The Stiff Elbow

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Abstract Elbow motion is essential for upper extremity function to position the hand in space. Unfortunately, the elbow joint is prone to stiffness following a multitude of traumatic and atraumatic etiologies. Elbow stiffness can be diagnosed with a complete history and physical exam, supplemented with appropriate imaging studies. The stiff elbow is challenging to treat, and thus, its prevention is of paramount importance. When this approach fails, non-operative followed by operative treatment modalities should be pursued. Upon initial presentation in those who have minimal contractures of 6-month duration or less, static and dynamic splinting, serial casting, continuous passive motion, occupational/physical therapy, and manipulation are non-operative treatment modalities that may be attempted. A stiff elbow that is refractory to non-operative management can be treated surgically, either arthroscopically or open, to eliminate soft tissue or bony blocks to motion. In the future, efforts to prevent and treat elbow stiffness may target the basic science mechanisms involved. Our purpose was to review the etiologies, classification, evaluation, prevention, operative, and non-operative treatment of the stiff elbow.

Keywords Elbow · Stiff · Contracture · Capsulectomy

Introduction

The elbow is a highly constrained synovial hinge joint, intolerant of trauma, with a high propensity for stiffness and degeneration. Articulations between the trochlea and capitellum of the humerus with the trochlear notch of the ulna and radial head, respectively, are the bony foundation of the elbow joint (Fig. 1a, b). The soft tissue boundary of the elbow joint is the articular capsule, which is weakest anteriorly and posteriorly but has well-defined lateral and medial ligamentous complexes (Fig. 1c, d).

Elbow motion serves to position the hand in space. Morrey et al. [46] found the functional arc of elbow motion during activities of daily living to be 100° for both flexion–extension (30° to 130°) and pronation–supination (50° in either direction). Although functional limitations can be seen with less severe loss of motion, a stiff elbow has been defined as one with loss of extension of greater than 30° and flexion of less than 120° [64]. Elbow stiffness results from perturbations of bone, soft tissue, or a combination of both that may or may not follow a traumatic event. The etiology of elbow stiffness is the basis of its classification, diagnosis, prevention, and treatment. Given the multitude of atraumatic etiologies of elbow stiffness and at least a 5% incidence following elbow trauma, elbow stiffness is a condition affecting numerous patients who will certainly be encountered by the clinician treating upper extremity pathology [64]. Early rehabilitation, minimal immobilization, advances in surgical management, and basic science investigation are efforts to improve outcomes in the management of the stiff elbow. Our purpose was to review the etiologies, classification, evaluation, prevention, operative, and non-operative treatment of the stiff elbow.

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Figure 1 Anterior (a) and lateral (b) views of elbow bony anatomy. Anterior (c) and lateral (d) views of elbow ligamentous anatomy.

Etiologies

There are numerous and varied inciting events ultimately resulting in a stiff elbow that can be broadly categorized as either traumatic or atraumatic. Trauma, burns, and head injury are known causes of elbow contractures that

are directly proportional to the severity of the insult [64]. Elbow surgery involves controlled trauma to the tissues and may be complicated by postoperative stiffness. Atraumatic causes of elbow stiffness include osteoarthritis and inflammatory arthritis, post-septic arthritis, multiple hemarthroses in hemophiliacs, and congenital contractures

Figure 2 Plain radiograph, A-P and lateral view, of elbow with heterotopic ossification.

found in arthrogryposis and congenital radial head dislocation.

Bone and soft tissue are what ultimately provide mechanical blocks to motion resulting in elbow stiffness. Intra-articular fracture, osteochondral defects, and arthritic changes alter the geometry of the elbow joint, leading to stiffness. Heterotopic ossification occurs commonly about the elbow in response to tissue trauma; this acts as a physical block to elbow motion (Fig. 2). Heterotopic ossification can also create a synostosis between the radius and ulna, eliminating forearm pronation/supination. Approximately 3% of simple elbow dislocations and up to 20% of elbow fracture–dislocations are complicated by heterotopic ossification [29, 59, 69]. Five percent to 10% of patients with isolated closed head injury form heterotopic ossification, as do patients with spinal cord injuries below the level of their injury [18, 29, 58, 65]. Those patients who have sustained both head injury and elbow trauma develop heterotopic ossification at a rate of 76% to 89% and are thus at highest risk for its formation [17, 29, 61]. Thermal and electric burns cause elbow heterotopic ossification formation in proportion to their degree and severity [25, 26, 29, 53]. Additional reported risk factors for the development of heterotopic ossification include: (1) two-incision distal biceps repair [11], (2) elbow arthroscopy [20], and (3) multiple surgeries within 7 to 14 days after trauma [29].

Trauma has immediate effects on the elbow that are direct causes of stiffness, but may also lead to elbow stiffness through secondary processes [37]. A poorly aligned articular surface following intra-articular fracture impedes elbow motion [37]. Similarly, osteochondral defects can prevent smooth motion at the articular surface, especially if a loose fragment remains within the joint. Trauma to the elbow articular surface results in its degeneration long after the

initial insult in posttraumatic arthritis [37]. Once again, an incongruous articular surface hinders elbow motion, as does osteophyte formation, a hallmark of the arthritic process. Articular surface degeneration and osteophyte formation are the end result of all arthritic processes such as inflammatory arthritis, septic arthritis, as well as arthritis secondary to multiple hemarthroses in hemophiliacs.

Soft tissue contractures lead to stiffness by physically restricting elbow motion. These soft tissue changes typically occur with the bony pathology described above. More specifically, intra-articular elbow pathology is often followed by contracture of the articular capsule, collateral ligaments, and muscles [64, 72]. If skin overlying the elbow is no longer supple following a burn, motion is again compromised (Fig. 3) [29].

Some of the mechanisms of elbow stiffness have been elucidated at the basic science level. The formation of heterotopic ossification is thought to require an osteo-inductive agent acting upon mesenchymal progenitor cells in an environment that is favorable to osteogenesis [9, 29, 66]. Patients with closed head injuries, who are more likely to develop heterotopic ossification, have increased levels of circulating osteoblastic growth factors [4, 29]. It has been shown that the number of myofibroblasts and levels of alpha-smooth muscle actin in the articular capsule of elbows with posttraumatic contractures are increased as compared to elbows without contractures [23]. The level of joint capsule matrix turnover was also found to be higher in elbows with posttraumatic contractures as compared to controls [24].

Classification

The two primary elbow stiffness classification systems are those of Kay and Morrey [29, 47]. While Kay's classification is based on the structure impeding elbow motion,

Figure 3 Elbow with soft tissue contracture secondary to burn.

Morrey's classification is based on the etiology and its anatomic location [29]. Kay's five-part classification system includes soft tissue contracture (type I), soft tissue contracture with ossification (type II), non-displaced articular fracture with soft tissue contracture (type III), displaced intra-articular fracture with soft tissue contracture (type IV), and posttraumatic bony bars (type V) [29].

Morrey's three-part system classifies elbow stiffness as extrinsic, intrinsic, or mixed [29, 47]. Extrinsic stiffness is due to extra-articular causes, including capsular, collateral ligament, and muscle contractures as well as heterotopic ossification and extra-articular malunions. Intrinsic stiffness is due to intra-articular adhesions, loose bodies, osteophyte formation, or malalignment of the articular surface. Extrinsic contractures developing as a result of intrinsic pathology are classified as mixed.

Evaluation

A thorough history and physical examination complimented by imaging studies comprise the requisite evaluation for elbow stiffness. The history should include the onset, duration, character, and progression of symptoms. Inquiries should be made into elbow trauma or pathology, especially infection, and prior non-surgical or surgical treatments. Comorbid conditions should be investigated, as they may have implications on the elbow such as hemophilia with resulting hemarthroses or neurologic conditions involving spasticity. The patient's vocational and recreational pursuits should be established in order to determine the level of demand that will be placed on the elbow.

Physical examination should begin with a neurovascular exam with particular attention to ulnar nerve function. Not only is the ulnar nerve commonly involved in elbow trauma, but if operative treatment for the elbow is necessary, preoperative ulnar nerve function should be known [1, 13, 15, 22, 28, 29, 36, 40, 42–44, 49, 55, 62, 71, 74, 75]. Active and passive elbow range of motion, for both flexion–extension and pronation–supination, should be examined. The character of the endpoint at the extremes of motion should be noted. While a firm endpoint suggests a bony block to motion, a soft endpoint is indicative of a soft tissue contracture. Crepitus appreciated during elbow range of motion may signify degenerative changes, synovitis, or fracture.

The first imaging studies to evaluate a stiff elbow should be plain radiographs, including anterior–posterior, lateral, and two oblique views. Bony blocks to motion can often be detected using this modality. Should further detail of the articular surface be required, computed tomography of the elbow with two- and sometimes three-dimensional reconstructions should be performed which will aid in surgical planning for the removal of extensive heterotopic ossifica-

Figure 5 Lateral column approach (a). Skin incision (a-1). Anterior and posterior inter-muscular intervals (a-2). Anterior and posterior intervals carried down to joint capsule (a-3). Anterior interval carried down to capsular incision anterior to radial collateral ligament (a-4). Posterior interval carried down through capsule to posterior joint space (a-5). Medial over-the-top approach (b). Skin incision (b-1). Skin and subcutaneous tissue retracted to expose structures surrounding medial epicondyle (b-2). Common flexor tendon, pronator teres, and brachialis reflected anteriorly from medial epicondyle to reveal joint capsule (b-3). Anterior capsule incised to reveal joint (b-4). Posterior joint space exposed and ulnar nerve transposed (b-5). Release/excision of posterior medial collateral ligament (b-6).

tion. Live fluoroscopy can be used to distinguish between a bony block and soft tissue contracture.

Prevention

The stiff elbow is challenging to treat, and thus, its prevention is of paramount importance. The loss of soft tissue compliance that leads to elbow contracture results from bleeding, edema, granulation tissue formation, and ultimately fibrosis [50]. Splinting the elbow in full extension postoperatively creates sufficient pressure within tissues around the elbow to minimize bleeding and resist extravasation of fluid [2, 29, 50]. Continuous passive motion (CPM) applied to the elbow immediately postoperatively and continued for 3 to 4 weeks until soft tissue swelling is controlled drives fluids away from the joint and periarticular tissues, thus minimizing the cascade of events leading to soft tissue contracture [29, 50]. However, a requisite for splinting in extension and postoperative CPM is stable postoperative bony and soft tissue support of the elbow.

Elbow stiffness is also prevented with the effective treatment of disease processes that damage the elbow articular surface

Figure 4 Static progressive elbow splint.

a
1

2

3

4

5

Fig. 5 (continued).

and compromise motion. The underlying processes involved in inflammatory arthropathies should be medically controlled with a rheumatologist-prescribed anti-inflammatory/disease-modifying/biologic regimen to slow joint destruction. Hemophiliacs should receive appropriate blood factor repletion to prevent multiple hemarthroses. Joint degeneration may also be

avoided with the emergent irrigation and debridement of a septic elbow, which halts cartilage destruction by proteolytic enzymes found in purulent material.

Heterotopic ossification, a potential bony block to elbow motion, may be prevented following surgical release of stiff elbows with the use of radiation postoperatively [60].

Figure 6 Arthroscopic view of elbow with abundant soft tissue adhesions (a). Arthroscopic lysis of adhesions (b) and debridement (c).

While nonselective non-steroidal anti-inflammatory drugs (NSAIDs) such as indomethacin have been used effectively to prevent formation of heterotopic ossification around the hip, further investigation is required to elucidate the role of NSAIDs in preventing elbow heterotopic ossification [37].

Treatment

The goals in treating the stiff elbow are to provide patients with a pain-free, functional, and stable elbow. Both non-operative and operative treatment modalities are available. Timing, severity, patient specific factors, and underlying pathology guide the selection of specific treatment protocols. Non-operative treatment is considered upon initial presentation in those who have minimal contractures of 6-month duration or less [27, 35, 72]. Operative treatment is appropriate for those patients who have failed to achieve adequate pain relief or functional range of motion after initial non-operative management.

Non-operative treatments for elbow stiffness include static and dynamic splinting, serial casting, CPM, occupational/physical therapy, and manipulation [5, 8, 21, 29, 31, 47, 63, 64, 72, 76]. These treatment modalities have yielded variable results, with some patients gaining motion and others, ironically, losing motion [72, 73].

Soft tissue contractures that result in moderate loss of elbow flexion or extension have been treated effectively by Sojbjerg [64] using a dynamic splint. The contractures must

Table 1 Algorithm for surgical release of elbow contracture.

Pathology/motion loss	Ulnar nerve symptoms	Surgical preference
Lack extension	No	1—Open MOTT + CBTR/T 1—Open lateral column 1—Arthroscopic
	Yes	1—Open MOTT + CBTR/T 1—Arthroscopic + CBTR/T
Lacking flexion with <100 degrees present	No	1—Open MOTT + CBTR/T + pMCL 1—Arthroscopic + CBTR/T + pMCL
	Yes	2—Open lateral column 1—Open MOTT + CBTR/T + pMCL 1—Arthroscopic + CBTR/T + pMCL
Lacking flexion with >100 degrees present	No or Yes	1—Open MOTT + CBTR/T + pMCL 1—Arthroscopic (anterior + posterior) + CBTR/T + pMCL or (Arthroscopic anterior + open posterior)
Heterotopic bone	No or Yes	Open medial or lateral (+/- CBTR/T +/- pMCL depending on symptoms and pathology)

MOTT medial over-the-top, *CBTR/T* cubital tunnel release/ulnar nerve transposition, *pMCL* open resection of the posterior band of medial collateral ligament, 1 preferred, 2 alternative, + presence, – absence

be less than a year old in adults, but can be of indefinite duration in children. Once a stiff elbow is pain-free, this splint can be applied at night with serial increases in the tension of its adjustable spring. The patient must remain pain-free while the tension of the spring is increased, or the splint will not be tolerated. Non-steroidal anti-inflammatories are administered to minimize joint inflammation. Reversed dynamic slings were shown by Shewring et al. [63] to increase the range of motion in elbows with posttraumatic flexion contractures by 39%. However, patients often complain of pain and discomfort with dynamic splinting (resulting in non-compliance), likely from increased co-contraction of elbow flexors and extensors due to constant tension on the soft tissues [52].

Static progressive adjustable splints (Fig. 4), such as the turnbuckle splint, commercially available flexion–extension and pronation–supination splints, and serial above-the-elbow casts, have been shown to help recover elbow range of motion. Bonutti et al. [5], Green and McCoy [21], and Gelinas et al. [19] have reported a 25° to 43° increase in

range of motion in contracted elbows following static progressive splinting. Zander and Healy [76] have shown that elbow flexion contractures can be reduced by 33° with the use of serial casting. Some of these devices may be more cumbersome for the patient than a dynamic splint, but offer more comfort due to the inherent stress relaxation of the tissues [29, 64].

Manipulation of the stiff elbow can be beneficial, but the procedure is not without risks. Duke et al. [8] found an increase in elbow motion in 55% of patients; the only complications reported were in two out of 11 patients who had transient sensory ulnar neuropathies. Additional complications, such as periarticular fracture and heterotopic ossification formation/exacerbation, have been reported by others [29, 45, 72].

Children with upper brachial plexus palsy suffer from elbow flexion contractures. Non-operative treatment modalities such as electrical stimulation and physical therapy are the mainstays of treatment. Basciani and Intiso [3] have shown that in children who have failed serial cast treatment,

Figure 7 En face view of distal humerus with severe degenerative disease (a). Cutis graft preparation from abdomen (b, c). Distal humerus following cutis soft tissue resurfacing (d).

Figure 8 Plain radiograph, lateral view, of elbow with external fixator.

botulinum toxin type A injection followed by plaster casting has improved active elbow extension by approximately 27° .

A stiff elbow that is refractory to non-operative management can be treated surgically, either arthroscopically or open. The decision to operate is based on elbow function, patient factors, and surgeon preference. Flexion contractures/extension lag greater than 30° or the inability to flex the elbow to at least 130° is often an indication for surgery. However, surgery may be pursued for smaller deficiencies in elbow motion if a patient's lifestyle or vocation is significantly impaired. Patient factors that may influence the decision to operate are comorbidities and willingness or ability to comply with a rigorous postoperative rehabilitation program. Surgeon comfort with a procedure and the reliability and efficacy of a procedure in a surgeon's hands may also determine the type of surgery pursued [68]. All surgical procedures must: (1) respect the close proximity of critical neurovascular structures; (2) minimize soft tissue trauma by exploiting defined soft tissue planes/intervals; and (3) critically evaluate fracture reduction, stability, and intraoperative gains in range of motion. With that said, the technique for surgical release of elbow contractures should follow the pathology, the site/direction of loss of motion, and the presence or absence of ulnar nerve symptoms/signs.

Open surgery using a lateral approach to the stiff elbow as described by Morrey has been termed "the column procedure" (Fig. 5a) [29, 38]. Hotchkiss et al. described the medial over-the-top (MOTT) approach (Fig. 5b) [32]. Both involve anterior and posterior capsulectomy and preservation of collateral ligaments and consideration of partial release only in severe contractures. Flexion contractures greater than 100° require ulnar nerve decompression (we also prefer transposition), as cubital tunnel retinaculum and posterior band of the medial collateral ligament (pMCL)

contracture and changes intrinsic to the nerve may result in a stretch injury of the nerve with gains in flexion [29, 49].

Arthroscopy can be used to address both bony blocks to motion and soft tissue contracture about the elbow (Fig. 6a–c). However, capsular contracture causes decreased intra-articular volume; Gallay et al. [16] reported the capacity of the normal elbow joint as 14 mL and that of the stiff elbow as only 6 mL. This makes arthroscopic access and visualization difficult [29, 70]. There is also potential for injury to neurovascular structures, which lie particularly close to arthroscopic portals in the stiff elbow with low intracapsular volume [72]. The use of retractors greatly facilitates arthroscopic visualization of the stiff elbow [29, 33]. The risk of injury to anterior neurovascular structures also increases with a more extensive capsular excision [29]. Osteophytes at the tip of the olecranon or coronoid process and loose bodies have been removed arthroscopically with good results and few complications [64, 72].

In our hands, the technique for elbow release starts with the determination of whether the loss of motion is flexion,

Figure 9 Plain radiographs, A-P (a) and lateral (b) views, of total elbow arthroplasty.

extension, flexion and extension, and whether osteophytes or heterotopic bone contributes (Table 1). Patients that lack elbow flexion have significant thickening and contracture of the pMCL and medial joint capsule, and these structures require resection at the time of surgery. The pMCL lies on the floor of the cubital tunnel, and excessive scarring can also lead to ulnar nerve compression and symptoms. If a patient cannot passively flex greater than 90–100°, then open release of the ulnar nerve and resection of the pMCL should be performed [29, 33]. After that is done, the remainder of the release could be all arthroscopic, posterior open plus anterior arthroscopic, or all open via a MOTT procedure (see below). Our choice is to transpose the ulnar nerve subcutaneously when the nerve is required to be released.

If a patient has acceptable flexion and only lacks extension, then the release can be done either all arthroscopic, open via a lateral column (see below), or a MOTT technique. For patients with combined flexion and extension contractures, if a patient lacks flexion but can flex more than 100°, then it is surgeon preference as to technique, but one should be prepared to perform an adjuvant open medial incision to resect the pMCL. Patients with osteophyte formation can be treated as above with debridement of any bony blocks to motion, but when heterotopic bone is required to be removed, we generally prefer open resection only.

Many of the above arthroscopic techniques are employed in arthroscopic osteocapsular arthroplasty, as described by O'Driscoll [51]. This technique uses arthroscopic osteophyte excision, loose body removal, and capsulectomy to improve function and alleviate pain in those suffering from arthritis with contracture. Contraindications to this procedure include submuscular ulnar nerve transposition, which places the nerve at risk for injury during the procedure, posttraumatic arthritis with severe joint surface irregularities, and non-hypertrophic osteoarthritis in patients older than 65 years. While O'Driscoll [51] reports reliable success with this procedure, he warns that it should only be performed by experienced elbow arthroscopic surgeons. Of particular concern is any attempt to release the pMCL arthroscopically, as the ulnar nerve can be scarred directly to it.

When elbow stiffness is a result of the destruction of at least 50% of the articular surface, interposition arthroplasty is a viable option in the young, high-demand patient [10]. This procedure first involves contouring the ulno-humeral joint so that the surfaces are complementary (Fig. 7a). The joint is then resurfaced with a biologic material, such as autograft fascia lata or cutis (Fig. 7b–d) [14] or allograft Achilles or dermal graft (graft jacket). Following extensive soft tissue release and excision of bone to regain motion in a stiff elbow, the joint may be rendered unstable. External fixation (hinged) can be used in this situation to provide sufficient stability to allow for soft tissue healing without limiting early postoperative

motion (Fig. 8) [56, 67]. Joint distraction can also be applied across the joint using the hinged external fixator to minimize insult to the interposed tissue during early postoperative motion [7, 10]. It has been reported in the literature that distraction interposition arthroplasty yields satisfactory results 69–92% of the time [6, 14, 48, 54, 67]. However, the need for external fixation following a stable contracture release without interposition was shown to offer no added benefit and in fact causes increased numbers of complications [57].

Recently, the role of botulinum toxin-A in preventing posttraumatic elbow stiffness in adults has been explored. In patients who underwent open reduction and internal fixation following elbow fracture or fracture dislocation, intraoperative injection of botulinum toxin-A into the elbow flexors resulted in improved postoperative range-of-motion and function [34]. Presumably, this limits the overpowering flexor muscle spasticity that sets up a cycle of co-contraction with the triceps across the joint. Similarly, botulinum toxin-A in the triceps postoperatively has had promising results in our hands for patients undergoing pMCL and posterior capsular release to gain flexion.

While focus is largely placed on loss of elbow flexion and extension, loss of pronation and supination (forearm rotation) can also be disabling. Heterotopic ossification resulting in proximal radioulnar synostosis greatly limits forearm rotation and is a difficult problem to treat surgically given the close proximity of neurovascular structures. Proximal radial resection at a point just distal to the radioulnar synostosis, creating a pseudo joint, has shown to have favorable outcomes with an increase in average arc of forearm rotation from 0° to 98° [30]. In patients with congenital proximal radioulnar synostosis, it has been reported that acute elbow flexion contracture induced by forced hyperflexion resolves after excision of a hypoplastic annular ligament-like structure [41].

When the ulnohumeral joint surface cannot be salvaged (greater than 50% involvement of the articular surface) following surgical release of a severely contracted or ankylosed elbow, total elbow arthroplasty is considered in patients greater than 60 years (Fig. 9a, b). Instability often results following operative release of a stiff elbow, so a semi-constrained implant is recommended. Figgie et al. [12] reported a significant increase in mean arc of motion (0° preoperatively to 80° postoperatively) following total elbow arthroplasty using semi-constrained and custom prostheses in completely ankylosed elbows. Mansat and Morrey [39] showed a significant increase in mean arc of motion (7° preoperatively to 67° postoperatively) following total elbow arthroplasty without the use of custom implants in patients with stiff and ankylosed elbows. These are difficult procedures and high complication rates were reported.

Summary

The elbow joint is critical to upper extremity function as it positions the hand in space. With a stiff elbow, the entire upper extremity range of motion is diminished and function suffers. While there are multiple non-operative and operative treatment options available to address the bony and/or soft tissue basis of elbow stiffness, prevention is of paramount importance, as this is a difficult condition to treat. In the future, efforts to prevent elbow stiffness may target mechanisms involved at the basic science level.

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