Manuscript Title: The Examination and Treatment of Soft Tissue Contracture of the Elbow

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Normal Elbow Anatomy
The elbow is a complex constrained synovial hinge joint linking the distal humerus with the radius and ulna bones of the forearm. There are three bony articulations in the elbow. The ulnar trochlear groove articulates with the humeral trochlea, and the humeral capitellum articulates with the radial head, which together facilitate elbow flexion and extension. Additionally, the radial head and sigmoid notch of the proximal ulna articulate to create the proximal radioulnar joint (PRUJ), which, along with rotation of the radial head against the capitellum, allow forearm pronation and supination.

The bony elbow is immediately surrounded and stabilized by the articular capsule, which creates synovial fluid for chondral nutrition and joint lubrication and provides primary static stabilization medially and laterally through thickened portions of capsule termed the medial ulnar (MUCL) and lateral collateral ligaments (LCL). Surrounding the capsule are the muscular, or dynamic stabilizers of the elbow. This includes the anterior brachialis, the posterior triceps tendon, the medial flexor/pronator origin, and the lateral common extensor origin. The primary static stabilizers provide a fixed restraint to excess rotational and angular stress across the elbow, and the dynamic stabilizers work to keep the forces experienced by the static stabilizers below their respective thresholds of injury.

Adequate elbow range of motion is essential for positioning the hand in space for personal hygiene and during activities of daily living. Morrey et al (1) described the minimum functional arc of motion of the elbow joint in flexion and extension to be 100 degrees (30° extension to 130° flexion), and 50 degrees of pronation and supination from a neutral forearm. Elbow motion lacking in pronation and supination can be aided through glenohumeral abduction and humeral rotation, but stiffness that limits elbow flexion and extension is difficult to overcome through the glenohumeral joint and can produce significant functional limitation including the inability to reach one’s mouth or behind the back for toileting and perineal care.

Etiology of Soft Tissue Contracture of the Elbow
Soft tissue contractures of the elbow can have a traumatic origin, such as with burns, fractures and dislocations, spinal cord injuries, traumatic brain injuries, or surgery, or they may result from nontraumatic sources such as congenital limb abnormalities, inflammatory arthritis, infection, or recurrent hemarthroses as experienced by patients with hemophilia (2). Elbow stiffness secondary to soft tissue contracture may occur after elbow surgery with or without immobilization. More commonly, soft tissue contracture can occur over time secondary to the bony blocks to motion that accompany osteoarthritis or intraarticular malunion after fracture. When an elbow joint is limited to a constrained range of motion for an extended amount of time, the surrounding soft tissues including the capsule, the muscles, and in more severe cases,
the skin, become contracted and may become a contributing source of limited flexion, extension, and forearm rotation.

Our knowledge of the causes of soft tissue contracture in joints at the cellular level has improved through basic science research, however, we still have a limited understanding of this complex process (3).

Proinflammatory cytokines are triggered by trauma or some other instigating event, which in turn stimulate transformation of fibroblasts into myofibroblasts, a cell type that has been shown to be present in higher concentration in arthrofibrosis during adhesive capsulitis of the shoulder, in Dupuytren’s contracture, and with congenital clubfoot (3,4,5). Further supporting the evidence of myofibroblast’s role in the development of arthrofibrosis, myofibroblast upregulators TGF-β1, fibronectin, and connective tissue growth factor (CTGF), as well as their respective levels of mRNA, have been shown to be present in significantly higher concentrations in both a rabbit knee model and in the capsules of patients with elbow arthrofibrosis when compared to non-contracted controls (3, 4). In their rabbit model, Hildebrand et al have shown an interconnection between mast cells, myofibroblasts, and substance P in the development of elbow soft tissue contracture. Trauma, or some other instigating event, leads to nerve fiber release of substance P, which produces mast cell secretion of profibrotic cytokines, which triggers transformation of fibroblasts into myofibroblasts, ultimately producing arthrofibrosis and capsular contracture (3,4,6).

**Examination and Imaging of the Stiff Elbow**

Physical examination of a stiff elbow should begin with evaluation of the entire upper extremity, including the cervical spine, and from shoulder to fingertips. Asymmetry in station, bulk, and tone is noted. The skin is inspected for scars or other signs of trauma, as well as skin mobility and glide. The musculature of the hand, in particular the hypothenar and first dorsal interosseous muscles, are assessed for the presence of atrophy, which signals a possible ulnar neuropathy at the elbow.

Active elbow range of motion is assessed by instructing the patient to flex and extend both of their elbows simultaneously and noting any differences. Passive elbow range of motion is assessed with the patient’s arm adducted and flexed forward if possible, in neutral rotation (Figure 1). Flexion and extension between the affected and unaffected sides are compared. Although there is variation in formatting for how degrees of motion are recorded between examiners, one convention is to use 0° as full extension, with hyperextension past 0° recorded as “+15°” (Figure 2). Pronation and supination are recorded in degrees from neutral. Because the elbow and wrist connect through the forearm, active and passive wrist range of motion should be assessed and compared to the contralateral side as well.

Strength in elbow flexion, extension, pronation, and supination are recorded. The ulnar nerve is palpated posterior to the medial epicondyle. Stability of the nerve is assessed in elbow
extension and flexion, noting any subluxation of the nerve anterior to the medial epicondyle during elbow flexion.

Imaging of the stiff elbow starts with a standard three-view (anteroposterior, lateral, and oblique) Xray series. This will shed light on bony abnormalities and instability. CT scan with 3D reconstruction can help define malunion for correction, and MRI can help identify inflammatory and/or infectious causes of elbow contracture in the setting of normal bony architecture. Ultrasound can be helpful to evaluate ulnar nerve stability at the medial epicondyle.

**Treatment Options for Soft Tissue Contracture**

When treating soft tissue contracture of the elbow, the first step is to properly identify the causative factors for the stiffness. If the contracture is post-traumatic, the bony abnormalities must be addressed before the soft tissue. Malunited fractures must be corrected, and hardware removed if possible as retained hardware can contribute to stiffness caused by tendons or other soft tissue adhesions to plates and screws. In the setting of concurrent osteoarthritis, bony blocks to flexion and extension must be addressed before the soft tissue to eliminate mechanical obstruction.

When elbow stiffness results from soft tissue contracture and there are no obvious bony blocks to motion it may be beneficial to begin treatment with formal physiotherapy with static progressive and/or dynamic bracing (Figure 3). Soft tissue contractures have the capacity to improve over time, and bracing can help slowly stretch contracted capsule and muscle-tendon units such that surgery may be avoided. Hildebrand et al describe the timeline for potential range of motion gains in stiff elbows after trauma to be less than four months after injury their rabbit knee model, and from 6-12 months in their series of 25 patients with traumatic elbow injuries (3,6). Manipulation under anesthesia may work to break up early adhesions for motion gain early in the evolution of a contracture, but may have limited utility for more advanced stiffness or later in the process (7).

In cases of recalcitrant contracture when poor elbow range of motion is impacting function, elbow arthroscopy is a powerful tool to help achieve range of motion gains in a minimally-invasive fashion (Figure 4). Bony blocks to flexion and extension can be addressed through coronoid and olecranon tip osteoplasty, respectively, and anterior capsulotomy is performed concurrently (Figure 5). Care must be taken to protect the posterior interosseous nerve, which lies just anterior to the capsule over the radial head. Positioning the forearm in maximum supination during anterior capsulotomy may help protect this critical structure (8,9). The arthroscope may be used to facilitate release of the posterior band of the medial ulnar collateral ligament for greater gains in elbow flexion, but this places the ulnar nerve at risk for injury. For this reason, open ulnar nerve release and transposition is performed concurrently (10).
More chronic and/or severe elbow contractures may be better served with open capsulectomy due to risk of injury to neurovascular structures. Intraarticular malunion, prior surgery, and unclear location of the ulnar nerve are all indications for deferring the arthroscopy in favor of open surgery. This may be performed through a ligament-sparing lateral extended common extensor split approach, where the anterior capsule is dissected from the overlying brachialis muscle and excised to gain elbow extension (Figure 6). The triceps tendon and posterior capsule can be addressed through this approach concurrently, and hardware may be removed at this time. A medial approach is made to address the ulnar nerve, particularly when flexion gains are desired (10, 11). More chronic and severe cases may have secondary contracture that require release of the distal biceps tendon and/or complete medial ulnar collateral ligament release (14). Open and arthroscopic capsulotomy have produced similar results with respect to pain relief and improvement in elbow range of motion (10, 11, 12). Arthroscopic elbow osteoplasty and capsulotomy have a steep learning curve, however, but when compared to open capsulotomy arthroscopy is typically far less morbid and facilitates earlier aggressive range of motion rehabilitation (13). For these reasons, arthroscopy is the Author’s preferred first option when indicated to address the stiff elbow. Severe contractures in elderly, low demand patients with bony deformity may be treated with total elbow arthroplasty, however the risks of requirement for revision with this procedure compound over time, so this is not recommended for younger or more high-demand patients.

Ideally, rehabilitation is initiated promptly after open or arthroscopic soft tissue contracture release to help maintain the range of motion gains achieved during surgery and to help prevent post-op. More extensive dissection during open arthrolysis cases may necessitate more time before the initiation of therapy to allow time for soft tissue stabilization, however, recurrence of stiffness is common (up to 37%) with utilization of either technique (15, 16). It is important to note the range of motion that was achieved in the operating room after contracture release to help the physiotherapist know what range of motion is possible and helps them to establish expectations and goals for progress. The type of splint utilized after soft tissue release for elbow contracture continues to be a topic of debate, however, the use of a dynamic or a static progressive orthosis does not appear to affect maintenance of post-operative range of motion gains (17). A recent randomized trial compared continuous passive motion (CPM) to physical therapy following arthroscopic elbow contracture release. The authors reported faster postoperative recovery and greater elbow range of motion at one year with CPM compared to physical therapy (18). These results are promising, however, the expense and time required for CPM use should be taken into consideration and applied on a case-by-case basis.

References:


Figure 1: Examination of elbow extension (left), and flexion (right). Note the lack of approximately 30° of terminal extension (red arrow, left).
Figure 2: Demonstration of physiologic hyperextension of the elbow. In this case, the patient hyperextends 15 degrees.
Figure 3: Patient with soft tissue elbow contracture in a static-progressive elbow brace (Joint Active Systems, Effingham IL, USA). The brace can be adjusted to emphasize extension (left), or flexion (right).
Figure 4: Operative positioning for elbow arthroscopy, before (left) and after (right) sterile draping.
Figure 5: Intraoperative arthroscopic photos of anterior capsulotomy demonstrating an intact anterior capsule (left), during capsulotomy (center), and after capsulotomy (right). CP = Capsule; RH = Radial head; Cor = Coronoid. Red arrows represent progression of capsule release.
Figure 6: Intraoperative photo of open elbow anterior capsulectomy utilizing a lateral extended common extensor split approach. The anterior capsule is isolated (left) and excised (center). Posterior release and osteoplasty can be performed through this approach as well (right). CP = Capitellum; RH = Radial head.
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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: