide a stable position for an unstable fracture during the healing process. Surgeons have been using this method for over 100 years to stabilize bony fragments. Percutaneous pins, also known as Kirschner wires or K-wires, are sharp stainless steel pieces of wire that are pierced through the skin and then through the bony fragment, and into the stable part of the bone. After the pin is drilled into the fracture site, a portion of it is left on the outside of the arm and is cut down to size. The outer portion of the pin is then either bent to lay flush against the skin or is covered with a plastic ball to prevent it from being caught on clothing. Pins can be used as a stand-alone treatment or in conjunction with casting. They can cross a joint or can be placed outside of the joint. Typically, pins are placed for 4-6 weeks to allow full healing of the bony fragments. Active range of motion begins after the cast is removed and therapy is progressed as per physician protocol after that. If you have concerns on whether or not a patient should be moving with their pins in place, contact the operating physician for clarification.

IMAGE 6

Some of the complications that can occur with percutaneous pinning are infection (due to the pin piercing the skin, allowing for bacteria to enter the body), failure of the pin to hold the bony fragment in place, and failure of the pin to stay in place, essentially backing itself out of the body. Patients must be educated on pin care and monitoring in order for this treatment to be successful.

Amy's note: Just to wake you up at this point, I will share a story of a patient who did not properly understand the concept of his percutaneous pinning. I take full responsibility for not educating him much more extensively on the purpose of his pins (but would also like to mention that he was a horrible listener and most likely wouldn't have paid attention anyhow).

Many years ago I was treating a patient with a fracture of his right lateral epicondyle from a direct blow of a large metal object at work. He was not in a lot of pain, but had heavy job duties that he was hoping to return to, and had two K-wires pinning his lateral epicondyle. They did not go through the joint, so this patient was allowed to move his elbow freely per the MD protocol. During his third treatment, I was working on edema control and ROM of his uninvolved joints. I then told him to stand against the wall and perform his AROM at the elbow per his home program that we had discussed the week before.

Without a blink of an eye, my patient proceeded to pull his two pins out of his lateral epicondyle and place them on the treatment table and then walked over to the wall! After I recovered my jaw from the floor, I asked him what in the world he was doing. He said that his pins kept "clanking" around during his exercises and it was irritating, so he would just take them out while doing his program (three times per day) and then "shove" them back in when he was done. He had been doing this for four days at home and at work! He even told me that the short one went in the top hole and the long one went in the bottom hole! That is the day I almost died of shock. I sat him down, wrapped his elbow in sterile gauze, and called his surgeon immediately. Two hours later he had four steristrips and a fiberglass cast on his right elbow.

Takeaway: 1) Pins should not move around and are not supposed to be removed by the patient (or the therapist for that matter) under any circumstances. 2) This patient was very fortunate not to get an infection. 3) You cannot over-educate a patient. 4) If you are honest with the doctor, he will usually take your side. 5) All patients are clinically insane and cannot be trusted. 6) Number five is a generalization but is true in almost every scenario.

Back to work....

Spanning external fixators are sometimes used in conjunction with percutaneous pinning, depending on the severity of the injury. They can provide traction to a fracture site that has been crushed and can help keep soft tissue elongated during the immobilization phase. They are also used when traction across the joint cannot be maintained. Bone graft and bone graft substitutes can be used to augment treatment times with percutaneous pinning. External fixation is the treatment option of choice when the fracture is comminuted and the surgeon cannot place an internal plate in the associated fragments.

Open Reduction with Internal Fixation (ORIF)

Open reduction with internal fixation (ORIF) is considered the treatment of choice when more conservative treatments such as casting fail, the fracture is unstable, or closed reduction is insufficient. This involves exposing the bone surgically and placing a stainless steel or titanium plate or screws against the fractured bone to recreate alignment. Kirschner wires can be placed

permanently as well, and intermedullary rods can be used in the cavity of the long bones to provide stabilization. Some of the more common complications from undergoing an ORIF are development of infection or blood clots. Most of the time, the internal fixators are meant to stay in place and the body will heal around them. Occasionally, a patient might have sensitivity to the foreign object and the fixation will need to be removed. Some patients develop callus under the fixation, forcing it towards the surface of the skin. If the fixation becomes bothersome, removing it will require another surgery.

IMAGE 7

Generalized Healing Time for Fractures as Related to Rehabilitation

In general, most fractures heal within about 8-12 weeks (Einhorn & Gerstenfeld, 2015). Ideally, all patients would be seen within a week of immobilization so that therapists can orient them to edema control techniques and ADL adaptation ideas for living one-handed for several weeks (this is definitely a good marketing tool for any therapists looking to educate their doctors on the importance of treatment). However, most patients are not referred to therapy until fracture healing is certain; occasionally physicians will refer patients for therapy to address swelling in the elbow or hand prior to removal of immobilization. In the event that the patient had no initial complications during the immobilization phase, patients usually get referred for therapy the day their immobilization is removed, and usually are seen for an initial evaluation within 1-2 days of cast (or pin) removal.

Depending on the physician's prescription, patients who had external fixation or casting usually begin active range of motion (AROM) around 3 weeks after immobilization is removed; if the patient had internal fixation, AROM can begin around 1 week after surgery. Progress to passive range of motion (PROM) of the surrounding joints begins 2-3 weeks following AROM exercises as needed to resolve stiffness. (Of particular note, and worthy of emphasis to your patients, is the fact that most physicians recommend no driving for the first 6 weeks following immobilization.) Isometric strengthening begins around 3 weeks after immobilization is removed. Strengthening is typically started around week 8-10. Any variances from this generalized outline will be discussed in detail as we consider specific fractures to the elbow below.

Fractures to the Elbow

Capitulum Fracture

A capitulum fracture of the distal humerus accounts for only about 6% of all distal humerus fractures. The mechanism of injury is a low energy fall on an outstretched hand (typically from a standing position) with a direct, axial load causing compression of the elbow at the radiocapitellar joint with the elbow in a semi-flexed position, causing a shear force and fracturing the distal humerus. Capitellar fractures are often seen in conjunction with radial head injuries and lateral ulnar collateral ligamentous disruption in more than half the cases. Symptoms include elbow pain, obvious deformity, swelling, wrist pain, ecchymosis, and diffuse tenderness on the lateral aspect of the elbow.

IMAGE 8

Due to the importance of radiocapitellar joint integrity with relation to the lateral ulnar collateral ligament, stability at the lateral elbow – which is paramount for full functional use of the elbow – is a consideration if the joint is not stabilized. Luckily, the prognosis of regaining functional use after a fracture of the capitellum is fairly good after surgical repair. Most patients regain

functional range of motion and functional strength. Post-operative stiffness is the most common complication, resulting in further surgical needs such as a manipulation under anesthesia to regain motion in many cases.

Non-operative treatment of a capitulum fracture includes immobilization for about three weeks. These patients are only seen in therapy if they are unable to regain full ROM independently. The most common complication is stiffness or elbow contracture. Indications for therapy would be presence of complications such as flexion contracture, ulnar nerve injury or residual instability. Therapists should also be prepared to educate the patient to activity modification and joint protection in the event of post-traumatic arthritis or chronic instability.

Operative cases typically undergo an ORIF of the capitellum, arthroscopic-assisted ORIF, or fragment excision. Therapy timelines should be reviewed with the physician but will include AROM, PROM, careful strengthening of the elbow, wrist, and hand, prevention of contractures, nerve gliding exercises, sensory reeducation as needed, and education to joint protection, energy conservation, and work simplification techniques as needed. In the case of developing contracture, static progressive splinting can be initiated as early as week 6 with physician approval. Static progressive splinting will be discussed below, but can be accomplished with custom fabrication by the therapist or by contacting a vendor to provide a commercial static progressive orthosis (Andrews et al., 2012).

Coronoid Fractures

As a reminder, the coronoid process is the anterior portion of the greater sigmoid notch of the proximal ulna, which articulates with the coronoid fossa of the anterior humerus during elbow flexion. Approximately 10-15% of elbow injuries involve a coronoid fracture and are most commonly associated with elbow dislocations. This typically occurs due to a severe varus stress or a posterior subluxation, with the tip of the coronoid shearing over the distal humerus. Depending on the position of the elbow at the time of injury, the coronoid can break anywhere from the very tip to its base on the shaft of the ulna. The larger the area fractured, the more severe the injury.

IMAGE 9

The coronoid is important for varus stability. The ulnar collateral ligament inserts onto the coronoid near its base. The coronoid also functions as an anterior buttress of the greater sigmoid notch of the olecranon. Therefore, fractures lower on the coronoid affect UCL integrity as well as medial elbow stability. Repair of these fractures is necessary to prevent recurrent posterior subluxation or dislocation of the elbow. Chronic posterior subluxation and dislocation of the elbow due to a coronoid fracture is known as posterolateral rotatory instability (PLRI), which will be discussed below as part of the "Elbow Instability and Throwing Injuries" section.

Coronoid fractures are also part of a more serious injury called a terrible triad of the elbow, where the coronoid fracture is seen in conjunction with a radial head/neck fracture and an elbow dislocation. This will also be discussed separately below, as the rehabilitation timeline is slightly different due to the severity of the injury.

Due to the coronoid process' important role in elbow stability, complications are common. The most typical complications are elbow stiffness, post traumatic arthritis, heterotopic ossification, and failure of surgical implants to provide bony alignment and stability. Non-operative treatment includes brief immobilization followed by early range of motion approved by the physician. An operative approach using open reduction with internal fixation is commonly indicated in large

coronoid fractures (meaning the coronoid fracture is closer to the base of the coronoid where the ulnar collateral ligament inserts) and when persistent elbow instability is seen or anticipated.

Open reduction and internal fixation (ORIF) options used for coronoid fractures vary widely. The surgeon will fixate with either Kirschner wire fixation, pins, screws, or a buttress plate and repair the ligaments as needed. Depending on the procedure, patients are typically placed in a thermoplastic resting elbow orthosis with the elbow resting at 90 degrees and the forearm in neutral for 2-4 weeks per physician protocol. The patient is typically allowed to remove the splint only during therapy, but therapist should restrict terminal elbow extension to 30 degrees for the first 4 weeks. Shoulder abduction is also restricted for 4-6 weeks to reduce varus strain on the elbow. Early active motion of the elbow MUST be approved by the operating physician. Some physicians may allow dynamic muscle contraction to prevent ulnohumeral joint gapping, but again, this must be discussed with the operating physician and is not at the discretion of the therapist.

To review, the post-operative timeline is as follows:

Rehabilitation after Coronoid Fractures (with MD approval)

Weeks 1-4

- Static splinting at 90 degrees of elbow flexion, neutral forearm
- Restrict terminal elbow extension to 30 degrees

Weeks 1-6

- Restrict shoulder abduction to reduce varus strain

Early active motion and isometrics are at the discretion of the surgeon. DO NOT ATTEMPT until release is given by surgeon.

Manual soft tissue mobilization, edema control methods, AROM, and PROM can be employed to reduce occurrence of adhesions of the tissues surrounding the injury. Physical agent modalities to reduce pain and swelling are typically approved by the surgeon and accepted well by patients. Again, static progressive splinting can be beneficial in reducing flexion contracture development as needed. Dynamic splinting has not been shown to be as effective in reducing flexion contracture, as they tend to provoke muscle guarding in some patients. However, other patients tolerate dynamic splinting very well. Splinting with either option has been shown to be effective in reducing elbow flexion contractures, so the type of splinting used is really patient dependent and at the discretion of the therapist and operating surgeon (Lindenholvius et al., 2012).

Olecranon Fractures

The olecranon forms the posterior portion of the greater sigmoid notch of the ulna along with the coronoid process anteriorly which articulates with the trochlea of the humerus. The olecranon moves around the trochlea during elbow flexion and extension and prevents elbow extension beyond neutral. The anconeus muscle inserts onto the lateral aspect of the olecranon, giving the posterior joint support and preventing the posterior capsule from being pinched during elbow extension.

IMAGE 10

Olecranon fractures occur due to high energy injuries in the young and low energy falls in the elderly. Patients will report that their elbow hyperextended during the fall. They can also be caused by a direct blow to the elbow by something hard such as a baseball bat resulting in a

comminuted fracture. The olecranon can also sustain a transverse or oblique fracture by falling on an outstretched hand. A more rare olecranon fracture is caused by severe contraction of the triceps muscle (performed by competitive gymnasts, wrestlers, and fitness athletes): the triceps muscle contracts so severely that it avulses the tip of the olecranon and tears the distal triceps expansion. Horne and Tanzer created a specialized classification for olecranon fractures as noted in the table below.

Horne and Tanzer Classification of Olecranon Fractures

Type I	Transverse Intra-articular, Proximal $\frac{1}{3}$ of olecranon articular surface or oblique extra-articular, involving the tip of the olecranon
Type II	Oblique or transverse, involving middle $\frac{1}{3}$ of greater sigmoid notch
Type III	Involving distal $\frac{1}{3}$ of the greater sigmoid notch with or without coronoid fracture

If the fracture is simple and non-displaced, it is typically immobilized at 45-90 degrees of elbow flexion for about a week, with light ROM beginning at one week. These patients are rarely seen in therapy as they have excellent outcomes and do not typically require skilled treatment. If the fracture is displaced or comminuted, surgery is indicated. A specific technique that is unique to olecranon fractures is the tension band technique, where the surgeon uses the triceps insertion to create a compressive force to stabilize the elbow. This is a highly technical surgery and can lead to decreased forearm rotation as a complication but is often used as a salvage technique after hardware removal. The triceps can also be excised and advanced into the proximal ulna in osteoporotic patients.

More common procedures that can be used are open reduction and internal fixation with plate and screw fixation on the dorsal surface of the olecranon for comminuted fractures or Monteggia fractures, or intramedullary rod fixation for transverse fractures with no comminution. Several of these techniques can be combined to provide bony fixation as well as ligamentous support. Surgery in this area often leads to elbow stiffness and posttraumatic arthritis. Some common complications include heterotopic ossification, olecranon bursitis, radial head dislocation, ulnar nerve compression, anterior interosseous nerve injury, and chronic loss of strength and range of motion in extension.

As with other fractures, full healing of the olecranon after surgery takes a minimum of 12 weeks. During the first week after surgery, patients are typically placed in about 60 degrees of elbow flexion using a cast or locked hinged elbow brace per the physician discretion. During this time, the physician will order AROM to the shoulder, wrist, and hand, edema control, and education for adaptive strategies for performing ADLs with the uninjured UE only. At week 2, the patient is allowed to flex the elbow to about 90 degrees within the hinged brace and will continue with AROM to surrounding joints, edema control, and modified use of the involved extremity as noted previously.

Typically around week 4-6 the physician will allow the patient to perform full AROM of the elbow if the fracture is deemed stable through follow-up x-rays. Gentle isometrics can begin for elbow flexion and extension with permission from the operating surgeon. Patients can also begin using the affected arm for light ADL activities and self-care. Patients should be free of their hinged

brace at this point, but should be instructed to wear the brace if they are in a precarious environment, such as working with toddlers or animals, or out in large crowds.

Amy's note: My advice = "Wear your brace when you attend toddler graduations and Metallica concerts."

Between weeks 8-12, as long as the physician determines that the fracture is clinically healed, the therapist can begin gentle passive range of motion as needed to regain end range measurements, and gentle weight bearing to the arm. Dynamic or static progressive splinting is also initiated at this stage as necessary. Progressive resistive exercises can begin at this stage as well, regaining functional strength to the arm. As with all post-operative recommendations, these are guidelines to help you with treatment planning. Please contact the referring surgeon for any specifics in protocol.

Rehabilitation after Olecranon Fractures (with MD approval)

Week 1

- Goals:
 - Minimize edema and pain
 - Maintain ROM of surround joints
- Therapy:
 - Hinged brace at about 60 degrees of elbow flexion
 - AROM or AAROM to surrounding joints
 - Edema control and ADL adaptation as needed
 - Modalities such as TENS, IFC, cold laser, and ice for pain control

Week 2

- Advance elbow flexion in brace to 90 degrees as tolerated
- All other treatment remains the same

Week 4-6

- Goals:
 - Regain full ROM of the elbow
 - Begin isometric strengthening of elbow
 - Minimize pain and swelling
 - Modalities as needed
- Therapy:
 - Full AROM of the elbow
 - Gentle isometric contractions at the elbow
 - Light ADL activities

Week 8-12

- Goals:
 - Advance to full function
- Therapy:
 - Begin PROM as needed to regain extension
 - Begin strengthening protocol
 - Begin weight bearing
 - Dynamic or static progressive splinting as needed
 - Work or sport-specific training as tolerated
 - Open and closed-chain exercises
 - Work hardening as needed to return to full duty work

Radial Head Fractures

Radial head fractures account for almost one-third of all elbow fractures, and are seen most commonly in post-menopausal women with a history of osteoporosis, and in younger men due to a high-velocity fall (Kodde et al., 2015). Unfortunately, the radial head is a key player in the stability of the elbow due to its involvement in both elbow flexion and extension at the radiocapitellar joint and pronation and supination at the radioulnar joint. The radial head also has several ligamentous attachments that are crucial for lateral and longitudinal stability of the forearm during valgus stress or external rotation including the lateral collateral ligament and the annular ligament. In a large review of the literature, Kodde et al. found that 61-80% of patients with radial head fractures had some degree of ligamentous injury, although this was not necessarily clinically relevant.

IMAGE 11

Monteggia fractures are a specific injury involving the fracture and dislocation of the radial head in conjunction with a fracture of the distal third of the ulna. The mechanism of injury is a fall on an outstretched hand with the forearm in pronation or hyperpronation. Monteggia fractures may require some modifications of treatment protocols by some surgeons, but can also follow the rehabilitation protocols for radial head fractures and dislocations as described below.

The integrity of the radial head itself along with its ligamentous support is imperative in providing varus and longitudinal stability of the radius and the ulna both at both the proximal and distal radioulnar joints. In cases of radial head fracture, it must be fixed or replaced in order to restore stability. Otherwise, the lack of stability can cause proximal migration of the radius or distal migration of the ulna resulting in ulnocarpal impaction. Ulnocarpal impaction causes chronic wrist pain, difficulty weight bearing, and eventual joint derangement, leading to long-term hand weakness and loss of function.

Radial head fractures have a specific fracture classification system called the Mason Classification.

Mason Classification for Radial Head Fractures

Type I	Non-displaced segmental/marginal fracture Intra-articular displacement of less than 2mm
Type II	Displaced segmental fracture Intra-articular displacement of more than 2 mm or angulated
Type III	Comminuted fracture
Type IV	Fracture associated with posterior dislocation

With Mason Type I fractures, patients are typically immobilized for a short period of time and then allowed to begin AROM fairly quickly. Most of these patients do well and make a full recovery functionally. Follow-up studies on Mason Type I fractures confirm that patients tend to have better outcomes (less pain, more mobility, better recovery of function) with shorter immobilization times. One large study of over 300 patients with Mason Type I fractures found that patients who were allowed flexion and extension only for the first week, with the addition of pronation and supination in subsequent weeks, had less pain and better outcomes than those patients who began all motions in the first week. Furthermore, all patients who were allowed motion reported better outcomes than those who were completely immobilized (Paschos et al., 2013).

Rehabilitation for Non-Operative Radial Head Fractures (with MD approval)

Week 1

- Goals:
 - Control pain and edema
 - Protect fracture site
 - Minimize deconditioning of the UE
 - Maintain range in unininvolved joints of the UE (shoulder, wrist, fingers)
- Therapy:
 - Modalities, such as TENS, IFC, cold laser, and ice for pain control
 - Splint/Sling as directed by MD
 - Monitor use and weight bearing instructions per MD, typically non-weight bearing for at least one week
 - Gentle range of motion exercises of the shoulder, wrist, and fingers
 - Passive flexion/extension of the elbow
 - Passive pronation/supination of the elbow (check this with MD as it may be withheld until day 7-14)

Week 3-6

- Goals:
 - Continue to control pain and edema as needed
 - Minimize deconditioning
 - Regain range of motion within pain limits
 - Prevent muscle atrophy
- Therapy:
 - Active assistive flexion/extension of the elbow
 - Active assistive pronation/supination of the elbow
 - Isometrics: flexion, extension, and pronation, supination
 - Active assistive hyperextension of elbow as needed (at 6 weeks)
 - Gentle gripping exercises

Week 6-8

- Goals:
 - Regain full range of motion
 - Begin increasing strength
- Therapy:
 - Active flexion/extension, pronation/supination of the elbow
 - Active assisted shoulder flexion/ scaption in standing with wand
 - Pulleys with eccentric control of the elbow with flexion/extension
 - Dynamic or static progressive splinting as needed to regain full elbow motion

Week 8-12

- Goals:
 - Educate patient on proper joint protection and exercises to increase ROM
 - Gain adequate strength in the forearm flexors and extensors to increase stability at the elbow
 - Strengthen the elbow flexors and extensors to gain full active range of motion
- Therapy:
 - Resistive exercises: free weights, theraband, body weight exercises
 - Self-stretching: flexion/extension, pronation/supination, shoulder flexion/extension, and wrist flexion/extension, ulnar deviation/ radial deviation to increase PROM
 - Work or sport-specific training as tolerated
 - Open and closed-chain exercises
 - Work hardening as needed to return to full duty work

For all other radial head fractures (II-IV), the current consensus is that surgery is indicated. The two options for surgical fixation are ORIF or radial head resection and replacement. Open reduction internal fixation works well in fractures with less than three fragments. 120 degrees of the radial head is devoid of articular cartilage, which allows the surgeon a surface area to attach the ORIF without damaging the joint articular surface. Open reduction internal fixation can be accomplished using a low-profile plate or Herbert screws. Patients are usually placed in a cast for the first 2 weeks at about 90 degrees of elbow flexion, and then progress to a hinged elbow brace for the next 2-4 weeks to regain full AROM as tolerated.

With any fractures more complicated than this (including Essex-Lopresti injuries which will be discussed under ligamentous injury), radial head replacement is indicated. The most common joint prosthesis used in the elbow is the radial head prosthesis. Prosthetics are available in a variety of materials including silicone, polyethylene, pyrocarbon and metal. Currently, there are very few research studies that identify one particular prosthetic material or surgical procedure as superior to the others. Radial head replacement is still considered a new procedure, not standard protocol. Minimal evidence has been presented discussing the long-term effects of radial head prosthesis as it relates to function. Research over the next several years will reveal a more standardized protocol for the use of radial head replacements, but for now the material selection and protocol is left to the training and discretion of the surgeon.

IMAGE 12

Replacing the radial head with a prosthetic maintains relative elbow stability and prevents proximal radial migration and ulnocarpal impingement. Radial head excision can cause muscle weakness, wrist pain, valgus elbow instability, heterotopic ossification, arthritis, proximal radial migration, and decreased strength, so maintaining the length of the radius through a prosthetic radial head is the treatment of choice by most orthopedic surgeons. Radial head replacement is found clinically to be more effective than internal fixation, but, again, long-term efficacy has not yet been established in the literature (Kodde et al., 2015).

Rehabilitation for Operative Radial Head Fractures (ORIF and Radial Head Resection) (with MD approval)

Immobilization: 3-5 days post-op

- Goals:
 - Control pain and edema
 - Protect fracture site with posterior splint or post-op dressing
 - Maintain range in uninvolved joints (shoulder, wrist, and fingers)

- Educate to don/doff sling independently with elbow at 90 degrees flexion and forearm in neutral
- Therapy:
 - Modalities, such as TENS, IFC, cold laser, and ice for pain control
 - Splint/Sling as directed by MD
 - Monitor use and weight bearing instructions per MD
 - Gentle range of motion exercises of the shoulder, wrist, and fingers
 - Passive flexion/extension of the elbow
 - Passive pronation/supination of the elbow

Phase I: Weeks 1-3

- Goals:
 - Continue to control pain and edema as needed
 - Regain range of motion within pain limits
 - Prevent muscle atrophy (gentle isometrics as allowed by MD)
- Therapy:
- Active assistive flexion/extension with cane or shoulder pulleys
 - Active assistive pronation/supination with cane
 - Increase mobility to tolerance, prevent stiffness
 - CPM if ordered by physician

Phase II: Week 4-6

- Goals:
 - Regain full range of motion
 - Increase strength
- Therapy:
 - Active flexion/extension, pronation/supination of the elbow
 - Pulleys with eccentric control during flexion/extension
 - Isometric strengthening: flexion, extension, pronation, supination
 - Joint mobilization to increase range of motion as needed
 - Dynamic or static progressive splinting as needed to regain full elbow motion

Phase III: Week 8-12

- Goals:
 - Increase strength (especially at end ranges)
 - Educate patient on proper joint protection and home exercise program
 - Gain adequate strength in the forearm flexors and extensors to increase stability at the elbow
 - Strengthen the elbow flexors and extensors to gain full range of motion
 - Increase functional speed and coordination of the affected limb
- Therapy:
 - Resistive exercises: free weights, theraband, body weight exercises
 - Self-stretching: flexion/extension, pronation/supination, shoulder flexion/extension, and wrist flexion/extension, ulnar deviation/ radial deviation to increase PROM
 - Work or sport-specific training as tolerated
 - Open and closed-chain exercises
 - Work hardening as needed to return to full duty work

Terrible Triad Injuries

A terrible triad injury at the elbow is a traumatic injury to the elbow consisting of a coronoid fracture, a radial head (or radial neck) fracture, and an elbow dislocation, often associated with posterolateral dislocation or lateral collateral ligament injury. This is usually caused by a fall on

an extended arm that involves a combination of valgus, and posterolateral rotatory forces, and sudden axial loading. The elbow dislocates in a posterolateral direction, and the lateral collateral ligament fails, the anterior capsule is injured, and both the radius and humerus sustain fractures. The prognosis following a terrible triad is historically poor due to persistent instability, pain, stiffness, and arthrosis.

IMAGE 13

Non-operative treatment for the terrible triad injury is immobilization in 90 degrees of elbow flexion for 7-10 days if both fractures do not meet surgical indications. This means that the physician was able to reduce both fractures and feels they are stable enough to allow early ROM. Also, coronoid fractures involving less than 10% of the coronoid do not tend to affect elbow stability so they are not considered surgical cases. Typically after the first week of immobilization, the physician will allow for AROM to tolerance, avoiding terminal extension of the elbow. At 4-6 weeks following injury, the physician may order static progressive extension splinting to regain full extension. Research has shown that static progressive splinting in the earlier stages of healing are more beneficial in reducing flexion contracture complications. As long as bony healing is achieved, strengthening begins at about 6 weeks (Matthew et al., 2009).

Operative treatment for a terrible triad injury is much more common and involves either an ORIF of the radius or a radial head arthroplasty, lateral collateral ligament reconstruction, ORIF of the coronoid, and possible medial collateral ligament reconstruction. The surgeon will determine the surgical necessity for hardware such as joint replacement, sutures, suture anchors, screws, or plate fixation. Ligament repairs are achieved with suture anchors or transosseous sutures and the surgeon will have specific ROM considerations and restrictions according to each individual repair. Depending on the technique used and the nature of the specific injury, the patient will be placed in either a static or hinged elbow brace following surgery. Typically the elbow is placed in flexion with the forearm in pronation to provide stability to prevent posterior subluxation. If the patient had a repair of both the MCL and LCL, the forearm will be placed in neutral as opposed to pronation (Matthew et al., 2009).

All terrible triad injuries should be handled with care during the initial stages of rehabilitation. They are often unstable in extension and with any amount of valgus stress, which is why hinged braces are often blocked from allowing full extension; typically, the extension block is released at about 6-8 weeks post-op. Make sure you communicate with the surgeon about any specific post-operative protocol considerations that may apply to your patient: for example, sometimes the physician will allow the patient to remove the brace for showering as long as the patient can be compliant with no movement and maintaining a pronated position of the forearm when out of the brace. Review the operative report and establish a timeline of expected advancement in protocol with your patient. Progressing to AROM, PROM to end range, and strength training must be cleared through the operative physician.

The most common complication following a terrible triad injury is post-traumatic stiffness leading to contracture and development of heterotopic ossification. The best way to combat this is an early ROM protocol: immobilization longer than 3 weeks tends to lead to poor final ROM results. Occasionally the internal fixation can fail, or the patient can develop heterotopic ossification or post-traumatic arthritis due to loss of cartilage at the time of injury or due to prolonged residual instability. These things are beyond the control of the therapist, so they will require a change in focus of the therapeutic treatment plan from full recovery to compensatory techniques and activity modification (Matthew et al., 2009).

The timeline for a patient following the repair of a terrible triad injury is listed below. Typical precautions include wearing the postoperative splint or hinged brace at all times (unless given permission to take off in the shower as noted previously), no abduction of the shoulder until approved by the physician, and no weight bearing to the affected extremity. As always, please discuss the patient-specific protocol with the surgeon before following this outline.

Rehabilitation for Terrible Triad Injuries (with MD approval)

Therapy begins between 5-7 days post-op

Phase I

- Goals:
 - Protect the repair
 - Regain ROM
 - Minimize swelling and pain
- Therapy:
 - Therapy 2-3 times per week for 6 weeks
 - Weeks 1-2 – limit motion to 30-110 degrees
 - Weeks 2-4 – limit motion to 15-130 degrees
 - Weeks 4-6 – no limits in brace with forearm pronated
 - Patient is fitted to hinged elbow brace with forearm in neutral. Patient should be educated on proper donning and doffing of brace.
 - AROM/AAROM in gravity assisted extension with forearm in pronation. This is most comfortable in supine position with elbow propped on a bolster, shoulder resting in the plane of the scapula.
 - Modalities such as TENS, IFC, cold laser, or ice as needed for pain
 - Gentle ER and IR of the shoulder within limits of patient's tolerance, no abduction
 - NO WEIGHT BEARING, NO SHOULDER ABDUCTION, NO MOTION OUTSIDE OF BRACE

Phase II

- Goals:
 - Regain ROM
 - Wean from splinting
 - Minimize pain and swelling
- Therapy:
 - Continue therapy 2-3 times per week
 - Wean from brace as tolerated
 - Begin AROM in single planes of motion
 - Flexion/Extension
 - Pronation/Supination
 - Allow AROM of the shoulder, wrist, and hand
 - Begin PROM or static progressive splint for extension if patient lacks more than 30 degrees of extension or splinting for flexion if he has less than 130 degrees of flexion.
 - Begin light, controlled isometric rotator cuff and scapular strengthening and light grip strengthening
 - Modalities such as TENS, IFC, cold laser, or ice as needed for pain

Phase III

- Goals:
 - Regain strength
 - Maximize ROM
 - Work on functional goals for return to work/activities

- Therapy:
 - Continue AROM/PROM with goal of 10-140 degrees of motion
 - Progressive strengthening of shoulder and grip
 - Initiate elbow-centric strengthening of biceps, triceps, pronators, supinators
 - Progress to work conditioning as needed for heavier duty jobs
 - Throwing athletes can begin interval throwing program (see ITP information in the "Elbow Instability and Throwing Injuries" section below) after week 10 with MD approval

Patients with terrible triad injuries can expect to return to work in 2-4 weeks if they have a sedentary job, 8 weeks for light labor jobs, and 3-4 months for medium to heavy labor jobs. Throwers can expect to return to sport 6-8 months after injury when their throwing is pain free. More information on specific throwing protocols can be found under throwing injuries.

Essex-Lopresti Injuries

An Essex-Lopresti injury (ELI) is an associated injury with a severe radial head fracture involving the rupture of the interosseous membrane (IOM) between the radius and ulna, and a rupture of the triangular fibrocartilage complex (TFCC) located in the wrist. The mechanism of injury for ELI usually involves an axial compressive load to the forearm with the elbow in an extended position, either from a fall or from high-energy trauma. This causes axial and longitudinal instability of the forearm. The stability of the radial head is the primary player in providing stability to the interosseous membrane, and therefore the integrity of the distal radioulnar joint (Fontana et al., 2018).

IMAGE 14

This injury is missed acutely in almost 80% of emergency room cases as it is difficult to appreciate in the acute phase. This is why it is so important for the therapist to take a detailed medical history from the patient, documenting any information the patient has on his position when he fell. Any patient that has a radial head fracture that reports a high energy fall as described above in conjunction with complaints of wrist pain are suspicious of Essex-Lopresti injury. If left untreated, it leads to chronic wrist pain due to ulnar abutment against the proximal carpal row, or chronic elbow pain due to radiocapitellar arthrosis. On average, patients do not become symptomatic for Essex-Lopresti until nine months after injury (Adams et al., 2010). 20% of ELI also result in injury to the median or ulnar nerves in the forearm. A severe dislocation anteriorly of the radial head can result in damage to the posterior compartment of the forearm, causing radial nerve injury as well (Rodriguez-Martin et al., 2010).

Essex-Lopresti injuries can be identified during open reduction internal fixation surgery of the radial head via the radial pull test. If the surgeon suspects disruption of the interosseous membrane, the radial pull test can be performed intraoperatively, and the IOM can be repaired at that time. It is important to note that the radial pull test will be negative if there is only a partial tear of the IOM, leaving room for symptoms to develop over time.

Amy's note: Keep in mind that therapists are not allowed to diagnose a patient with any specific injury, so if you suspect that your patient has an undiagnosed Essex-Lopresti injury, I would recommend that you send your patient back to the physician with a note describing the specific symptoms that lead you to believe this may be the case.

For example, your note can say something like this: "Patient X is now complaining of severe ulnar sided wrist pain while resting. The pain increases with gentle AROM of the forearm from pronation to supination, and increased pain is also noted with mid-range wrist flexion/extension. She describes her injury as a hard fall with her elbow in full extension. Her symptoms seem to have gotten worse with regards to wrist pain over the past six weeks." This gives the doctor several clues about her mechanism of injury, describes her distal symptoms, and gives justification for how this injury could have been missed initially (by saying her symptoms have gotten worse). Although this may be seen by some therapists as "dancing around the point," this avoids any liability you would assume from diagnosing someone (which you are not legally allowed to do), and doesn't step on the toes of the professional that CAN legally diagnose the patient, who also happens to be the same professional that refers patients to you and butters your bread. I will sacrifice being a "hero" for being "employed" every single time.

In the event that an Essex-Lopresti injury is found, surgery is very often indicated. The surgical intervention indicated depends on whether or not the injury is acute or chronic. If the ELI is acute, the patient will undergo a radial head replacement, surgical fixation of the distal radioulnar joint with wires or screws, and possibly reconstruction of the interosseous membrane. If the ELI is found several months after injury, the surgical intervention can include a radial head replacement or excision and reconstruction of the interosseous membrane, and will also include an ulnar shortening osteotomy to reduce the abutment of the ulna against the first carpal row. Although some surgeons point to research and evidence suggesting that reconstruction is unnecessary, a review of the literature shows a significant increase in pain relief and increased patient satisfaction with the reconstruction as opposed to performing only the proximal and distal procedures. In addition, surgical outcomes are much more favorable for patients diagnosed acutely, rather than reconstruction and salvage procedures performed months down the line (Matson & Ruch, 2016).

Therapy following the ELI surgical procedure involves the patient being placed in a sugar tong splint for the first 2 weeks, until her first follow up appointment with the doctor. A sugar tong splint is a long arm splint on the posterior surface of the elbow, forearm and wrist, that immobilizes the elbow in flexion, the forearm in neutral, and the wrist in neutral. It extends down to the distal palmar crease of the hand to protect any surgical fixation at the wrist. After the first 2 weeks, the patient is placed in a Muenster splint for the next four weeks. A Muenster splint is actually a modified sugar tong splint that has a removable piece over the olecranon of the elbow that will allow elbow flexion and extension when removed. The Muenster splint does not allow for forearm rotation or wrist motion. As long as the doctor feels that the fracture and surgical fixations are healing, the patient is allowed to perform gentle elbow ROM with the Muenster splint in place. At 6-8 weeks following surgery, the patient is allowed to take off the Muenster splint and begin gentle ROM exercises to the wrist.

IMAGE 15

These injuries are fairly uncommon, so open communication with the operating surgeon is crucial for the therapist.

Rehabilitation for Essex-Lopresti Injuries (with MD approval)

Phase I: Weeks 1-2

- Goals:
 - Protect the repairs with sugar tong splint
 - Minimize swelling and pain
- Therapy:

- Therapy 2-3 times per week for 2 weeks
- Patient is fitted to custom sugar tong splint with elbow in flexion per surgeon protocol (usually 90 degrees), forearm and wrist in neutral. Patient should be educated on proper donning and doffing of splint as necessary but will not be removing splint at home independently.
- AROM/AAROM of shoulder and fingers at the discretion of the surgeon
- Edema control methods employed
- Modalities such as TENS, IFC, cold laser, or ice as needed for pain

Phase II: Weeks 3-6

- Goals:
 - Regain initial elbow ROM
 - Move from sugar tong splint to Muenster splint
 - Minimize pain and swelling
- Therapy:
 - Continue therapy 2-3 times per week
 - Patient to wear Muenster splint at all times when not with therapist
 - Begin AROM of elbow flexion and extension only
 - NO forearm pronation/supination
 - NO wrist motion
 - AROM of the shoulder and fingers as allowed by physician
 - Edema control methods continued
 - Modalities such as TENS, IFC, cold laser, or ice as needed for pain

Phase III: Weeks 6-10

- Goals:
 - Regain ROM of forearm and wrist
 - Maximize ROM of elbow
 - Discontinue use of Muenster splint
 - Begin isometric strengthening as tolerated and as ordered by MD
- Therapy:
 - Initiate mid-range motion for forearm and wrist, progressing to end ranges
 - Isometric strengthening of elbow
 - Continue to monitor pain and swelling and address as needed

Phase IV: Week 10 until discharge

- Goals:
 - Regain functional-full ROM at the elbow, forearm, and wrist
 - Regain strength to affected UE
 - Return to work/sport
- Therapy:
 - Regain end ranges of all joints
 - Dynamic or static progressive splinting as needed
 - Continue to address swelling and pain
 - Progress through strengthening of all joints
 - Progress to work conditioning as needed for heavy duty jobs
 - Activity modification as needed for any lingering pain-provoking positions

Elbow Instability and Throwing Injuries

Elbow Dislocation

Elbow dislocations are the most common major joint dislocation following shoulder dislocation. This happens more often in children ages 10-20, and accounts for up to one-fourth of the injuries to the elbow. Some people are at higher risk of dislocation of the elbow due to congenital anomalies such as a shallow coronoid fossa of the humerus, a shortened coronoid process of the ulna, or general joint and ligament laxity. The incidence of elbow dislocation is practically the same for males and females, and is associated with sports injuries about 50% of the time (Stoneback et al., 2012). 80% of dislocations are posterolateral due to a combination of axial loading and supination of the forearm. Usually the lateral collateral ligament fails first as it pulls off the lateral epicondyle. Over half of elbow dislocations have no associated fracture (De Haan et al., 2010).

Elbow dislocations are categorized as either simple or complex dislocations. Simple dislocations do not have any major bony involvement, while complex dislocations involve severe bone and/or ligament injuries. Severe dislocations can result in structural damage to the blood vessels and nerves that cross the elbow joint, further affecting the rehabilitation potential after dislocation.

The non-operative treatment for an elbow dislocation is closed reduction and splinting in at least 90 degrees of elbow flexion for 5-10 days. Careful AROM and gentle isometric strengthening is initiated after this immobilization as per physician instructions. Patients will often be in a hinged elbow brace for 1-3 weeks, according to the American Academy of Orthopedic Surgeons (AAOS), to allow full healing with protection against re-injury. Therapy may be indicated to regain full ROM through manual techniques, modalities for pain relief, and soft tissue mobilization to surrounding tissues to reduce muscle tightness and spasm. Patients may also require some closed-chain and open-chain activities to regain their proprioceptive sense in the elbow to regain full coordination and use of the affected limb. During the time of healing, a patient may benefit from external bracing or dynamic taping for joint support to return to functional activities.

Loss of terminal extension of the elbow is the most common complication following an elbow dislocation. This may or not be a functional deficit depending on the amount of extension regained. The commonly accepted amount of terminal extension for functional use is an extensor lag of less than 30 degrees. Aesthetically, an elbow that extends to a lag of 15 degrees or less is not noticeable. Early active range of motion within the physician's guidelines can minimize the risk for extension lag, so patients are often referred for physical or occupational therapy following immobilization. Static or static-progressive splinting can also help reduce the risk of permanent ROM loss and is typically indicated if full elbow extension is not achieved within 6-8 weeks of injury. Dynamic splinting can also be employed as noted in the discussion about other flexion contractures (AAOS.org).

Elbow Instability

Multiple elbow dislocations or severe ligament or bony disruption can result in chronic elbow instability, either Varus Posteromedial Rotatory Instability (VPMRI) or Valgus Posterolateral Rotatory Instability (VPLRI). The differences are best understood introduced in a side-by-side comparison as adapted from orthobullets.com, but will be described in detail as well.

Varus Posteromedial Rotatory Instability vs. Valgus Posterolateral Rotatory Instability

Structure	VPMRI	VPLRI
Radial Head	No involvement	Radial head fracture
Coronoid Process	More than 15% of coronoid is fractured	Less than 15% of coronoid is fractured
LCL	Full LCL avulsion	Full LCL avulsion
MCL	<i>Posterior</i> MCL rupture	<i>Anterior</i> MCL rupture
Provocative testing	Valgus stress, moving valgus, milking maneuver	Varus stress, chair rise, lateral pivot shift test

Varus Posteromedial Rotatory Instability (VPMRI)

Varus Posteromedial Rotatory Instability (VPMRI) is caused by a fall on an outstretched hand with the shoulder in a flexed, adducted position, resulting in an axial force combined with varus, posteromedial rotational stress to the elbow. The elbow subluxes at the ulnohumeral articulation, causing the coronoid to fracture, and the lateral collateral ligament to avulse from its insertion on the origin of the humerus. If these injuries are left untreated, they result in an instability pattern known as VPMRI.

As is the case with most injuries, there are conservative and surgical indications for the injuries resulting in VPMRI. Conservative intervention is considered a “wait and see” approach and is typically employed with stable, non-displaced coronoid fractures with a non-displaced avulsion of the lateral collateral ligament. The hope in these cases is that the elbow will heal itself with modified rest. The patient is placed in a sling or elbow brace for immobilization. The orthopedic physician will determine when it is appropriate for the patient to begin AAROM and AROM. When the patient is cleared to begin moving the elbow, he will perform elbow flexion and extension with the forearm in full pronation. Shoulder abduction is also contraindicated due to the varus stress that it puts on the elbow.

In cases where the coronoid fracture larger than 2-5 mm, surgical intervention is required. Surgical intervention for VPMRI involves open reduction and internal fixation of the coronoid facet fracture using a medial buttress plate or lasso suture to regain bony stability, a lateral collateral ligament repair, and associated injured soft-tissue repairs. If the posterior portion of the medial collateral ligament is damaged, it will also be repaired at this time. Therapy following this repair will be a combination of treatment guidelines for a coronoid fracture and a lateral collateral ligament repair. As with the conservative treatment, surgeons usually require that the elbow is splinted with the forearm in pronation, and when ROM begins, elbow flexion and extension is performed in pronation only to protect the repairs. An outline is provided below.

Rehabilitation for Varus Posteromedial Rotatory Instability (with MD approval)

Phase I – Maximum Protection: Days 0-14

- Goals:
 - Minimize pain and swelling
- Therapy:
 - Edema control
 - Immobilization in posterior splint with the forearm in full pronation
 - Sling for 2 to 3 weeks, no shoulder abduction
 - Modalities such as TENS, IFC, cold laser, or ice to reduce pain and inflammation

Phase II – Regain ROM: Weeks 2-4

- Goals:
 - Initiate pain free ROM
 - Minimize pain and swelling
- Therapy:
 - Elbow hinge brace setting 30 degrees of extension to full flexion
 - Maintain full forearm pronation
 - Passive/Active assisted motion 30 degrees of extension gradually moving to full flexion over the course of the 2 weeks with forearm in full pronation
 - Active wrist flexion/extension and gripping exercise – 2 weeks
 - Active pronation/supination at 4 weeks, no aggressive supination stretching
 - Scapular strengthening exercises
 - No active shoulder abduction unless instructed to do so by physician
 - Continue use of modalities to reduce pain and swelling

Phase III – Early strengthening: Weeks 4-16

- Goals:
 - Full ROM
 - Begin strengthening program
- Therapy:
 - Gradually progress to full extension over the next 3 months. A five degree extension limitation is acceptable and may provide some protection against recurrence.
 - 12 weeks – Begin gentle resisted shoulder ER/IR, biceps, triceps and wrist/forearm strengthening, all planes
 - 16 weeks – may begin a general strengthening including elbow with light resistance, progressing as tolerated

Phase IV – Advanced strengthening and plyometric drills: Weeks 16-20

- Goals:
 - Regain full strength and functional use for lifestyle and work duties
- Therapy:
 - Educate patient to continue using arm while avoiding varus stress
 - Progress to heavier lifting, weight bearing activities, and work hardening as indicated
 - May return to unrestricted activity at 1 year

Valgus Posterolateral Rotatory Instability (VPLRI or PLRI)

Posterolateral Rotatory Instability (PLRI) is the term used for lateral ulnar collateral damage with a radial head fracture and small fracture of the tip of the coronoid process, causing instability with valgus stress. Symptoms of LUCL ligamentous injury include complaints of pain and clicking and locking with the elbow in extension. Provocative testing includes testing for varus and valgus instability and examination of the distal radio-ulnar joint for possible Essex-Lopresti injury. Since the LUCL portion of the UCL is of primary importance to lateral stability, its integrity is crucial for patients to have normal function of the elbow, especially with throwing. Throwing athletes can develop PLRI from repetitive stress to the medial elbow caused by throwing with

poor mechanics, or inadequate proximal strength and range of motion. Surgical repair of the medial collateral ligament is commonly referred to as Tommy John surgery, and will be discussed in the section labeled “Medial Collateral Ligament Injury,” as the rehabilitation after medial collateral ligament repair is specific and arduous. Extensive rehab including several months of coordinated interval throwing is necessary to return to sport after a reconstruction of the UCL.

Complications with PLRI include ulnar nerve traction or damage, and fracture of the ulna or medial epicondyle in addition to the fractures of the radial head and avulsion of the tip of the coronoid process. Obviously the more areas of fracture to the medial aspect of the elbow, the more complicated the rehabilitation due to the increased inflammation and subsequent development of scar tissue.

Throwing Injuries

Medial Collateral Ligament (or UCL) Injury or Valgus Instability

The medial collateral ligament of the elbow is the primary restraint against valgus force to the elbow. Although this ligament is not under a great amount of strain in normal daily living, it is under a tremendous amount of stress with repetitive throwing, such as seen in baseball pitchers. As an athlete starts to complain of medial elbow pain, they are usually put on a resting program. If a resting program does not alleviate symptoms, UCL repair or UCL reconstruction is the most viable option for return to sport.

Ulnar collateral ligament surgery has improved drastically over the last thirty years. In 1986, Dr Frank Jobe performed the reconstruction technique that became known as the Tommy John surgery on a famous baseball pitcher for the Dodgers who was able to return to major league baseball afterwards. Dr Jobe's UCL reconstruction technique was long considered the gold standard for UCL laxity or valgus instability in throwing athletes.

Since that time, return-to-sport rates have improved to 66-97% of athletes based on their level of competition (from recreational to professional sports) and the surgical technique employed. Today there are several different surgical techniques available, ranging from repair of the stressed UCL using suture anchors to reconstruction using the palmaris longus as a graft. In fact, a recent review of the studies shows that UCL repair using suture anchors has actually resulted in better subjective outcomes in patients than the Tommy John surgery. Patient satisfaction has risen as well as return-to-sport percentages: non-professional athletes are returning to sport at about a rate of 95% with the UCL repair using suture anchors or an internal brace, and most athletes are returning to sport within 6 months of injury (Erickson et al., 2017).

Valgus Extension Overload (Pitcher's Elbow)

Another sports-related injury at the elbow is valgus extension overload (VEO). This condition is also seen in pitching athletes. Repetitive pitching leads to excessive shearing on the medial aspect of the olecranon tip of the ulna and the olecranon fossa of the humerus, compression of the radiocapitellar joint, posterior extension overload, and medial tension at the ulnar collateral ligament. This excessive shearing causes injury to the cartilage of the posterior portion of the ulnohumeral joint, osteophyte formation, loose bodies from fraying and fragmentation of the cartilage, and attenuation of the UCL due to the repetition. Athletes will complain of posteromedial elbow pain with the elbow in full extension, loss of terminal elbow extension due to osteophyte formation and loose bodies blocking the joint space. Pain is typically felt during the deceleration phase of the pitch (phases of pitching will be discussed at length later in this series).

Conservative treatment for valgus extension overload is NSAIDs, a resting program from throwing, and steroid injection. Therapy can include strengthening of the flexor-pronator motions and correction of pitching techniques in the deceleration phase of the pitch. If conservative treatment fails, surgical resection of osteophytes, removal of loose bodies, and debridement of chondromalacia are needed. X-rays can confirm this diagnosis, as the posterior elbow will show osteophyte formation and calcium deposits in the ulnar collateral ligament. Patients can return to sport following therapy to strengthen, correct pitching form, and completing a thrower's program as described below.

Little Leaguer's Elbow

"Little leaguer's elbow" is the common name for medial or posterior elbow pain that decreases a player's throwing effectiveness (speed, control, and distance). This is most often an overuse injury caused from microtrauma of repetitive valgus stress to the anterior band of the medial UCL, leading to rupture. Repetition is not the only culprit of causing valgus overload, though; the valgus load also increases with poor throwing mechanics. Little leaguer's elbow is not limited to baseball pitchers: other overhead athletes such as football quarterbacks and javelin throwers can suffer from repetitive strain to the medial elbow as well. This valgus stress occurs in the late cocking and early acceleration phase of throwing. Valgus load is highest in the acceleration phase of the throw; throwers can also have posteromedial elbow pain due to valgus extension overload during the deceleration phase of the throw. Acute little leaguer's elbow can also be seen with a dislocation injury, but this is much less common.

Phases of Throwing

To understand the mechanics of the role of the ulnar collateral ligament play in throwing, let's review the phases of overhead throwing specifically for baseball and softball players, as these are the athletes we see most often with UCL dysfunction. Unfortunately, as you will see, the UCL can be affected by strength and motion deficiencies in almost every phase of throwing; injuries are not necessarily caused by elbow pathomechanics in the first place (Seroyer et al., 2010).

Phase 1: Windup

The windup officially begins with the athlete's feet on the ground and ends with the athlete standing on one foot, coiling up his body and balancing on his back foot with the stance leg positioned with slight knee flexion. The pelvis should be either even between both legs or slightly lower on the stance leg compared to the swing leg. This is important to note, as the lower body positioning and strength will determine the proper positioning for the upper body. Lack of hip strength and proper pelvic positioning can lead to shoulder injury. Most importantly to note for this course, knee hyperextension can lead to injuries of the UCL of the elbow.

Phase 2: Stride

The stride phase begins as the hands come apart, and ends when the lead foot lands on the ground. For proper positioning in the stride phase the landing foot should be pointing towards the targeted direction of the ball; the stride leg, stance leg, and target should all be in midline, and should line up with each other. The stance hip rotates internally while the stride hip rotates externally. With regards to the upper extremity, if the stride leg over-rotates externally, this can lead to injuries at the UCL of the elbow and shoulder instability and tears.

Phase 3: Arm Cocking

This phase begins when the lead (or stride) foot hits the ground and ends with the throwing arm in maximum external rotation. This is when the forces on the shoulder, elbow, trunk, and legs

are at their highest, meaning they are most prone to injury during this phase. The hips and trunk should be rotating towards the target. The weight should be shifted to the stance leg, and that leg will need to slow down the force of the weight being shifted forward with momentum. The arm is in maximal external rotation abducted at 90 degrees and in midline with the body. The scapula should be retracted and depressed, and the hand should be on top of the ball.

If the stride leg is not stable or the trunk rotates too soon, this can increase the strain at the UCL as well. Improper hand positioning on the ball (under it or to the side) can also lead to injury of the UCL. The shoulder is also at risk for labral tears and rotator cuff impingement if internal rotation is limited or the ipsilateral scapula is weak.

Unfortunately we see this often in young throwers, because as they are developing, their open growth plates in the shoulder joint will accommodate for the high number of throws by thickening the posterior capsule of the shoulder and actually adapting the bony anatomy of the throwing shoulder, causing deficits in internal rotation mobility. Lack of internal rotation mobility also leads to medial elbow pain and UCL damage.

Phase 4: Acceleration

This phase begins with the throwing arm in maximum external rotation and ends with the release of the ball. The thrower's trunk moves from extension to flexion, the obliques twist the arm into a forward motion, and the shoulder goes from external rotation into internal rotation with elbow extension at a high velocity which creates the speed on the ball. The elbow should stay above the shoulder until release of the ball in order to avoid impingement at the shoulder or (you guessed it) UCL injury.

Phase 5: Deceleration

Deceleration begins when the ball is released and ends when the shoulder is in maximum internal rotation, which is the natural follow through of the arm after the ball is released. The posterior rotator cuff decelerates the arm as it comes across the body. This function of the posterior rotator cuff is necessary to slow down the throwing arm, but this also contributes to hypertrophy of the posterior musculature which leads to reduced internal rotation of the shoulder and therefore puts more strain on the UCL of the elbow. Most overuse injuries of the shoulder and upper arm occur during this phase.

Phase 6: Follow Through

This phase begins with the arm in full internal rotation, and ends with the thrower's full weight over the stride leg. This should be a natural progression of the forward forces on the body which will be absorbed by the stride leg. The thrower should not be abruptly trying to stop the momentum of the throwing arm, which risks injury.

Provocative testing for little leaguer's elbow includes a valgus stress test, milking maneuver, and a moving valgus stress test.

Obviously, some of these phases are modified for other throwing athletes, but all throwers have several biomechanical things in common:

- Throwers begin their throwing phase with most of their body weight on one foot and end up transferring that weight through their body to the other foot.
- Throwers need adequate lower body strength ON ONE LEG to provide stability for their upper body during all phases of throwing.
- Throwers need adequate core strength to use their bodies to manipulate the upper extremities for power and speed.

- Shoulder health (ROM, stability, and flexibility) are essential for elbow health in the throwing athlete.
- When these mechanics are ignored, the throwing arm will eventually fail.

With these things in mind, the American Sports Medicine Institute (ASMI) has recommendations for limiting the number of pitches that a little leaguer is allowed to throw daily and in a game in order to protect our young athletes.

Age	Pitches in a game	Daily Pitches
7-8 years	N/A	50/day
9-10 years	50/game	75/day
11-12 years	75/game	85/game
13-14 years	75/game	95/day
15-16 years	N/A	95/day
17-18 years	N/A	105/day

The ASMI also released their official position on pitching with regards to Tommy John surgery (UCL repair) and baseball pitchers. They discuss the reasons for the high prevalence of pitching injuries in baseball players with accompanying research. Research has proven that the most common reasons for throwing injuries are:

- Excessive competitive pitching
- Pitching when fatigued
- Pitching on multiple teams
- Playing catcher when not pitching
- Poor body mechanics
- Pitching year-round
- Poor overall conditioning

Discussing these potential hazards with your patients and their parents, trainers, and coaches can help to identify the risk factors that may be affecting their elbow health.

The ASMI position statement can be found at

<http://www.asmi.org/research.php?page=research§ion=TJpositionstatement>, but I will list the recommendations as a sidebar for your review, and to encourage you to use this as patient education. Although these are recommendations for professional pitchers, this is prudent advice to all athletes (and more importantly their crazy parents and coaches) on the health concerns of too much pitching. Money at the professional level is not the only motivating factor for players to overpitch. Consider scholarship status, school pride, personal pride, and family dynamics (building a legacy) that may be “orange flags” when it comes to your patient athletes. These are all very real motivators and can put your patients at undue risk of injury.

SIDEBAR BEGINS

RECOMMENDATIONS FOR PROFESSIONAL PITCHERS AND TEAMS

FOR REDUCING RISK OF TOMMY JOHN INJURY

1. Optimize pitching mechanics to ensure using the whole body in a coordinated sequence (kinetic chain). A biomechanical analysis is recommended, as it provides objective data to the pitching coach, strength coach, and pitcher. A biomechanical analysis can also serve as a baseline for re-evaluation later in the pitcher's career, after performance improvement or after return from injury.
2. Vary speeds for each of your pitch types. This will not only reduce the overuse on the elbow, but also can be an effective strategy. The best professional pitchers pitch with a range of ball velocity, good ball movement, good control, and consistent mechanics among their pitches. The professional pitcher's objectives are to prevent baserunners and runs, not to light up the radar gun.
3. Open communication between a pitcher and his professional coaching and medical staff is paramount. The pitcher's elbow and body are living tissue. Pitching and training create small tears in the tissue; rest, nutrition, and hydration repair the tears. A pitcher and his team should have a plan, but that plan needs to be monitored and sometimes adjusted depending on how the pitcher feels. Specifically, the pitcher should keep his trainer or coach up to date about any soreness, stiffness, and pain. That way when there is an issue, the player and team can consider rest, modified activity, or examination from the team physician to allow the elbow to heal and avert serious injury.
4. The pitching coach needs to watch for signs of fatigue on the mound. This could be seen in-game as well as in bullpen sessions.
5. The team trainers, coaches, medical staff, and front office must share knowledge in a holistic approach to minimize the risk of injury.
6. Flat-ground throwing drills and bullpen sessions should not always be at maximum effort. Reduced effort will allow for physical fitness and technique without adding undue stress to the UCL.
7. Take off at least two consecutive months each year from all throwing. During this "active rest" period, you can do other physical activities and exercises, as well as continue proper nutrition. The UCL and body need time to recover and build strength, so the concept of annual periodization should include adequate rest from pitching.
8. Exercise, rest, and nutrition are vital for a pitcher's health. Performance-Enhancing Drugs (PEDs) may enable the athlete to achieve disproportionately strong muscles that overwhelm the UCL and lead to injury.
9. Pitchers with high ball velocity are at increased risk of injury. The higher the ball velocity, the more important to follow the guidelines above.

Copied directly from *Position Statement for Tommy John Injuries in Baseball Pitchers* (updated in September 2016).

****SIDEBAR ENDS****

Author's note: Although this course is focused on the elbow injury, please consider a whole-body conditioning for your throwing athletes. Assess their core strength, their lower body strength (specifically working off one leg at a time), their scapular strength, and overall health of the shoulder as well. A comprehensive evaluation of the body conditioning with the knowledge of the biomechanics and phases of throwing can help you assess where there are mechanical breakdowns in the throwing process.

When you are treating patients after UCL repair, make sure to get clearance from the surgeon to assess all of the systems mentioned above. Some of these things may be appropriate to work on even in the early stages of healing, and can keep an athlete in the right mindset of rehabilitation, especially if they are out for the season or missing a big game. Athletes in general want to push forward quickly in their rehab, so working on other aspects of their biomechanics can help prepare them for rehabbing the elbow when it is appropriate.

When the athlete is approved to begin throwing again, the surgeon will typically order an Interval Throwing Program, or ITP. Just as with all post-surgical protocols, the surgeon may have a specific throwing program that he recommends; still, it is wise to familiarize yourself with a standard throwing program prior to this stage of rehab so that you have a working knowledge of the high level of rehab that awaits your athlete/patient. We'll consider the ITP developed by the American Academy of Orthopedic Surgeons (AAOS): available at AAOS.org, it serves as a template for many ITPs created by surgeons in the United States.

The AAOS recommends that all throwers begin with the crow-hop method of throwing, meaning the thrower takes a hop, a skip, and then throws the ball, so as to not throw flat-footed, which puts the thrower at risk for re-injury. Athletes begin throwing at 35-40 feet using the crow-hop method for 75 pain free throws (including the warm-up). They will do this 2-3 times before moving on to the next step, and are only allowed to throw every other day. It is considered normal to feel a dull ache or soreness in the arm, but sharp pain or pain lasting longer than a half hour after throwing is a sign that an athlete is moving too quickly through the program.

The key point here is that athletes do NOT advance to the next step unless they are pain free after 75 throws. Also note that the first six steps of throwing are NOT pitches: throwers do not start using full pitching mechanics until they can throw 75 throws 180 feet from flat ground. This is a painfully slow process but is extremely important for avoiding re-injury. Of course, the specifics of the timeline may vary by physician, so clarify with the surgeon as to any preference for a throwing protocol.

Prior to any session involving throwing, athletes should do some light conditioning to warm up the entire body, followed by systematic stretching of the legs, trunk, back, neck, shoulders, and elbows. Educate your athletes to the importance of preparing their bodies for throwing in this fashion every session so as to avoid re-injury.

Interval Throwing Program Developed by the AAOS

Phase I

Stage 1: Crow-hop, flat ground throwing

45 foot phase

- Step 1:
 - A. warm up throwing
 - B. 45' (25 throws)
 - C. rest 5-10 min
 - D. warm up throwing

- E. 45' (25 throws)
- Step 2:
 - A. warm up throwing
 - B. 45' (25 throws)
 - C. rest 5-10 min
 - D. warm up throwing
 - E. 45' (25 throws)
 - F. rest 5-10 min
 - G. warm up throwing
 - H. 45' (25 throws)

60 foot phase

- Step 3:
 - A. warm up throwing
 - B. 60' (25 throws)
 - C. rest 5-10 min
 - D. warm up throwing
 - E. 60' (25 throws)
- Step 4:
 - A. warm up throwing
 - B. 60' (25 throws)
 - C. rest 5-10 min
 - D. warm up throwing
 - E. 60' (25 throws)
 - F. rest 5-10 min
 - G. warm up throwing
 - H. 60' (25 throws)

90 foot phase (repeat same drill)

- Steps 5 and 6

120 foot phase (repeat same drill)

- Steps 7 and 8

150 foot phase (repeat same drill)

- Steps 9 and 10

180 foot phase (repeat same drill)

- Steps 11 and 12

After the athlete can comfortably complete 75 throws at 180 feet, flat ground throwing using pitching mechanics can be initiated.

Stage 2: Flat ground throwing (incorporating pitching mechanics):

- A. warm up throwing
- B. throw 60' (10-15 throws)
- C. throw 90' (10 throws)
- D. throw 120' (10 throws)
- E. throw 60' (flat ground) using pitching mechanics (20-30 throws)
- F. throw 60-90' (10-15 throws)
- G. throw 60' (flat ground) using pitching mechanics (20 throws)

If your patient is a high level athlete, you will incorporate more advanced pitches at this point. Again, you will not advance to Phase II unless the patient is pain free with all previous steps in the ITP process. The patient should have overall conditioning and strengthening in place as

discussed prior to starting the throwing program. As with the rest of the program, the thrower advances from fastballs to breaking balls when he is pain free.

Phase II – Throwing off the mound and simulated games

Stage 1: fastballs only

- Step 1:
 - A. interval throwing 120' phase as warm up
 - B. 15 throws off mound at 50% velocity
- Step 2:
 - A. interval throwing 120' phase as warm up
 - B. 30 throws off mound at 50% velocity
- Step 3:
 - A. interval throwing 120' phase as warm up
 - B. 45 throws off mound at 50% velocity
- Step 4:
 - A. interval throwing 120' phase as warm up
 - B. 60 throws off mound at 50% velocity
- Step 5:
 - A. interval throwing 120' phase as warm up
 - B. 70 throws off mound at 50% velocity
- Step 6:
 - A. 45 throws off mound at 50% velocity
 - B. 30 throws off mound at 75% velocity
- Step 7:
 - A. 30 throws off mound at 50% velocity
 - B. 45 throws off mound at 75% velocity
- Step 8:
 - A. 65 throws off mound at 75% velocity
 - B. 10 throws off mound at 50% velocity

Stage 2: fastballs only

- Step 9:
 - A. 60 throws off mound at 75% velocity
 - B. 15 throws in batting practice
- Step 10:
 - A. 50-60 throws off mound at 75% velocity
 - B. 30 throws in batting practice
- Step 11:
 - A. 45-50 throws off mound at 75% velocity
 - B. 45 throws in batting practice

Stage 3: initiate breaking ball pitches

- Step 12:
 - A. 30 throws off mound at 75% velocity warm up
 - B. 15 throws off mound at 50% velocity, breaking balls
 - C. 45-60 throws in batting practice, fastballs only
- Step 13:
 - A. 30 throws off mound at 75% velocity warm up
- Step 14:
 - A. 30 throws off mound at 75% velocity, breaking balls
 - B. 30 throws in batting practice
- Step 15:

- A. 30 throws off mound at 75% velocity warm up
- B. 60-90 throws in batting practice, gradually increase breaking balls Simulated game, progress by 15 throws per workout (keep pitch count)

Other Athletic Injuries

Biceps Tendon Rupture

The biceps brachii is the main flexor at the elbow joint (along with the brachioradialis and brachialis muscles) and is also a powerful supinator when the elbow is in a flexed position. It assists with shoulder flexion and stabilization of the humeral head during deltoid contraction, and can also assist in abduction and internal rotation of the humerus at its proximal origin. As a review, the long head of the biceps originates at the supraglenoid tubercle of the scapula and the short head from the coracoid process of the scapula. It then travels on the anterior portion of the upper arm and inserts anteriorly on the radial tuberosity of the ulna.

IMAGE 16

Complete rupture of the distal biceps brachii accounts for approximately 3% of all biceps ruptures, with most biceps injuries occurring at the origin in the shoulder. Biceps tendon ruptures can be either partial or complete, and most commonly occur due to a sudden and unanticipated load being placed on the biceps with it in a flexed position. This injury is most often seen in men over the age of thirty. Weightlifters will sustain this injury when attempting to catch a dropped weight or lift a weight in a sudden manner. With a full rupture of the biceps tendon, the injury is quite obvious, as the person hears an audible “pop” with simultaneous searing pain to the anterior elbow. The biceps muscle will also “roll up” into the proximal upper arm, causing a large bulge and almost immediate bruising. Partial tears are less obvious, but are also commonly experienced as a “pop” with severe pain.

Although partial tears can sometimes heal on their own, a full biceps tendon rupture must be surgically repaired. Left without surgical repair, the injured arm will have a 30-40% decrease specifically in supination strength, as the brachialis and brachioradialis can compensate for pure flexion strength. Functional endurance for activities is also drastically reduced in the affected arm when the biceps is not intact. Therefore, immediate surgical repair is the recommended course of action when available in order to minimize downtime for the patient. Ironically, delayed surgical treatment (3 weeks to 5 months after diagnosis) has also been shown to be beneficial in long term follow-up results when compared to patients treated early (within 8 days of initial injury). The true takeaway here is that regardless of the timing of surgery, surgical intervention is preferable to conservative treatment (Horschig et al., 2012).

There are two main surgical techniques employed to fixate the ruptured biceps tendon to the radial tuberosity of the ulna. The first is a one-incision technique where the surgeon creates an anterior incision and sutures the biceps tendon to the ulna using 1-2 suture anchors. The second technique involves drilling a hole in the ulna, feeding the end of the biceps tendon through the bone, and anchoring the tendon on the posterior aspect of the bone. This involves a second incision on the posterior aspect of the forearm in order to complete the procedure.

Of primary concern in early rehabilitation is placing too much stress on the suture anchors with aggressive ROM and strengthening exercises. Although tendons repaired via new surgical techniques under development have demonstrated the ability to withstand higher loads prior to failure, recommendations for the introduction of strengthening exercises post-surgery have not been modified to reflect these surgical advances. Thus, you'll find that some surgeons are more

progressive with their rehab protocols while others are more conservative. We will examine the typical course of treatment at this time, but keep in mind that as more evidence is available, the rehabilitation timeline of biceps tendon ruptures will be changing. As always, discuss your timeline expectations with the surgeon to ensure that you are on the same page.

The initial phase of rehabilitation is immobilization with a hinged elbow brace or cast, the second phase focuses on regaining motion, and the third phase focuses on regaining strength and return to functional use of the arm. Aggressive protocols recommend that the elbow should have full AOM by week 6 and that strengthening should begin at week 8. More conservative protocols have the elbow immobilized the first 6 weeks, with ROM regained between weeks 6-12, and strengthening to begin between weeks 12-16. Along with the physician's protocol, the therapist can adjust the protocol according to an individual's development of scar tissue, use of nicotine (slows healing), and use of corticosteroids (athletes who have a history of corticosteroid use tend to heal more slowly and are at greater risk of re-rupture).

Standard Rehabilitation of Distal Biceps Rupture (with MD approval)

Physician orders call for no active flexion of the elbow or supination at the forearm

Phase I – Weeks 0-6

- Goals:
 - Maintain integrity of repair
 - Wear hinged elbow brace at all times
 - Decrease pain and inflammation
 - Promote tissue healing (nutrition, no smoking, no steroid use)
- Therapy:
 - Precautions
 - No active biceps contraction for 6-8 weeks
 - No quick movements
 - No lifting of heavy objects on contralateral side
 - No lifting with affected side
 - No weight bearing over affected arm

Weeks 1-2

- Hinged brace is locked at 90 degrees of elbow flexion at all times
- Address pain and swelling
- Monitor incisions

Around 3 weeks (per MD protocol)

- Unlock brace and allow passive full elbow flexion and gentle active extension to -30 degrees
- All motion must be passive. NO active biceps contraction
- Active/passive wrist, finger, and shoulder range of motion as tolerated (no active supination)
- Monitor incisions
- Address pain and swelling
- Modalities such as TENS, IFC, cold laser, or ice for pain

4-6 weeks

- Continue passive flexion/active extension and incrementally increase extension by 10 degrees weekly with goal of full extension by 6 weeks
- Initiate triceps isometrics
- Initiate wrist and submax grip strengthening

Phase II – Weeks 6-12

- Criteria to progress to Phase II:

- Appropriate healing by adhering to precautions in phase I
- Staged ROM goals achieved
- Minimal pain and effusion
- Goals:
 - Allow healing of soft tissue
 - Do not overstress healing tissue
 - Restore full PROM by week 12
 - Normalize AROM in flexion and extension
 - Begin to increase strength and endurance
 - Initiate gradual return to functional activities and light work activities

6-8 weeks

- Initiate PROM elbow extension to tolerance (no aggressive stretching)
- Grade III/IV joint mobilizations
- Continue/advance AROM wrist/shoulder

8-12 weeks

- Initiate AROM elbow flexion/supination
- Initiate isotonic strengthening shoulder
- Advance strengthening wrist/grip as tolerated
- Discontinue brace at 9 weeks post-op unless otherwise directed by physician

Phase III: Weeks 12+

- Criteria to progress to Phase III:
 - Minimal to no pain/effusion
 - Full ROM elbow without pain
 - Full shoulder/wrist strength
- Goals:
 - Gradual restoration of strength and endurance
 - Advance neuromuscular control
 - Return to full ADLs/work

12+ weeks

- Initiate biceps strengthening
- Initiate and advance functional activities based upon patient needs
- Work conditioning or work hardening as needed for return to work
- Progressive weightlifting as needed for weightlifting population

Osteochondritis Dissecans

Osteochondritis dissecans (OCD) of the elbow occurs most often in children and adolescents who are active in high energy sports such as football, gymnastics, weightlifting, pitching, and wrestling. It is caused by lack of blood flow to the bones underneath the cartilage at the joint from repetitive stress or impact. This causes the bone to become somewhat brittle and fracture, and also leads to cartilage damage in the same area. As the tissue fragments, it can get caught in the joint, causing pain and locking of the joint. Osteochondritis dissecans can heal on its own if caught in the early stages, but as it advances, surgery may be necessary to remove floating fragments that cause pain and locking. Symptoms include chronic pain in the elbow joint, joint swelling, redness, and complaints of locking in place during activities.

IMAGE 17

Patients who develop OCD should be educated on proper mechanics of their sport, strength and stability training, and the importance of cross training as well as rest. A proper resting program can take as long as 2-4 months, which can be considered “devastating” to an athlete

trying to get a college scholarship or perform for professional scouts. Not only does the patient need to understand the resting program, but it is extremely important to educate the patient's parents, coaches, and trainers as well, as children in competitive sports may not be the only influencing factor in their level of activity.

If conservative treatment fails or the bony lesion is larger than 1 cm in diameter, surgical treatment is indicated. Several surgical procedures can be employed depending on the case. Sometimes the lesion will be fixated with a pin or screw as with a typical fracture. Sometimes the physician will drill holes in the end of the bone to increase blood supply to the area in order for the bone to heal. In other cases, the physician may remove the bony fragments and use bone graft or cartilage to fill in the space left by the missing pieces. These patients then follow a rehabilitation protocol of 2-4 months of rest and healing with therapy to regain motion, strength, and eventual return to sport. Most athletes who undergo surgery will not return to sport for at least 4-6 months.

Therapy following the surgical treatment of OCD depends on the procedure performed and the area of the elbow affected. You can use the information provided under elbow fractures to help guide you in creating a plan of care timeline once you know exactly what area of the elbow was treated.

Amy's note: I have found OCD to be a particularly frustrating diagnosis because of the population in which it occurs. Student athletes present with symptoms of pain, swelling, and locking joints, and oftentimes their coaches and parents are pushing them to compete and "push through the pain" during practice and competition. "No pain, no gain," right? Students typically do not consider the long-term ramifications of pushing their bodies too hard during sport. They assume every athlete goes through injury. Coaches, parents, and trainers can often feel the same way. The dynamics between the coach, the athlete, and the parents are a huge predictor in compliance. Permanent damage may be prevented if the entire team of support around the athlete is on the same page.

I had an 11-year old athlete come to me for evaluation after his third surgery to the right elbow for OCD. He had traveled almost six hours away for surgery with a specialist. His mother's first question was, "When can he get back to the gym?" I tried to educate the mother to the mechanism of injury and the surgical procedure as best I could. I would like to say that I was able to convince the mother that her son required a substantial amount of rest before returning to sport, regardless of the fact that it was going to put his gymnastics scholarship chances (seven years in the future) in jeopardy. His mother pulled him from therapy when I refused to let him begin handstands two weeks after surgery.

For reasons I won't divulge due to HIPAA, this patient ended up with an elbow fusion at the age of 23. He will now live the rest of his life with only partial use of his right arm because he was forced to "tough it out." Ironically, he is now a physical medicine and rehabilitation doctor, educating others on the importance of listening to your body. (Which also means I'm very old, because I treated him when he was a grade-schooler.)

Considerations for Elbow Evaluation

Gathering History

The first vital piece of information when gathering your patient's history is an account of the actual injury itself. We know that most elbow trauma stems from a high velocity fall, but there is a lot more information that can be gleaned from hearing about the injury. Have the patient describe the injury or accident to you so that you can get a clear picture of the direction of force over the wrist, the relative velocity of the fall, and any other specifics that can affect your treatment, such as the precipitating factor in the fall. Did your patient lose his balance for no particular reason, trip over a throw rug, or fall down the stairs? Was he adjusting to a new medication or did the dog walk out in front of him? You may find that performing a fall risk assessment is wise to prevent further injury. This also helps you treatment plan any home modifications that may be necessary to avoid future falls.

After gathering the history of the fall or accident, getting a full and accurate medical and surgical history is next. Does the patient have any other known medical conditions such as osteoporosis, osteopenia, or diabetes that will affect her rate of healing? Does she have a history of falls, dizziness, or head injury, or use psychotropic or cardiac medications that would cause dizziness or lightheadedness? Has she ever injured this elbow or any other part of the affected UE prior to this injury? Are there any other known issues besides the elbow injury, like distal radius fracture, humeral fracture, rotator cuff tear, or labral injury? Does she have a previous surgical history involving her neck or UE? Any underlying osteoarthritis or disc compression? All of these things can affect your patient's return to full function and also the course of treatment you are providing. Other factors that can affect healing times are tobacco and alcohol use, steroid use, and general nutritional health. Does your patient take any supplements of which you need to be aware?

A comprehensive checklist of known complicating diagnoses can easily be filled out by your patient prior to initial evaluation. Medical conditions to consider are osteoarthritis, rheumatoid arthritis, osteoporosis, osteopenia, anxiety disorders, lymphedema, fibromyalgia, history of previous complex regional pain syndrome (CRPS), previous UE or neck injuries, elbow tendinopathies, carpal tunnel syndrome, diabetes, cancer, and history of self-harming/dissociation. Make sure to allow room for "other" on your list so that patients can go into detail and/or give you approximate surgical dates. Some significant diagnoses surgically would include any previous fractures of the UE, mastectomy or lumpectomy, cervical fusions, ulnar nerve decompression, carpal tunnel release, trigger fingers, or any joint replacements in the hand.

Comorbidities

Osteoarthritis

Osteoarthritis occurs when the cartilage that cushions the ends of bones in synovial joints gradually deteriorates and becomes rough. As the cartilage starts to deteriorate, movement/activity causes increased friction on the two ends of the bones, which irritates the cartilage even more, causing the "wear and tear" to the joint surfaces. Eventually, if the cartilage wears down completely, the patient has bone rubbing against bone, which is typically (but not always) painful.

It is important to be aware of a history of OA in the elbow as this will affect your treatment regimen and your patient's tolerance for activity and manual treatment. Joints with articular breakdown should be handled carefully, making sure that you don't put too much stress using PROM, joint manipulations, or repetitive exercise which can exacerbate pain related to the arthritis. Oftentimes patients with underlying asymptomatic osteoarthritis may suddenly develop

joint pain as a result of an injury, so it is not enough to ask the patient if they have OA, but rather, clarify with the physician if OA has been identified on x-ray or other diagnostic scans.

Amy's note: Patients will often ask if they are going to develop arthritis after injury. While patients do have a higher risk of developing secondary arthritis, particularly patients with intra-articular fractures, this question should be deferred to the physician so as to not cause any confusion or conflicting information. Not all cases of arthritis are symptomatic, so I believe it is not within our scope of practice ethically to determine whether or not a patient is at risk for developing painful arthritis.

Rheumatoid Arthritis

Rheumatoid arthritis is an autoimmune disorder; increased healing will need to be factored in when deciding on a timeline of return to functional activity, as patients with RA tend to heal more slowly than their fellow patients. Many patients with RA also have other autoimmune diseases which can slow healing times as well.

As with osteoarthritis, PROM of joints in patients with rheumatoid arthritis is contraindicated due to the enzymatic breakdown of the joint tissue and subsequent ligamentous and tendinous mal-alignment that is accompanied with it. Passively stretching patients with rheumatoid arthritis should be done with extreme care, as this could exacerbate alignment dysfunction and cause more pain and disability for patients. Not only can overstretching cause alignment issues, it has also been known to "flare up" RA that is currently dormant. Rheumatoid arthritis is not commonly symptomatic in the elbows, but should be considered and reviewed with the patient and physician.

If you are unsure how your patient's RA will affect their treatment, discuss your concerns and course of treatment with the surgeon or physician.

Osteoporosis

Osteoporosis and osteopenia are common degenerative changes noted in the elderly population, where the body has a reduced capacity to rebuild or remodel bone. Not only is osteoporosis a positive predictor for increased likelihood of UE fracture, but it directly correlates to the increased severity of fractures and increased incidence of intra-articular fractures (Munk et al., 2007).

Fibromyalgia and CRPS

Although we do not have good research or answers on what causes a patient to develop complex regional pain syndrome (CRPS) after injury, and researchers are unsure how or why CRPS and fibromyalgia are linked, we do know that patients with a history of fibromyalgia have a higher incidence of developing this painful complication. Likewise, patients with a history of anxiety disorders also have an increased risk of development of CRPS (Lipman et al., 2017). CRPS causes central sensitization, which is a loss of brain-orchestrated pain inhibitory mechanisms and hyper-activation of the ascending pain pathways. In other words, the body perceives otherwise normal stimuli as painful, and responds with severe pain.

If the patient has a history of CRPS or fibromyalgia, and/or anxiety disorders, the therapist should be hyper-vigilant in watching for the tell-tale signs of developing CRPS. This can happen at any time during the course of treatment. Common symptoms are:

- Shiny, wax-like skin
- Increased vasomotor instability (blue or red skin color changes)
- Increased sympathetic activity such as profuse sweating of the UE

- Temperature differences between the affected and unaffected side
- Brawny edema

As the therapist can see, CRPS causes other symptoms in the patient besides the physical changes in the extremity. Patients begin having difficulty sleeping, making them more irritable and less tolerant of pain. Patients can also begin having increased anxiety, forgetfulness, and loss of concentration. Patients may have increased difficulty remembering their home programs and even clinic exercises because they become consumed with pain. They report that they feel “out of control” in many area of their lives as the symptoms persist.

If these symptoms present themselves, contact the physician to discuss your findings. Medical treatment will most likely be modified to address and hopefully resolve the CRPS before it becomes debilitating. Rehabilitation strategies to address and/or avoid CRPS include a stress loading program, functional activities, desensitization, and graded motor imagery.

CRPS is difficult and frustrating to treat, as it presents differently in every patient and takes many months to resolve, if it resolves at all. The most important part of treatment is to maintain as much functional use of the hand as possible so that the patient has limited residual stiffness and muscle atrophy as the CRPS resolves. Patients do not respond well to any passive treatment such as manual soft tissue mobilizations, joint mobilizations, or passive range of motion. Even when the patient does not complain of pain during these activities, they will oftentimes have a rebound and exacerbation of symptoms following a manual treatment.

Education on the progression and the mechanism of injury for CRPS is vital in helping patients deal with their symptoms. The therapist can assist with this by providing sound medical advice about CRPS, helping the patient find a support group if need be, and continuing to offer the patient moral support and autonomy to self-direct their therapy.

Amy's note: If you suspect that your patient is developing CRPS-like symptoms, immediately adjust your treatment plan to a self-directed list of various functional activities, stress loading program, and graded motor imagery protocol. Allow your patient to work at her own pace and her own comfort level, which will most likely change from treatment to treatment. Although your patient may not get “full range of motion” or seem to be making significant gains, the premise behind this type of treatment is that you are reducing the central sensitization that has occurred in the brain. Patients need to be reminded to respect their body, and that they have total control over their rehabilitation.

I usually put together a clipboard of suggested activities including desensitization, stress loading, fine motor, gross motor, open-chain and closed-chain activities, and even online apps and games to play. The focus of activities is not based on elbow function, but is geared towards shoulder motion and/or wrist/hand activities in order to get the patient's focus off of the elbow. My patients are told to do the activities in any order they please at whatever pace they please and to report back how they are feeling. I stress the importance of laterality training, visualizing the affected side doing pain-free activity, and mirror therapy (the three phases of graded motor imagery, or GMI) to reduce their disability long-term. Patients respond very favorably to GMI as it isn't painful. More information on GMI can be easily accessed online or through other continuing education courses.

Lymphedema

Patients with a history of lymphedema will need extra care and attention toward their edema management, as swelling is the complication that most commonly affects functional outcomes in

patients with elbow trauma. Discuss your patient's current lymphedema management strategies, and review and emphasize the importance of consistent diaphragmatic breathing, proximal lymphatic drainage strategies, and careful compliance with edema management specific to the elbow, wrist and hand to ensure that your patient is getting adequate lymphatic exchange. Make sure to educate your patients who feel that they have their lymphedema under control that an onset of new injury can exacerbate their symptoms. Lymphedema management takes diligence and consistency and should not be overlooked in this population.

Other pertinent questions, considerations, and clarifications after trauma to the elbow:

- How long was the patient immobilized?
- What type of immobilization?
- Did the doctor provide the patient with instruction on how long to wear the immobilization?
- Have there been follow-up x-rays and what is the doctor's report from these?
- Can you obtain a report from the physician verifying the results of the latest x-rays?
- What medications is the patient taking for the injury, and at what dosage?
- Any current or previous use of a bone stimulator?

Clarification with MD

Although some of the items on this list are questions you might ask the patient, there are times when a patient doesn't have all of the information, especially when discussing the intricacies of their injury. Patients tend to have very little anatomical knowledge of their injuries, so they may not be able to provide accurate answers to these questions. If you suspect your patient doesn't have a complete working knowledge of their condition, make sure to clarify: call the physician or the physician's office to ask for an operative report. If your patient has had surgery, it is valuable to have a copy of the operative report in your file to refer to during the course of treatment.

Some clarifications to be obtained from the physician:

- Does the patient have any notable joint breakdown not related to the injury?

As discussed previously, recognizing any underlying osteoarthritis or joint deformities will be helpful in not exacerbating joint irritation during treatment. Many elbow fractures occur in high velocity falls, or standing height falls in postmenopausal women. It can be assumed that many of them have asymptomatic joint breakdown whether or not they know it.

- Is there intra-articular extension of the fracture?

This increases your patient's risk of developing arthritis and also suggests a more complicated fracture with increased healing times.

- Is there any expected disruption in radial length, inclination, or tilt of the ulna? Is there any concern of a developing Essex-Lopresti injury? Does the physician feel confident that the patient will regain full motion in all directions?

Keep in mind that the physician will know best what the patient's available range of motion will be, because he/she is able to ascertain that during surgery through PROM evaluation while the patient cannot feel anything: tissues are relaxed, pain is blocked, and there is no edema present. If the physician cannot achieve full PROM under those

conditions, then the patient will not regain full active range of motion. The surgeon will also know if excellent alignment of the fracture pieces was achieved, giving you a better indicator of how successful the treatment will be. Full ROM immediately following surgery usually indicates good bony alignment, but this needs to be verified with the physician before you begin treatment.

- Will hardware be removed during the course of treatment?

Even internal fixation can be used with the expectation of removing it after the patient has full fracture healing. Although the intent is typically to leave the hardware in place permanently, patients can develop excessive scarring, nerve irritation, infection, and other soft tissue compromise that make leaving the hardware in place more detrimental than removing it. Unfortunately, this requires another surgery, but sometimes is the best case scenario in order to restore bony alignment early on in the healing process.

- Does the doctor have a specific post-op protocol following the medical treatment that he/she would like you to follow?

Outlines given in this course are generalities, meant to give you an idea of a typical protocol following immobilization or fixation. Your physicians most likely will have specific protocols that work best with their type of treatment. It is considered best practice to have a conversation with your referring physicians about what protocols they like to follow for rehabilitation following their fixations, including wound care and specific pin site care. If they do not have a specific protocol that they like to use, make sure to give them a general idea of the timeline you are considering to ensure that you are on the same page with regards to treatment. You can use the guidelines given in this course, or any guidelines that may be used in your region of the country.

For example, if you would normally start strengthening your patient at 8 weeks post-op, but you know your patient has a history of diabetes and osteoarthritis, you may decide that strengthening would not be appropriate until post-op week 9 or 10. Discuss this rationale with your referring physician (either through a phone call or progress note) so that he/she can approve or adjust your timeline accordingly. More communication with your physician will lead to better outcomes and increased rapport with both your patients and referral sources.

- Are there any other known soft-tissue injuries related to the fall or noted on diagnostics that would affect the treatment timeline or protocol, such as TFCC derangement, ligament damage, nerve damage, signs of heterotopic ossification, or avascular necrosis?

Functional Outcome Screens

Functional outcome screens are commonly employed in today's clinics to gain subjective and objective data from the patient that can be used as a baseline and to show improvement. Much of our research on the efficacy of treatment is based off of results from functional outcome screens. Physicians and payers can easily see a "snapshot" of a patient's status with some of the more commonly used functional outcome screens.

DASH or QuickDASH

The Disability of the Arm, Shoulder, and Hand (DASH) and QuickDASH screens are the most commonly used UE outcome measuring tools in the field today and were meant for patients

between the ages of 18-65, although they can be used on patients outlying this age range. They are designed to measure the physical function and symptoms in people with UE musculoskeletal disorders. The DASH consists of 30 activities; patients self-rate their level of difficulty performing each on a scale from 0% (no difficulty) to 100% (unable to perform). It is important to note that these screens are DISABILITY ratings, so the higher the number, the more difficulty a patient is having. The QuickDASH is a condensed version of the same test, consisting of only 11 of the 30 activities. Both of these tests can be used without obtaining license, and can be accessed and scored online at orthopaedicscore.com. There is also an application on Apple products that is downloadable to use the screens on mobile devices. In addition, there are two specialty modules that can be added to the DASH that include work or sports, depending on your needs.

The DASH and QuickDASH are simple to use, easy to understand, and give valuable data to the patient, therapist, doctor, and payer. These screens do not discriminate which hand is used in a task, just how easily the patient can get the task completed (this is different from some of the other tests we will review, such as fine motor coordination and function tests). A minimally clinically important difference (MCID) score exceeding a 15 point change is considered a significant change in function, while the minimal detectable change at the 95% confidence level (MDC95) is 13 (Hudak et al., 1996).

Visual Analog Scale (VAS)

A standard visual analog scale is a psychometric numerical rating scale that can be given upon evaluation and at each visit to assess a patient's pain level. The therapist asks the patient their pain rating on a scale from 0 to 10, 0 representing no pain and 10 representing the worst pain imaginable. This is a subjective response on the part of patient, and is considered an accurate and reliable scale to measure a patient's pain level during a visit and between visits. This is the most widely used outcome screen across all medical disciplines and patients are very familiar with it. Many patients understand the concept of the 0-10 numerical rating scale, but many visual representations of the scale can be found through an image search on the internet.

Amy's note: My favorite visual copy of the VAS is the LEGO pain assessment tool. You can easily find this using the search engine on your internet browser. You're welcome.

IMAGE 18

Created by Brendan Powell Smith (www.TheBrickTestament.com). This chart is not sponsored, authorized, or endorsed by the LEGO Group.

Observation and Establishing Rapport

Patients with traumatic elbow injuries and bracing tend to be nervous their first day of therapy and do not typically respond well to excessive measurements and manual evaluation. They have most likely been instructed to leave their brace on 100% of the time and may not feel comfortable with a stranger telling them to remove the brace, even if they understand that you are the therapist and are there to follow through with the doctor's orders. Reducing your amount of "hands-on" evaluation the first day can help establish rapport with your patient and put them at ease with the therapy process. Of course measurements provide valuable information, but establishing trust the first day is much more vital to the success of your overall treatment plan than painting the picture of the elbow, wrist, and hand with number values. Good observation skills are vital to performing a thorough evaluation of your patient, and can be performed simultaneously with time spent taking the patient's history.

Spending time observing the patient's current acceptance of the injury, guarding patterns, compliance with immobilization if applicable, swelling, trophic status, use of external support, incision health, and cleanliness provides a wealth of information on day one of treatment. In addition, asking your patient about their lifestyle and goals is valuable in determining what is important to them: it can strengthen rapport and trust and reveal a lot about a patient's motivation towards full recovery. This will be crucial to establishing appropriate goals and ideas for functional treatment.

Acceptance of Injury

Following a severe injury to the elbow, patients often are concerned that they will not regain full use of the affected arm, which is obviously a warranted concern. In addition, consider the mechanism of injury: the patient may have fallen from a high place, for example, injuring not only the elbow but other body parts as well. Traumatic falls can cause some degree of post-traumatic stress and may lead to patients not trusting their balance, reducing their activity levels and changing the hobbies and pastimes they enjoyed prior to the injury. Patients should be educated to the typical course of treatment and return of function for their particular injury in order to regain acceptance of the limb as soon as possible. Educating your patient develops open and honest communication and trust. It's the responsibility of the therapist to initiate that communication.

Guarding Patterns

Does your patient display the appropriate amount of guarding in relation to her particular injury? Is your patient excessively guarding the arm by holding it against her body? Is he keeping the arm adducted and protected when he walks instead of allowing his arm to hang freely and swing naturally as he walks? Is she posturing with her elbow flexed most of the time to protect it? Does she avoid attempting to use the hand for normal tasks such as filling out paperwork? Does he seem nervous to allow you to move or touch her shoulder, elbow, wrist, or hand? Will she attempt to actively move the shoulder or wrist (when uninvolved) when asked? All of this information allows you to get a sense of how much more objective assessment you can perform the first visit or two.

Swelling

In general, how edematous is the elbow? The hand and fingers? Of course circumferential measurements can be of value, but if your patient seems hesitant to allow you to manipulate the extremity, then a general assessment through observation can be made the first day. Note any pitting edema, the severity of edema noted to the elbow, wrist, and fingers (mild, moderate, severe), and talk to the patient about any edema management they've employed so far. Educate the patient that edema control will be a main goal of treatment, and controlling it appropriately is one of the primary indicators for long-term success. Since lack of motion at the shoulder and elbow will lead to edema distal to the site of injury, educate your patients to edema control methods to the elbow, wrist, and hand.

Trophic Status

Compare your patient's affected side to the unaffected side. Does it seem more purple, pink, or white than the other arm? Is your patient having increased sweating on one side more than the other? Do you notice any differences in skin texture or nail texture? Document any differences that you see and monitor these things as your course of treatment proceeds. These changes can be noted at the site of injury or distal to it, so check the shoulder, elbow, forearm, wrist, hand, and fingers for trophic changes.

External Support

Did your patient arrive with any external support such as a hinge brace or shoulder sling? Is the amount of support appropriate for the injury? Some patients will over-guard their injury by wearing an unnecessary brace or sling, while others could benefit from support but decide not to wear it. Compare the amount of support they are wearing with what you consider clinically appropriate for their stage of healing and address this with your patient. Patients with elbow fractures and dislocations often get dependent on bracing much longer than is clinically necessary, and it is the duty of the therapist to help wean the patient out of the splint as soon as possible to avoid this dependency.

Physicians typically have a very specific protocol for trauma of the elbow, so clarify this if you have any questions. If the patient is wearing an orthosis, it should be evaluated as well for proper fit and appropriate positioning. The brace may have ROM "stops" or restrictions set on it. Are they appropriate for the stage of healing of your patient? If you are unsure, contact the surgeon for clarification. Also, if you suspect that the brace is not fitting correctly due to a reduction in swelling, adjust the fit and educate the patient to monitor for changes in swelling or skin irritation following the adjustment.

Incision Health

It is the responsibility of the therapist to monitor the health of the patient's surgical incision (when necessary). Whether the patient has an associated wound from an open fracture or surgical incision with sutures, inspect the incision/wound for signs of infection. Any sudden onset of increased swelling, redness, purulent drainage, or even fever or malaise can be signs of infection in the wound and should be reported immediately to the physician. Do not remove sutures or steri-strips unless you have permission from the physician to do so. Pin sites are notorious for allowing bacteria to enter the skin and must be treated appropriately to avoid infection. Be sure to educate your patient to the signs of infection such as increased pain at the pin site, redness, increased swelling, purulent drainage, a foul odor, or increase in skin temperature. Any red streaking should be addressed immediately by calling the physician, as this could be sign of an infection spreading into the bloodstream.

Cleanliness

Is the patient able to adequately clean the affected elbow, wrist, and hand? If dressings are being used as with open fractures with associated wounds, are the dressings clean and appropriately applied? Has the patient been applying any creams, lotions, or gels to the incision or wound and are they approved by the physician? Many physicians have strict protocols on what is appropriate to apply to an incision, so clarify this with your patient and/or physician. If the patient has an external fixator, are they adequately caring for the pin sites as instructed by their doctor's office? Are they cleaning each pin site with a new q-tip and only using approved medications as noted by their post-surgical instructions? If you have any concerns in this area, be sure to address with the physician's office.

Lifestyle and Goals

Commonly used in sales, a great way to get to know your patient is to ask them questions based on the acronym FORM:

F: Family
O: Occupation
R: Recreation
M: Motivation

Some of these topics are natural and seem obvious to the therapist, such as finding out what the patient does for a living and what he does for fun, but investigating what motivates a patient will help the therapist to understand what else will affect the patient's treatment. For example, patients are often not as concerned about returning to their desk job as they are being able to play catch with their grandson or go fishing on the weekends. Also, remember that it is our job to educate the patient to how to return to the highest level of function possible, but this may not necessarily be the goal of the patient. For example, some patients will sacrifice full motion just to be out of pain sooner. Some are willing to do whatever it takes to be back at 100% capacity, and others just want to be released from therapy as soon as possible so they can go on with their lives.

In some cases, the history gathering can reveal "orange flags." Orange flags concerns can include items such as the patient has an upcoming vacation or holiday and doesn't want to recover too quickly so she doesn't have to return to work right away, or the patient reports that he never heals quickly and he doesn't expect to do well. These are concerns that can negatively affect the patient's outcome, but aren't necessarily as serious as "red flags." Red flags concerns are things like a patient who is counting on a large settlement for her injury, or a patient who hates his job and doesn't want to return to it. Any of these situations can lead to patients not trying their best, or even sabotaging their recovery. Although we commonly think of these as intentional acts, they may or may not be consciously created by the patient. Open and honest communication with your patient about what you are observing is the best form of treatment for a patient who is displaying orange and red flags. We are the healthcare providers that see patients the most, so we have the responsibility of helping them choose the healthiest path to recovery. The sooner any issues are addressed, the less likely they are to affect the patients' outcomes.

Fall Prevention

People with long term upper extremity dysfunction such as those with elbow trauma have risk factors such as overall decreased function, muscle weakness, and impaired balance that make them more likely to fall, especially in the elderly population. Side effects from medications (such as narcotics) used for pain relief can also contribute to falls because a patient may feel dizzy and unbalanced. Discuss your patient's environment with them. Removing throw rugs, timing pain medication with food, using an assistive device for walking long distances, and taking rest breaks are a good starting point. You may also need to discuss the fear of falling if you notice that your patient is much more fearful since their accident. Incorporating a falls assessment or referring your patient for vestibular rehabilitation may be necessary in preventing any further injury related to falls. If you are an occupational therapist who is untrained in falls assessment, refer your patient to a physical therapist to rule out any underlying dangers your patient may be facing.

Objective Measurements

After a complete history has been taken and initial observations have been made, the therapist can begin the objective portion of the evaluation. Active and passive range of motion, various brachial plexus nerve gliding (and subsequent radial nerve, median nerve, and ulnar nerve gliding as needed), joint integrity, musculotendinous tightness, edema, fine motor coordination, and strength testing are all objective measurements that may or may not be appropriate during the initial evaluation. As we review these areas of assessment, be mindful that the physician's protocol may prohibit some of these assessments initially. Please clear active range of motion (AROM), passive range of motion (PROM), and strength testing with the physician prior to your assessment.

Active Range of Motion

Prior to assessing AROM, the therapist should make sure that the patient has been cleared by the physician for motion of all involved joints. Occasionally a patient will be sent to therapy prior to being cleared for motion of the elbow with an order to move the unininvolved joints. This is a great strategy to avoid complications at the shoulder, wrist and hand, and can actually speed up healing and establishing trust between the patient and the therapist. If you have any question on what your physician intends, please clarify before moving the elbow outside the confines of immobilization or hinge bracing.

Elbow Flexion/Extension

Elbow flexion and extension are easiest measured in the standing position against a wall to avoid compensation at the shoulder. The axis of the goniometer should be placed in line with the elbow joint (the lateral epicondyle is a nice landmark for this). The stationary arm follows the humerus, and the movement arm follows the radius. Standard goniometry is performed with the forearm in neutral, but can also be recorded with the patient's forearm in pronation or supination in accordance with the physician's restrictions or if the therapist is trying to clarify functional positioning for the patient during a particular activity. For example, if the patient is able to flex the elbow to 130 degrees with the forearm in neutral but can only flex to 110 degrees with supination, this can be clinically relevant to the patient's job duties. Make sure to document the position of the forearm during testing if it deviates from neutral. Also ensure that the patient does not compensate with rolling the shoulder forward when attempting elbow extension, or lean backward when attempting elbow flexion.

IMAGE 19

Pronation/Supination

Pronation and supination are also easiest measured in a standing position. While it endorses both methods, the American Society of Hand Therapists (ASHT) prefers that pronation and supination be measured at the distal radius (as opposed to having the patient hold a pencil in their hand and measuring the movement of the pencil). With the shoulder adducted, elbow at 90 degrees, and forearm in neutral, the stationary arm of the goniometer should be aligned with the humerus, and the movement arm is placed either dorsal (for measuring pronation) or volar (for measuring supination). Make sure that the patient does not compensate by leaning to either side, or by abducting the arm away from the body (MacDermid et al., 2015).

IMAGE 20

Related Deficits

Patients with chronic disuse of the upper extremity due to severe injury at the elbow will oftentimes have ROM deficits at the shoulder, wrist, and hand as well. Screening the joint health of the shoulder, wrist, and hand can reveal sympathy stiffness that can impact function greatly. During this screening, the therapist should educate the patient to the importance of moving any joint not associated with the injury in order to prevent complications due to prolonged immobilization at the elbow. In cases of persistent stiffness to unininvolved joints, patients may need to attend therapy more often to address these issues even before the therapy can begin on the elbow.

Considerations for Elbow Treatment

Therapeutic Modalities

Edema Control

Edema is the most underrated complication following a traumatic or chronic elbow injury. It can lead to treatment complications such as nerve irritation, tendon irritation, and scar tissue development. Patients may complain more of pain as their primary concern, but edema is the leading cause of poor outcomes, as it can “clog” up the elbow and every structure distal to the elbow and create soft tissue adhesions which lead to poor outcomes. Without good motion in the wrist and fingers, it is very difficult to get full function back in the hand regardless of the motion and strength at the elbow. Avoiding the pitfalls of chronic edema can be achieved through a comprehensive program of breathing, motion, and nerve gliding. In this section, we will discuss all three components and how they can assist the therapist in achieving the best outcome for the patient.

Inflammation is a normal response to injury, and is necessary to bring in the chemical protein properties responsible for fracture healing. The body's natural response to injury is an influx of healing cells including cytokines, histamines, prostaglandins, and fibrinogen to increase stability and vascularity. This process takes from one to five days and the edema from it lasts about ten days. Over the next several weeks, the fibroblasts start to form a collagen network, creating interstitial scar. This lasts around six weeks and is the time when regaining motion is most easily attained. Unfortunately, many times in the elbow must remain immobilized for a great portion of this six weeks in order to regain bony or ligamentous stability. After the original collagen network formation, the cells begin the maturation phase, which starts around the sixth week and can continue on for up to two years. Adhesions become increasingly resistant to change as time goes on, making improvement in ROM more difficult, so explaining the process of normal inflammatory phases to patients will assist with compliance with AROM exercises in the early stages of treatment.

Stages of the Normal Inflammatory Process

Stage One (Days 1-5)

Influx of fluid carrying healing cells to increase vascularity and stability

Stage Two (After week 1 to week 6)

Collagen network begins to form

*Easiest time to regain motion related to contracting tissue

Stage Three (6 weeks to 2 years)

Maturation of the collagen tissue

Contracted tissue if not acted upon by external force

Breathing

One of the simplest ways to encourage the reduction of edema is through active range of motion of the joint, as the motion itself creates a squeezing force on the cells of the elbow, moving the edema proximally. Proximal edema control techniques such as active or passive range of motion of the shoulder can help stimulate lymphatic exchange which will help indirectly reduce edema and improve tissue healing at the elbow. Unfortunately, patients are oftentimes immobilized following an elbow trauma in order to allow structural healing to occur. Active and

passive range of motion are contraindicated. In these cases, other edema control methods should be employed.

A specific type of breathing called diaphragmatic breathing will help reduce edema throughout the extremity. Diaphragmatic breathing involves breathing in while pushing the belly out, and breathing out while pushing the belly in. This is the type of breathing that is encouraged with meditation. Many YouTube videos are available to help educate your patients on proper diaphragmatic breathing. Diaphragmatic breathing essentially creates a vacuum effect in the lymphatic system that will pull the edema from the extremities and return it into the larger part of the system. These methods can greatly reduce complications related to chronic edema in the injured tissue but must be cleared by the physician in case they are contraindicated due to other medical illnesses. The patient's full medical history should be cleared of congestive heart failure, as an influx of edema into the overall system can overload the system, causing undue stress on the heart and shortness of breath. If your patient has a multitude of health concerns, be sure to clear your techniques with the appropriate medical staff.

In the otherwise healthy patient, not only does diaphragmatic breathing help mechanically pull the swelling out of the extremity and into the system to be removed, it has many other benefits that are grossly underestimated. Breathing, by its very nature, delivers oxygen to the damaged cells of the body, assisting with repair. Breathing also increases relaxation and reduces stress (created by the injury, loss of function, loss of income, loss of independence, etc.) by increasing endorphin release, reducing cortisol (the stress hormone) and lowering blood pressure. Lastly, diaphragmatic breathing improves core strength, making a person less likely to fall in the future.

Active and Passive Range of Motion: Uninvolved Joints

Although it is easy to overlook, the therapist should check frequently on the PROM and strength of the associated shoulder and wrist, as they can be adversely affected by elbow immobilization. Oftentimes patients will use a sling immediately following injury, and almost always will guard their UE in some way during the immobilization phase. Naturally, if a person is not using their hand for function, they will posture the arm in an adducted position with the elbow flexed. If left unchecked, this can cause soft tissue tightness and shortening of the internal rotators of the shoulder and the flexors of the elbow.

Educate your patient to active shoulder abduction, external and internal rotation both in adduction and varying degrees of abduction, circumduction, and wrist flexion, extension, radial, and ulnar deviation three to four times per day to prevent any proximal or distal joint complications. Patients who are instructed to "climb and swim" (pretend to be climbing a ladder, and do various swimming strokes) several times per day can avoid soft tissue tightness, and will also inadvertently reduce dependent edema. Proximal motion can also stimulate lymph drainage and increase circulation which aids in healing as noted above.

If a patient arrives in the clinic at a later stage of healing and already has some proximal joint (shoulder) tightness, a more aggressive approach to active or passive motion may be necessary. In addition to AROM exercises, the patient may need anterior pectoral stretching (a doorway stretch), soft tissue mobilization to the anterior pectorals, shoulder PROM and joint mobilizations. Patients who have been guarding their upper extremity benefit from relaxing in a supine position during AROM and PROM exercises, as it decreases the postural guarding coming from the trunk. In cases of severe guarding, a patient may also benefit from supine deep breathing (or diaphragmatic breathing) techniques, manual soft tissue mobilization to the thoracic and cervical spine, neck muscles, and shoulder girdle and foam rolling techniques.

Amy's note: Never underestimate the power of good old-fashioned TLC to reduce your patients' anxiety regarding treatment. When you address their concerns by giving them exercises that don't hurt, you gain their trust and compliance with treatment. Proximal shoulder ROM exercises are a great example of non-painful exercises that can be very beneficial. Also remind them that taking the medication that their doctor prescribed for pain relief and muscle relaxation can be crucial to gaining the most out of their therapy as possible.

As discussed previously, the first six to eight weeks of healing are the “window of opportunity” for regaining the motion compromised by the injury. This is the phase of healing where collagen is being deposited but has not begun to mature. Patients must be educated to this in order to motivate them to participate in exercises that might be somewhat uncomfortable. Excessive chronic edema to the wrist and fingers from lack of motion/activity can result in permanent loss in range of motion in otherwise healthy joints if not addressed appropriately.

Action Range of Motion of Elbow

As reported earlier, active range of motion of the elbow should begin gently with permission from the surgeon following immobilization. When initiating education regarding AROM, it is more important to stress “intentional movement” with the patient rather than number of repetitions, amount of time spent at end range, or number of exercise sessions per day. Although all of these factors are important, if the patient isn’t reaching the end range of the joint during AROM exercises, they are losing the efficacy of the workout and will have suboptimal results. Patients will often only complete the pain-free range of motion in the elbow, which does not stimulate lymph exchange, soft tissue stretch, or stimulate circulation, and does not result in improvements in motion. On the other hand, active range of motion can be done too aggressively, causing increased pain and swelling. Therapists should be careful to monitor a patient’s subjective complaints and his compliance with home programming before and after adding active range of motion to the affected elbow.

One modification to AROM exercises if they are causing irritation is exercising from neutral to end range 10-15 repetitions and then moving on to the next exercise. For example, when performing elbow active flexion and extension, have the patient exercise from mid-range to end-range extension 10-15 times, and then mid-range to end-range flexion 10-15 times, et cetera. This is less painful subjectively than performing exercises from the end-range of flexion to the end-range of extension. Patients tend to tolerate this modification very well. Make sure to include pronation and supination exercises if clinically appropriate, and combining motions as well: ie, elbow flexion with forearm supination, and elbow extension with forearm pronation. Verify that all combinations of motion are approved by the physician protocol.

You may notice when simulating functional activities that we typically move in patterns of forearm supination in conjunction with elbow flexion, and forearm pronation in conjunction with elbow extension. Educate your patient to this normal movement pattern in order to help them understand the concepts of multi-planar movement. Mimic the motion of picking a cookie up off a plate (forearm is pronated and elbow is extended out in front of you), and putting it up to your mouth (moving into a supinated position while simultaneously flexing the elbow to bring the hand to the mouth).

Patients can easily incorporate proximal ROM and diaphragmatic breathing into their daily routine, and should be encouraged to perform proximal edema control techniques at the beginning of each clinic session as well. This ensures that the patient is performing the exercise and stresses the importance of edema control as a crucial part of treatment. It also relaxes the patient and prepares the tissue for stretch by increasing oxygen and blood supply to the arm.

Proximal ROM and breathing exercises are usually received very well by patients as they are not painful and give the patient a sense of achievement and progress with their program, especially when elbow function-related goals are not yet being addressed.

Amy's note: I start most of my patients in a supine position on a plinth, purposefully deep breathing to engage the diaphragm for lymphatic stimulation. Then they perform AROM at the shoulder (if approved) or AAROM using the unaffected hand or holding onto a cane for assistance. Shoulder flexion, scaption, abduction, and external rotation are performed if clinically appropriate. I also encourage patients to relax in an "arm-chair quarterback" position, with hands relaxed behind their head, shoulder in full scaption and external rotation for a 5 minute stretch. This "warm-up" takes about 10-15 minutes prior to other treatment and is well received by most patients.

Nerve Gliding

Long-term edema can cause compression of the sensitive neural structures of the elbow. The ulnar, median, and radial nerves all pass through the elbow joint on their way to the forearm, wrist, and elbow. The most sensitive of these three nerves at the elbow is the ulnar nerve, which can suffer irritation and adhesions with longstanding elbow edema. If the ulnar nerve develops adhesions, patients will have subsequent sensory and motor loss to the forearm and hand. The most common side effects of ulnar nerve irritation are numbness and tingling to the small finger and half the ring finger, and reduced strength in pinching, small finger control (resulting in a claw hand deformity), and compensatory thumb motion.

In order to circumvent adhesions to the ulnar nerve, a proximal nerve gliding program should be initiated as long as it does not violate any other contraindications for immobilization of the elbow. Ulnar nerve gliding and flossing are easy exercises to add to the home program, but it is important to educate the patient not to overdo their nerve gliding exercises, as this will cause increased nerve irritation, or neuritis in the arm. Unfortunately, when a patient is overzealous with nerve gliding, they increase their pain levels drastically for several days. Modalities and medication are fairly ineffective with an acute neuritis, and the nerve must simply rest for several days in order to heal.

IMAGE 21

Although we've discussed the ulnar nerve in particular since it is most commonly affected from injuries at the elbow, the radial nerve and median nerve can also be damaged and adhered to the healing tissue. In order to assess the health of each nerve, the therapist should evaluate the patient's tolerance through several nerve gliding sequences of the upper extremity, including the brachial plexus glides, radial nerve, ulnar nerve, and median nerve.

Amy's note: There is a multitude of nerve gliding protocols or nerve flossing sequences available on the internet. My suggestion is that you familiarize yourself with several sequences and experiment with the different patterns of gliding with your patient to see which glide provides the most comfort and achieves the goal of gliding the nerve.

My education to the patient is to "listen carefully" to the arm during the course of the glide for any feelings of a "pull," a "tingle," or any weird sensation. When they feel this, they are to reverse the position they are in to the previous position in the nerve gliding sequence. Let's say there are 6 phases in a nerve gliding sequence. Each position is held carefully for 3-5 seconds. If they get a pain or weird sensation when moving from position 3 to position 4, I tell them to return to position 3, then 2, then back to 3, then carefully to 4 again. They DO NOT push

through the sensation to attempt to complete the sequence. Patients are instructed to do 8-10 of each sequence (or the portion of the sequence they can tolerate), two to three times per day.

Soft Tissue Adhesions and Tendinitis

Chronic edema can lead to acute tendinitis at the medial and lateral epicondyles as well, due to their proximity to the elbow joint. Although extensive information is available on the treatment of epicondylalgia from chronic overuse, acute tendinitis is a common symptom following elbow injury and is not often discussed in that capacity. If you suspect that your patient has signs of acute tendinitis, evaluate for these conditions using the Mills maneuver, Cozen's test, and Maudsley's test as described in the definitions at the beginning of this course. Treatment for acute tendinitis involves modified rest, reduction of swelling to the tendon (through manual techniques such as cross friction massage and dry needling), and counterforce bracing or kinesiotaping to reduce stress on the tendons.

Hypersensitivity

Many patients will complain of skin hypersensitivity after a cast or hinge brace has been removed, which can be distracting to the patient as they begin their rehabilitation. Although hypersensitivity is quite normal and often resolves on its own, the therapist can provide a desensitization program of sensory dowels (rubbing different textures on the surface of the skin), particle immersion (such as beans, rice, cotton, balls), and vibration to the skin to re-educate the sensory endings of the skin and reduce the hyperactive ascending (pain) pathways to the brain.

Fine Motor Activities

Fine motor activities may not appear to be the biggest priority for elbow injuries; however, any function of the hand is affected by the health of the elbow. That is to say, elbow health will greatly impact the functional dexterity and strength of the hand. Therefore, fine motor coordination, hand endurance, and dexterity should be assessed as part of a comprehensive rehabilitation program for the elbow. Fine motor activities should be added to the program as soon as the patient is cleared for active range of motion. Not only will this help the patient regain some finger motion, but it will reduce the likelihood of compensatory patterns, reduce soft tissue adhesions, and encourage the patient to engage the hand in activity as soon as possible.

For baseline measurement of fine motor control, the therapist can use a standardized test such as a nine-hole peg test, Purdue pegboard, Jebsen-Taylor Hand Function Test, or the Minnesota Manual Dexterity test. Each of these tests have been studied and found to have adequate statistical validity and inter-rater reliability. In order to benefit from the normative data, the therapist must be sure to follow the standardized testing procedures closely. Each test comes with instructions, but most can also be found now online by typing the name of the test into a search engine. Standardized tests are a good way to measure progress as well because the data is objective. Sometimes this can be motivating to a patient as they have difficulty seeing how much improvement they've made over the span of treatment.

Nine-Hole Peg Test

Therapists have been using the nine-hole peg test since 1971, and it is still the simplest and most well-known dexterity test used in clinics today. Inter-rater reliability of the nine-hole peg test is very high; test-retest reliability of two back-to-back tests is fairly low, but can be accounted for by the practice effect. Research suggests that test-retest reliability actually improves with multiple tests of three or more. Studies also note that the normative data established by Mathiowetz, Weber, Kashman, and Volland in their main study in 1985 continues to be reliable for all commercially available nine-hole peg boards (Grice et al., 2003).

IMAGE 22

The nine-hole peg test is an excellent tool to assess finger dexterity as a baseline when patients are approved to begin active range of motion. It is a preferred test because it is fast and easy to administer and it does not require prolonged use of a hand that may have very poor endurance due to pain and prolonged casting or bracing of the upper extremity. Other standardized assessments of finger dexterity listed tend to take longer and may not be appropriate in the early stages of treatment.

Patients are tested on how quickly they can pick up nine pegs, one at a time, and place them in separate holes, and then remove them one at a time and place them back into the dish. The dominant hand is tested first, followed by the non-dominant hand. The test is invalid if the patient drops a peg on the floor or is interrupted in any way, and a new test trial should be completed. The timer starts when the first peg is picked up and stops when the last peg is placed back in the dish. Precise instructions are given to the patient prior to the trial. These instructions come with the kit (or can be extracted from the internet), and must be given as written in order to accurately compare the patient's results to the normative data. Normative data is divided between male and female subjects, and is broken down into five year age ranges from ages 20-75+. In general, people between the ages of 20-75 can typically finish the test in 16-20 seconds.

Amy's note: As an aside, I also like to use the nine-hole peg test with vision occluded to assess a patient's functional nerve return. This is not what the test was designed to measure and standardized scoring is not established, but I find the data collected to directly correlate with a patient's proficiency in performing fine motor tasks with vision occluded. For example, a mechanic who reaches into an engine to turn a screw without looking needs fine motor coordination in addition to functional sensation. If the patient has noted nerve damage and sensory loss from his elbow injury, this can affect proficiency at these kinds of tasks. Although the data is not standardized, it's a nice objective test to show progress or lack of progress in nerve return.

Purdue Pegboard

The Purdue pegboard can be used to measure fine motor coordination in one hand or in both hands simultaneously. The test is a board that consists of two parallel rows of 25 holes each. The test consists of four sub-tests, where the patient places small metal components (pins, collars, and washers) in the holes in a specific assembly pattern. The dominant hand is tested first, then the non-dominant hand, then both hands together, and then an assembly test is completed. Each sub-test takes about 30-60 seconds. Test score reliability increases if more than one trial of the tests is completed. To perform an entire test using three trials of each sub-test will take the therapist about 10-15 minutes, as the therapist is required to show the patient the testing procedure prior to testing. Normative data is available on subjects aged 5-89 years.

IMAGE 23

Lafayette Instrument Company has developed an app called Purdue Pegboard Scoring for iPhone and Android. It allows the therapist to administer the testing through the appropriate procedure while it keeps track of the patient's individualized data. It is free to download, but has in-app purchases if you would like to add organizational data for multiple patients. Normative data and associated research is also available.

Functionally, having a patient perform the Purdue pegboard test can help the patient see that fine motor function is affected by elbow injury. Testing and retesting as therapy progresses will allow the patient to see the benefit of fine motor activities issued both in the clinic and as part of the home program as valuable components of the treatment plan. Patients are typically motivated by the objective improvements they've made in fine motor function from week to week or month to month.

JebSEN-Taylor Hand Function Test

The Jebsen-Taylor Hand Function Test (JHFT) is a functional hand assessment that evaluates a patient's ability to perform common functional tasks after injury or surgery. This test has been deemed a reliable test by industry standards; however, its validity in measuring hand function is questionable despite its widespread use. In other words, a patient's score may or may not measure a patient's ability to perform typical activities of daily living. Despite this fact, the Jebsen is well-received by patients, and continues to be considered a recognized outcome tool for measuring hand function by third-party payers.

The original version of the test was developed in 1969 and has seven activities, but a modified JHFT was approved for use in 2004, using three activities. Due to the impact of distal radius fractures on all aspects of hand function, this therapist recommends using the original version of the test, as it assesses fine motor skills, weighted functional tasks, and non-weighted functional tasks. The modified version assesses fine motor skills only.

IMAGE 24

The full JHFT consists of seven subtests:

- Writing a short sentence (24 letters, 3rd grade reading difficulty)
- Turning over a 3x5 inch card
- Picking up small common objects
- Simulated feeding
- Stacking checkers
- Picking up large light cans
- Picking up large heavy cans

Specific guidelines for administering the test can be found online, but do not require any specialized training or authorization. The reader can also find the normative data in the original Jebsen article, which is readily available online as well. The test assesses speed only, not quality of performance. All items except for the writing subtest can typically be completed by a non-injured person in under 10 seconds. The entire assessment takes between 15-45 minutes to administer (Jebsen et al., 1969).

Although the kit can be purchased online, the norms can still be used if the therapist instead gathers all appropriate items for the test:

- 4 sheets of unruled white paper & clipboard
- Sentences typed in upper case centered on a 5x8" index card on a bookstand
- 5 index cards (ruled on one side only)
- Empty 1 pound coffee can
- 2 paper clips
- 2 regular sized bottle caps
- 2 U.S. pennies

- 5 kidney beans (~5/8" long)
- 1 regular teaspoon
- Wooden board (41 1/2" long, 11 1/4" wide, 3/4" thick)
- 4 standard size (1 1/4" diameter) red wooden checkers
- 5 No. 303 cans

Again, patients enjoy seeing the objective improvements they've made over time, so this test can be motivating to the discouraged patient. Improvements in therapy can be slow after a traumatic elbow injury, and patients tend to forget what their baseline function looked like at the beginning of treatment. Objective functional testing reassures them that they are indeed making gains.

Minnesota Manual Dexterity Test

The Minnesota Manual Dexterity Test (MMDT) is a standardized test for assessing the gross motor movement of the upper extremity and hand-eye coordination (as opposed to the other tests that measure just fine motor coordination). The MMDT was developed by the American Guidance Service in 1969 and is still in use today across the therapy field. The revised edition (1998) is currently available through Lafayette Instrument Company.

IMAGE 25

There are two ways to administer the test: either placing the disks from above the board into the board, or turning the discs over in the board. The therapist can also add displacing, 1-hand turning and placing, and 2-hand turning and placing as assessment options. Several trials can be performed at the discretion of the therapist. This test is easy to administer, but can be quite time consuming if several test batteries are completed. Normative data for the MMDT is not considered "critical," and should be used with caution: in other words, it is prudent to assess a patient's performance against his own trials in addition to comparing them to the normative data provided. Either way, it is important that the arrangement of materials (disks and board) and testing procedures follow the suggested protocol (Surrey et al., 2003).

In addition to its assessment function, this test can be used as a treatment method to re-engage the affected UE in activity and normal movement patterns.

Amy's note: Another functional adaptation that I have made using the Minnesota Manual Dexterity test is to have the patient document when the elbow or hand begins to feel "fatigue," and also to rate the fatigue at the end of the test on a visual analog scale. This can allow the therapist to have a somewhat objective measurement of improvement in fatigue factors over the period of treatment. Obviously this is not the intention of the MMDT, but has become valuable information for me with patients who work in assembly type jobs. Documenting their fatigue factors can also be encouraging for the patient so they can "see" or "feel" the improvement even if their test scores don't show much improvement. My intention is to find as many factors as possible that show improvement in order to keep patients motivated and encouraged.

Physical Agent Modalities

Physical agent modalities have been a complement to hands-on treatment for many decades, and can be used both to prepare tissue for manual treatment and to calm it after aggressive exercise. Ensure that your physical agent modalities are approved by the treating physician before applying them to your patient. Also be aware that many modalities can be

contraindicated in patients with internal fixation or prosthetic joints. Finally, please check your state practice act to clarify which modalities you are approved to administer.

Heat Modalities

Heat increases blood flow, and helps to increase the flexibility of tissues. Patients typically report temporary relief with heat treatments, and tend to tolerate exercise better following heat modalities. Heat modalities commonly used in the clinic are continuous ultrasound, moist heat packs, diathermy, and paraffin. Heat treatments involving energy waves such as ultrasound and diathermy should not be used on patients with internal fixation unless ordered by the physician. Ultrasound has long been considered contraindicated in the case of any metal implants, and its effect on fracture sites is controversial.

Cold Laser

Cold laser (low level laser therapy, or LLLT) also reduces pain in patients with soft tissue injuries and those who have undergone recent surgery. Cold laser is reported to reduce inflammation of surrounding tissue by stimulating ATP production to the area, thereby reducing pain. Essentially, the patient's body responds to the laser by sending stimulating ATP uptake, which helps the cells to heal more quickly. Minimal research has been completed on LLLT compared to other modalities, but patient satisfaction is very high (Medrado et al., 2003).

Amy's note: Most of my patients report less pain with motion and a general sense of well-being after cold laser treatment. I believe patients have less post-operative swelling, bruising, and pain with use of the cold laser three times per week, but I have not done any formal research to substantiate my claims. After using a cold laser for the last ten years of my practice, I believe it has allowed me to return my patients to pain free function much more quickly than prior to using it. I was as skeptical as the rest before trying it, but can't imagine my practice without it anymore.

There are several companies that manufacture cold laser now. Some units incorporate other modalities such as microcurrent or infrared. My suggestion would be to call several companies and request an inservice and trial of their unit to see for yourself if this is something you would like to add to your practice.

Most insurances will not pay for cold laser use, so that is something else to consider.

Moist Heat and Ice Treatments at Home

Moist heat will not necessarily heal a patient more quickly, but will provide increased vascularity to the area (even if only temporarily) and will elasticize the tissue in preparation for stretch. If patients report that they like moist heat better than ice, a common recommendation would be for the patient to apply moist heat at home prior to their exercises.

Patients can achieve this by taking a short shower (a few minutes) prior to performing their exercises. Patients who complain of elbow stiffness in the morning can do the same thing after they get out of bed: moist heat tends to decrease stiffness from lack of motion at night, and prepares a patient for their daily routine. Using moist heat in the morning is especially helpful for people who like to take their showers in the evening.

Another simple alternative that is very popular with patients is to take a bath towel, wet it down, and place it in the microwave for about two minutes, checking on it every 30 seconds to see if it is warm enough. Patients can heat up the towel and place their elbow, wrist, and hand in that

moist heat for several minutes before it cools down. Wrapping the wet towel in a dry towel will also hold the heat in for a little bit longer (and keep the mess to a minimum).

Ice can be indicated as part of a home program following the patient's exercise program and after excess activity. As far as cold treatments are concerned, there are commercially available cold packs that are quite comfortable: Elastogel.com is an excellent source for a commercial cold pack; they can also be purchased on Amazon and other therapy websites. Patients who really enjoy cold as their treatment of choice may choose to invest in a gel pack. Otherwise, a bag of frozen peas works very well and is readily available; it's also a much cheaper treatment option since Elastogel packs cost somewhere between \$30-50 each.

IMAGE 26

Strengthening

Initiating a strengthening program – not only strengthening the elbow joint, but addressing deficits or maintaining strength in the surrounding joints – must be approved by the physician for all elbow trauma cases. Weight bearing concerns usually coincide with strengthening restrictions, so these should be clarified with the physician as well. Surrounding joints (shoulder and wrist) may be approved for strengthening prior to the elbow joint itself. Regardless, always clarify before taking baseline strengthening measurements, of any kind, on either upper extremity: even isometrically testing the contralateral side can cause up to 45% contraction to the surgical side (Lee et al., 2014).

IMAGE 27

Shoulder Strength

Rotator cuff strength and stability should be assessed and addressed, specifically in those elbow injuries that require prolonged immobilization or bracing such as fractures and UCL repairs. Shoulder strength is almost always affected negatively by elbow injury and the nature of prolonged rehabilitation. Make sure to assess the rotator cuff strength (internal and external rotation, flexion and extension of the shoulder in adduction) and gross shoulder strength as well (shoulder flexion, extension, abduction in the plane of the scapula).

Grip and Pinch Strength

Diminished and or painful grip strength is another common side effect of elbow injury and must be addressed specifically to regain pre-injury function.

The expected timeline for beginning a strengthening protocol can vary from 8-12 weeks depending on the stability of the healing fracture, ligament, or nerve repair of the elbow. A therapist must never begin a strengthening phase without expressed consent from the treating physician. Gripping causes stress to the wrist and elbow, and it should be emphasized to the patient that they should not be gripping or lifting prior to getting consent from their physician and therapist. Patients with external fixation are usually restricted from testing grip and pinch until the initial stages of strengthening are ordered, which is usually between weeks 6-12 depending on the surgery. In addition, resistive activities such as using scissors should be discussed with the patient, as they may underestimate the role of grip strength as it relates to their elbow injury.

When strengthening has been approved, the therapist should obtain a baseline grip and pinch value for the affected and non-affected hand. When performing isometric testing for the first time, make sure to educate your patients to try their best, but do not cause the elbow, wrist, or

hand any pain. Use clinical judgment and encourage patients to achieve their best score, but keep in mind that the value is only beneficial if they doesn't harm themselves and cause increased swelling and pain response to the affected arm.

Using a dynamometer, test the patient's grip and pinch in normal fashion: seated with arm adducted comfortably to the side, elbow at 90 degrees, forearm and wrist in neutral. A standard grip test is three trials on the second handle-width setting. Any variations from this position should be noted in the patient's chart. Compare to the unaffected side. Document any complaints related to testing such as a sharp pain, difficulty with grasp, or inability to hold the testing equipment comfortably. Normative data can be found online and in many textbooks but should be used with caution. The average of three trials is the calculated score to compare to normative data.

Since pinch strength can be directly affected by injury to the ulnar nerve, it is considered important to test it as part of a thorough baseline for patients following an elbow injury. The three positions for testing pinch strength are lateral pinch, three-point pinch, and two-point pinch. The accepted patient position is seated, elbow flexed to 90 degrees, arm adducted, forearm in neutral. The lateral pinch is between the radial side of the index finger and the thumb. The three-point pinch (or three jaw chuck pinch) is between the thumb and the pulp of the index and middle fingers; instruct the patient to place the ring and small fingers in a full fist to avoid compensation. The two-point pinch (or tip to tip pinch) is between the thumb and the pulp of the index finger; instruct the patient to place all other fingers in a full fist to avoid compensation. Each of the tests should be performed with three trials on the affected and unaffected side. The average of three trials is the calculated score to compare to normative data.

Share the results for both sides, and discuss patients' expectations for strength in relation to their ADLs, job duties, and recreational goals. Most daily activities require about 20 pounds of grip strength and 5-7 pounds of pinch strength. This information can be helpful in encouraging and motivating patients to perform their exercises in order to regain the minimum strength required to perform activities independently (Smaby et al., 2004).

Grip and pinch strength can be improved using theraputty, dynamic grippers, or even by doing functional activities such as wringing out a wet washcloth or squeezing a foam ball. Encourage your patient to perform grip strengthening exercises with all different angles of wrist extension and flexion in order to simulate functional activities. Single plane exercises are simple, but do not necessarily translate to functional activity.

Amy's note: Increasing grip strength seems to be one of the most important clinical factors that influence whether or not patients feel they have made adequate progress with therapy. Patients enjoy knowing what their numbers are on the dynamometer and pinch gauge and can become frustrated when they don't show improvements every week. It is not realistic to expect grip strength to improve dramatically from week to week, just as it would not be realistic to expect massive gains in any other muscle group from week to week. Encourage patients to try their best during testing, but educate them that grip testing will only be tested every three to four weeks to monitor for true change in strength.

Wrist, Forearm, and Elbow Strength

In addition to grip and pinch strength, wrist, forearm, and elbow strength can be evaluated at the initiation of strength training as well as throughout the remainder of the treatment.

Manual muscle testing can be used to assess strength using the Trace to Normal scale, or using the numeral manual muscle testing scale. The elbow and shoulder strength can also be evaluated.

- 1 / Trace
- 2 / Poor
- 3 / Fair
- 4 / Good
- 5 / Normal

Please note that some physicians do not accept the manual muscle test data as functional data and would prefer that strength is measured by lifting instead. In these cases, the therapist should assess a patient's ability to safely lift using the affected arm (compared to the unaffected arm), and bilateral lifting as well. The therapist can also document the patient's ability to lift from various levels, such as floor to waist, waist to overhead, etc. This information is widely accepted by physicians, case managers, and insurance adjusters.

With regards to wrist strengthening, performing exercises in a dart-thrower's plane of the wrist is much more functional and better tolerated by the patient. Dart-thrower's motion is the combination of wrist extension with radial deviation (radial extension) and wrist flexion with ulnar deviation (ulnar flexion) as opposed to the single plane movements of wrist flexion/extension, and radial/ulnar deviation. Wrist strengthening exercises will translate into increased stability, and therefore increased natural grip strength as well. Progressive resistive strengthening using therabands, free weights, manual resistance, or functional activities such as turning wrenches, shoveling, or climbing ladders will all translate into better grip strength. These are very important activities to incorporate after elbow injuries, but are crucial in severe cases such as radial head fractures, terrible triad injuries, and Essex-Lopresti injuries.

Higher level strengthening and proprioceptive rehab activities include bilateral weight-bearing over a table, floor, or ball, isometric exercises in various joint positions, eccentric and concentric strengthening, and use of items such as a Dynaflex Powerball, Gyroscope, Flexbar or Body Blade exercises to add perturbation and endurance training, or Hand Maze to work through various wrist motion patterns. Patients with heavy job demands may be appropriate for work conditioning or work hardening. If you do not provide these services in your clinic, you should make contact with clinics in your area that do, or consider adding this to your line of services.

Conclusion

In conclusion, injuries to the elbow can be complex and frustrating due to the intricacies of the articulating surfaces of the joint itself and the multitude of soft tissue structures surrounding them. Elbow stability is crucial for full function of the wrist and hand, making it very important in the independence of our patients. It is the goal of this course to provide the therapist with insights into the anatomy of the elbow, how it heals, and the most relevant research to date on how we can get our patients back to work, to play, and to living their best lives. As always, continued research will reveal best practices in surgical and therapeutic techniques, and we will continue to advance our practices the more we learn.

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DASH and QuickDASH: <http://www.dash.iwh.on.ca>

Functional outcome screens (can be used freely online): <http://www.orthopaedicscores.com/>
MMDT, Purdue Pegboard: <http://lafayetteinstrument.com/>

Elbow Trauma: Rehabilitative Evaluation and Treatment

6 CE HOURS

FINAL EXAM

1. _____: Any fracture that does not puncture the skin. These may or may not require surgery depending on the degree of displacement or comminution.

- a. Closed fracture
- b. Comminuted fracture
- c. Displaced fracture
- d. Open fracture

2. _____: Involves a radial head fracture and less than 15% coronoid fracture; the anterior band of the medial collateral ligament is ruptured and the lateral collateral complex including the lateral ulnar collateral ligament is avulsed from the bone. Provocative testing includes the varus stress test, chair rise, and lateral pivot shift.

- a. Terrible triad
- b. Valgus extension overload (VEO)
- c. Valgus posterolateral rotatory instability (VPLRI)
- d. Varus posteromedial rotatory instability (VPMRI)

3. _____: A large fibrous membrane traveling between the radius and ulna extending the length both bones. This membrane provides stability in the forearm and also serves to compartmentalize the volar and dorsal portions of the forearm.

- a. Cubital fossa
- b. Interosseous membrane
- c. Mobile wad
- d. Musculocutaneous membrane

4. A displaced fracture results in movement of the bony fragment away from its proper alignment. Technically any fracture that is displaced more than _____ in any plane on x-ray is considered displaced.

- a. 1 mm
- b. 2 mm
- c. 2 cm
- d. 3 cm

5. _____: Caused by lateral ulnar collateral ligament injury allowing more movement laterally in the elbow joint. When placing pressure laterally on the medial aspect of the elbow, the lateral elbow is not stable enough to withstand the pressure.

- a. Radial translation
- b. Ulnar translation
- c. Valgus instability
- d. Varus stress

6. _____: This test is performed by a physician and tests the integrity of the lateral ulnar collateral ligament (LUCL), checking for posterior elbow rotatory instability.

- a. Cozen's test
- b. Lateral Pivot Shift test
- c. Milking Maneuver
- d. Rule of Nine test

7. Which of the following is NOT a provocative test to rule out lateral epicondylagia, or tennis elbow?

- a. Axial Interosseous Load test
- b. Cozen's test
- c. Maudsley's test
- d. Mills test

8. This test begins in the same position as the milking maneuver, and is positive with subjective apprehension, instability, or medial joint pain at the MCL origin between 70-120 degrees of elbow flexion.

- a. Lateral Pivot Shift test
- b. Moving Valgus Stress test
- c. Radius Pull test
- d. Rule of Nine test

9. Due to the shape of the humerus, the when the arm is in full extension, the long axis of the forearm (radius and ulna) is offset by roughly _____ degrees compared to the long axis of the humerus.

- a. 0-6
- b. 4-12
- c. 11-16
- d. 15-22

10. Understanding the role of the _____ in normal elbow function is crucial as we prepare to learn the importance of its role in hand function: not only does it have three distinct articulating points that contribute to motion, it also is an anchor point for muscles that act on the elbow, wrist, and hand and acts as the primary absorber of weightbearing stress.

- a. Carpal
- b. Humerus
- c. Radius
- d. Ulna

11. Within the joint capsule of the elbow there are as many as seven different bursae, but there are _____ main bursa sacs found in most people that help cushion the joint and reduce friction during movement.

- a. 2
- b. 3
- c. 4
- d. 5

12. The _____ muscle has the most “square footage” when crossing over the elbow joint, but it has a poor mechanical advantage in elbow flexion due to being so close to the axis of rotation. Its origin is the entire anterior distal half of the humerus; it crosses just anterior to the joint capsule (the deepest elbow flexor), and inserts into the coronoid process. Some of its fibers attach to the joint capsule itself, and assist in retracting the anterior joint capsule during elbow flexion.

- a. Brachialis
- b. Brachioradialis
- c. Supinator
- d. Triceps brachii

13. The third portion of the ulnar collateral ligament (UCL) is the _____, which does not actually contribute to stability.

- a. Annular ligament
- b. Anterior oblique ligament
- c. Posterior oblique ligament
- d. Transverse ligament

14. The cardinal sign of _____ nerve damage is an “ape hand,” or noted thenar atrophy. Other common complaints are numbness and tingling to the radial aspect of the hand, pain at night, and a positive Phalen’s maneuver (prolonged wrist flexion causes numbness).

- a. Median
- b. Posterior interosseous
- c. Radial
- d. Ulnar

15. With regards to the radiocapitellar joint, functionally, a person needs _____ degrees of motion in the flexion/extension arc to perform most personal hygiene and sedentary tasks.

- a. 10-110
- b. 20-120
- c. 30-130
- d. 40-140

16. Which of the following is NOT typically a situation where open reduction with internal fixation (ORIF) is the treatment of choice?

- a. Closed reduction is insufficient
- b. More conservative treatments such as casting fail
- c. The fracture is non-displaced
- d. The fracture is unstable

17. In a _____ fracture, the mechanism of injury is a low energy fall on an outstretched hand (typically from a standing position) with a direct, axial load causing compression of the elbow at the radiocapitellar joint with the elbow in a semi-flexed position. Symptoms include elbow pain,

obvious deformity, swelling, wrist pain, ecchymosis, and diffuse tenderness on the lateral aspect of the elbow.

- a. Capitulum
- b. Coronoid
- c. Olecranon
- d. Radial head

18. Per the Mason Classification for Radial Head Fractures, a "fracture associated with posterior dislocation" would be considered _____.

- a. Type I
- b. Type II
- c. Type III
- d. Type IV

19. Patients with terrible triad injuries can expect to return to work in _____ for medium to heavy labor jobs.

- a. 2-4 weeks
- b. 8 weeks
- c. 3-4 months
- d. 6 months

20. _____ are missed acutely in almost 80% of emergency room cases as they are difficult to appreciate in the acute phase.

- a. Essex-Lopresti injuries
- b. Olecranon fractures
- c. Monteggia fractures
- d. Terrible triad injuries

21. Considering rehabilitation for Varus Posteromedial Rotatory Instability (VPMRI), therapeutic activities such as "active wrist flexion/extension and gripping exercise" and "scapular strengthening exercises" begin during which phase?

- a. Phase I
- b. Phase II
- c. Phase III
- d. Phase IV

22. During which phase of throwing are the forces on the shoulder, elbow, trunk, and legs are at their highest, meaning they are most prone to injury during this phase?

- a. Phase 1: Windup
- b. Phase 3: Arm Cocking
- c. Phase 4: Acceleration
- d. Phase 6: Follow Through

23. Provocative testing for _____ includes a valgus stress test, milking maneuver, and a moving valgus stress test.

- a. Elbow dislocation
- b. Little leaguer's elbow
- c. Pitcher's elbow
- d. Valgus Posterolateral Rotatory Instability (VPLRI)

24. Around weeks 4-6 of rehabilitation for a distal biceps rupture, which of the following therapeutic activities generally should take place?

- a. Grade III/IV joint mobilizations
- b. Initiate AROM elbow flexion/supination
- c. Initiate PROM elbow extension to tolerance
- d. Initiate triceps isometrics

25. Symptoms of _____ include chronic pain in the elbow joint, joint swelling, redness, and complaints of locking in place during activities.

- a. Medial collateral ligament injury
- b. Osteochondritis dissecans (OCD)
- c. Rupture of the distal biceps brachii
- d. Varus Posteromedial Rotatory Instability (VPMRI)

26. Which of the following is NOT one of the symptoms of complex regional pain syndrome (CRPS)?

- a. Brawny edema
- b. Dull, rough skin
- c. Increased vasomotor instability (blue or red skin color changes)
- d. Temperature differences between the affected and unaffected side

27. Considering clarifications to be obtained from your patient's physician, it's important to know if there is _____, because it increases your patient's risk of developing arthritis and also suggests a more complicated fracture with increased healing times.

- a. A specific post-op protocol that he/she would like you to follow
- b. Concern of a developing Essex-Lopresti injury
- c. Disruption in radial length
- d. Intra-articular extension of the fracture

28. The QuickDASH, a condensed version of the Disability of the Arm, Shoulder, and Hand (DASH) screen, consists of _____ activities; patients self-rate their level of difficulty performing each on a scale from 0% (no difficulty) to 100% (unable to perform).

- a. 11
- b. 17
- c. 24
- d. 30

29. History gathering may reveal "orange flags" - concerns that can negatively affect the patient's outcome, but aren't necessarily as serious as "red flags." An example of an "orange flag" might be _____.

- a. A patient who hates his job and doesn't want to return to it
- b. A patient who is counting on a large settlement for her injury
- c. A patient who reports that he never heals quickly and he doesn't expect to do well
- d. None of the above

30. While it endorses both methods, the American Society of Hand Therapists (ASHT) prefers that pronation and supination be measured _____.

- a. At the distal radius
- b. By having the patient hold a pencil in their hand and measuring the movement of the pencil
- c. Both of the above
- d. Neither of the above

31. Which stage of the normal inflammatory process is the easiest time to regain motion related to contracting tissue?

- a. Stage One (Days 1-5)
- b. Stage Two (After week 1 to week 6)
- c. Stage Three (6 weeks to 2 years)
- d. Anytime

32. When initiating education regarding active range of motion (AROM) of the elbow, it is MOST important to stress _____ with the patient.

- a. Amount of time spent at end range
- b. Intentional movement
- c. Number of exercise sessions
- d. Number of repetitions

33. The most sensitive of the three nerves at the elbow is the _____ nerve, which can suffer irritation and adhesions with longstanding elbow edema.

- a. Median
- b. Radial
- c. Ulnar
- d. There is no distinction; all three are affected equally

34. There are two ways to administer the _____: either placing the disks from above the board into the board, or turning the discs over in the board. The therapist can also add displacing, 1-hand turning and placing, and 2-hand turning and placing as assessment options.

- a. Jebsen-Taylor Hand Function Test (JHFT)
- b. Minnesota Manual Dexterity Test (MMDT)
- c. Nine-hole peg test
- d. Purdue Pegboard

35. Since pinch strength can be directly affected by injury to the ulnar nerve, it is considered important to test it as part of a thorough baseline for patients following an elbow injury. One of the three positions for testing pinch strength, the _____,) is between the thumb and the pulp

of the index finger; instruct the patient to place all other fingers in a full fist to avoid compensation.

- a. Chuck pinch
- b. Lateral pinch
- c. Three-point pinch
- d. Two-point pinch