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ELBOW SOFT TISSUE SURGERY (L OH, SECTION EDITOR)

The posttraumatic stiff elbow: an update

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Abstract Posttraumatic elbow stiffness is a disabling condition that remains challenging to treat despite improvement of our understanding of the pathogenesis of posttraumatic contractures and new treatment regimens. This review provides an update and overview of the etiology of posttraumatic elbow stiffness, its classification, evaluation, nonoperative and operative treatment, and postoperative management.

Keywords Posttraumatic · Contracture · Elbow · Release · Stiffness

Introduction

Stiffness of the elbow after trauma is a well-recognized disabling condition that interferes with daily activities [1]. Loss of motion after elbow injury results from abnormalities of bone, soft tissue, or a combination of both, which may be present intra-articular as well as extra-articular [2, 3]. Improved understanding of the cause of stiffness has led to advances in nonoperative and operative treatment [4•, 5–11]; however, restoration of joint motion in the posttraumatic stiff elbow remains difficult and poses a challenge for surgeons [12]. In this review, we discuss the etiology of posttraumatic elbow stiffness, its classification, evaluation, and management.

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Etiology

Posttraumatic stiffness of the elbow is caused by multiple factors, including soft tissue contractures, heterotopic ossification, extra- and intra-articular malunions, nonunions, and loss of articular cartilage.

Soft tissue contracture

Observations in patients with severe elbow stiffness suggested that contractures of soft tissue around the elbow, most especially the capsule, are associated with loss of motion after trauma [13]. Analyses of elbow joint capsules from patients undergoing surgery for elbow contracture have demonstrated capsular thickening [14], disorganization of collagen fiber arrangements [14], altered cytokine and enzyme levels [14, 15], and elevated myofibroblast numbers [16, 17]. Myofibroblasts have contractile and secretory properties that contribute to wound healing and tissue repair but can severely impair organ function if extra-cellular matrix protein secretion and contraction become excessive, such as in Dupuytren disease [18]. However, myofibroblasts seem absent in chronic elbow contractures (more than 5 months), suggesting that its influence is more prominent early after acute trauma [19•]. Animal models, designed to study posttraumatic stiffness and contracture, support the important role of myofibroblasts in the development of posttraumatic elbow stiffness and have identified complex interactions, such as the transforming growth factor-beta signaling pathway, which influence the differentiation and activity of myofibroblasts [20•, 21, 22].

Heterotopic ossification

Elbow stiffness may be secondary to heterotopic ossification [23]. Heterotopic ossification is defined as formation of mature lamellar bone in nonosseous tissue and can be distinguished from other pathologic bone formation, such as myositis ossificans and periarticular calcification [24]. The differentiation of progenitor cells to osteogenic precursor cells, induced by cell-mediated interactions and local microenvironment, leads to the formation of heterotopic ossification [25]. The newly formed ectopic bone restricts elbow motion and upper extremity function by a discrete block to motion. Several factors increase the risk of developing HO around the elbow, including central nervous system injury, burns, surgery (i.e., time to surgery and time to mobilization after surgery), and most commonly direct trauma [26–30].

Extra-articular malunions

Restriction of elbow motion after extra-articular malunions of the distal humerus is explained by its complex geometry. The capitellum and trochlea are translated anteriorly to the humeral diaphysis, which creates an angle between the long axis of the humerus and the distal articular segment. The lateral column follows this translation, whereas the medial column is more in line with the diaphysis. Anterior translation provides space for the coronoid process and anterior arm and forearm musculature during flexion of the elbow [31]. Compromising this relationship in treatment of distal humeral fractures can lead to loss of elbow motion [32]. A straight plate on the lateral column for fracture fixation, for example, may result in loss of anterior translation of the articular segment of the distal humerus. A plate that is precontoured to fit the lateral column helps to restore the original anatomy of the distal humerus and prevent malunion and thereby loss of elbow motion [33, 34]. The relationship between anterior translation of the distal humeral articular surface and elbow flexion after open reduction internal fixation (ORIF) has been established; however, loss of translation cannot explain the total variation in restricted elbow flexion after ORIF of a distal humerus fracture, which therefore seems to be multifactorial [35].

Intra-articular malunions

Malunion after an intra-articular fracture of the distal humerus may lead to loss of elbow motion. Malunited articular surface of the distal humerus distorts its complex articulation but may also lead to periarticular fibrosis and compromised ulnar nerve function [36]. Distortion of the geometric dimensions of the trochlea and its relationship with the greater sigmoid notch of the ulna (i.e., the ulnohumeral joint) impairs the intrinsic stability, normal kinematics, and function of the elbow [37]. Intra-articular malunion of the distal humerus can occur alone or together with nonunion [36, 38]. Malunited radial head fractures typically present with stiffness of the forearm rather than ulnohumeral stiffness or arthrosis of the radiocapitellar or proximal radioulnar joint [39].

Nonunions

Nonunion of the elbow leads commonly to elbow stiffness, which is attributed to articular distortion, intra-articular adhesions, or damage of the articular surface [36, 40]. Several factors predispose to nonunion, including patient and fracture characteristics (comminution, open fractures, high-energy injury, infection, devascularization of fracture fragments, interfragmentary defects, and metabolic or cellular abnormalities) and fracture management (inadequate fixation, interposition of soft tissue, and premature motion) [41]. Nonunions of fractures of the distal part of the humerus may be extra-articular (at the supracondylar level), intra-articular, or both intra-articular and extra-articular. Nonunions at the supracondylar level are most frequently seen [9]. Nonunions of the proximal ulna are most frequently encountered after posterior Monteggia fractures and olecranon fracture-dislocations. Olecranon nonunion may also be the result of inadequate treatment of simple fractures or osteotomy for fracture exposure [42]. Coronoid process nonunion is uncommon [43]. Nonunions of nonoperatively treated isolated radial head or neck fractures are rare [44–46] and typically do not interfere with elbow motion.

Loss of articular cartilage

Arthrosis is a common after elbow trauma and is associated with stiffness of the elbow [47–49]. Its development is attributed to a combination of biomechanical, biochemical, and, most likely, genetic factors [50]. Radiographic signs of elbow arthrosis are usually graded according to the criteria of Broberg and Morrey [51, 52], grade 0, normal joint; grade 1, slight joint-space narrowing with minimum osteophyte formation; grade 2, moderate joint-space narrowing with moderate osteophyte formation; and grade 3, severe degenerative change with gross destruction of the joint. Distal humerus fractures, including columnar, capitellum, and trochlear fractures, as well as elbow fracture-dislocations seem to be associated with moderate or severe radiographic arthrosis in the long term, whereas olecranon and radial head fractures and patient characteristics are not [53].

Classification

Posttraumatic elbow stiffness is most commonly classified based on specific structures involved (soft tissue, osseous, or combined) or anatomic location (intrinsic, extrinsic, or combined). Classification according to the structures involved is described by Kay [3], type 1, soft tissue contracture; type 2, soft tissue contracture with ossification; type 3, undisplaced articular fracture with soft tissue contracture; type 4, displaced intra-articular fracture with soft tissue contracture; and type 5, posttraumatic bony bars. Classification of posttraumatic elbow stiffness into intrinsic, extrinsic, or combined contractures has been purposed by Morrey [2]. Intrinsic contractures involve the articular surface (intra-articular adhesions, intra-articular malunions, or loss of articular cartilage), whereas extrinsic contractures do not (capsular and ligament contractures, heterotopic ossification, extra-articular malunions, and soft-tissue contractures following burns). Most posttraumatic stiff elbows have both intrinsic and extrinsic components (Fig. 1).

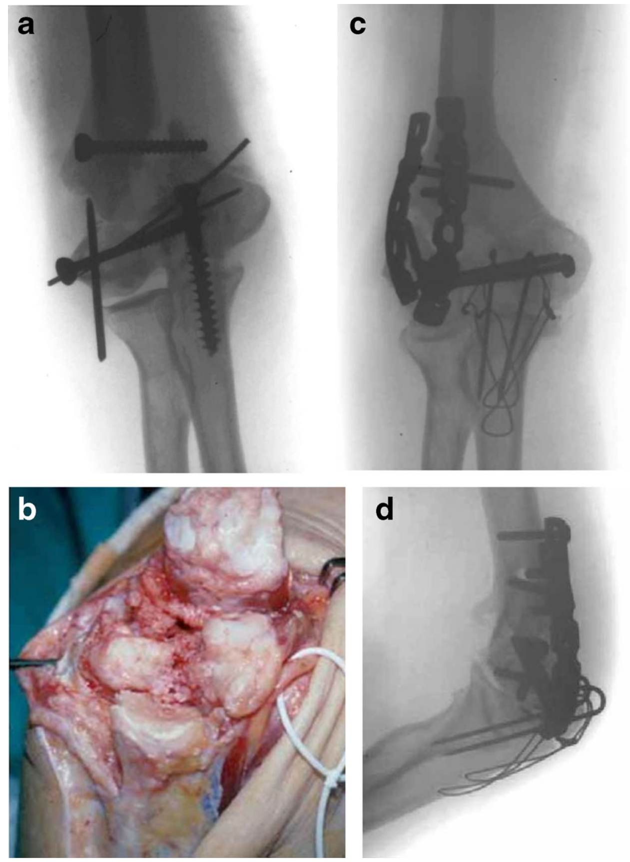

Fig. 1 A 49-year-old woman with intra- and extra-articular nonunion of the distal humerus and contracture of soft tissue around the elbow. **a** Radiograph before revision surgery (anteroposterior view). **b** Image obtained during revision surgery. **c** Radiograph after revision surgery (anteroposterior view). **d** Radiograph after revision surgery (lateral view)

Evaluation

A thorough history of patients with posttraumatic elbow stiffness should address the original injury and initial treatment [12]. In addition, associated conditions (e.g., nervous system disorders, infections, and ipsilateral injuries) need to be recognized [12, 39]. Timing of presentation, character and progression of symptoms, and functional level before injury, which may influence decision making, must be reviewed as well. It is also recommended to discuss patients' expectations in order to avoid disappointment due to unexpected events and outcomes. Patients might have unrealistic expectations, such as getting a perfect arm after operative treatment, while being able to depend on your arm is more important for good health.

Physical examination includes active and passive flexion-extension and pronation-supination, in which motion at the limits may be abrupt and rigid due to a bony block or compliant in case of soft tissue contracture [24]. Although most patients with a posttraumatic stiff elbow do not experience pain at rest, its presence after operative treatment might indicate a low-grade infection. Pain within the midarc of motion indicates incongruity of the joint or loss of cartilage, whereas pain at the limits of motion suggests impingement between the coronoid or olecranon process and the distal humerus [24, 48, 54]. There should be special attention for the function of the ulnar nerve during neurologic evaluation of the upper extremity, as impaired function of the ulnar nerve could be the result of elbow trauma and may lead to pain at motion [2, 12].

Anteroposterior and lateral radiographs must complement history and physical examination for full assessment [39]. The evaluation of the articular surface requires two separate anteroposterior views, one that is perpendicular to the radius and ulna and a second perpendicular to the humerus. Lateral views may be helpful for the recognition of bony impingement. The addition of computed tomography (CT), especially three-dimensional CT-based reconstructions, might be useful to identify or further characterize loose bodies, impinging osteophytes, and heterotopic ossification [23, 25, 55, 56]. In contrast, magnetic resonance imaging is not considered to be useful as heterotopic ossification and joint congruity is better defined on CT images [24]. Laboratory testing, measurement of inflammatory markers in particular, is helpful to detect infection. Elbow aspiration could be considered in case of abnormal laboratory findings or evident signs of inflammation.

Nonoperative treatment

Treatment may be indicated if loss of elbow motion interferes with activities of daily living. Most activities of daily living can be performed with 100° of elbow flexion (30° to 130°) and 100° of forearm rotation (50° of pronation and 50° of supination) [57]. However, patients may require motion beyond this average functional arc of motion. For patients presenting within 6 months after injury, nonoperative treatment with elbow splinting or manipulation under anesthesia could be considered.

Static progressive and dynamic elbow splinting can be used to regain motion in patients with posttraumatic elbow stiffness. In static progressive splinting, the joint angle stepwise increases to apply a force to contracted tissues that decreases as the tissues stretch, while in dynamic splinting, a consistent force is applied to the tissues that is maintained as the tissues stretch and improvement of motion is achieved. Both static progressive and dynamic elbow splinting help increase range of motion [58–63]. There seems no difference in improvement of flexion arc between static progressive and dynamic elbow splinting methods, and the choice of splinting protocols can be determined based on the preference of the surgeon and patient [6].

Manipulation of the elbow with patients under anesthesia can be attempted in case of radiographic evidence of osseous fracture healing. However, the outcomes of manipulation under anesthesia have only been reported for patients with elbow stiffness following surgery [64, 65]. To our knowledge, its effect has not been demonstrated in patients with elbow stiffness after trauma.

Operative treatment

In case nonoperative treatment fails or is not indicated, operative treatment can be considered. Before offering operative treatment, there must be radiographic evidence of union. In addition, the patient should demonstrate the motivation and ability to complete a challenging and prolonged rehabilitation program.

Open contracture release

Several approaches for open contracture release have been described. The preferred approach depends on the type of elbow contracture (i.e., intrinsic, extrinsic, or combined contractures), need for decompression of the ulnar nerve, location of prior elbow incisions, and location and extent of heterotopic ossification. Overall, complication rates are low [66]. The most common complications include peripheral neuropathy, postoperative infection, and recurrence of stiffness and heterotopic ossification.

The lateral approach [67] (i.e., lateral column procedure) allows arthrotomy, release of the anterior and posterior capsules, and exploration of the lateral side of the joint. However, this approach does not provide adequate exposure to address articular pathology of the medial part of the ulnohumeral joint and decompression of the ulnar nerve requires additional exposure. A curved incision is used in this procedure (i.e., a proximal one half of a Kocher incision), after which the capsule is entered at the radiohumeral joint. The lateral aspect of the capsule is excised, where the medial capsule is incised, and intra-articular adhesions and osteophytes are removed. The triceps is elevated from the distal humerus to allow release of the posterior capsule and debridement of the olecranon fossa. The olecranon tip is excised if necessary. This lateral procedure is associated with high patient satisfaction and improvement in elbow motion [67–73].

The medial approach [74] can be used to address the articular surface of the medial side of the ulnohumeral joint, decompress the ulnar nerve, remove heterotopic ossification, and release of the medial collateral ligament. This approach provides limited exposure to the lateral side of the joint. In this procedure, the incision is made medial along the midline over of the medial epicondyle. After incision, the antebrachial cutaneous nerve is protected. The ulnar nerve is mobilized and transposed anteriorly. Exposure is obtained by elevating the flexor pronator mass off the anterior aspect of the medial epicondyle. Once the anterior aspect of the capsule has been adequately exposed, it can be excised or incised if excision cannot be done safely. The medial aspect of the triceps is elevated to identify and excise the posterior capsule, release the posterior band of the medial collateral ligament, and remove osteophytes and heterotopic bone. Isolated medial approach has few indications, and it is most commonly used in addition to the lateral column procedure with satisfactory results [10, 73, 75–79].

The anterior approach [80] is limited. Neurovascular structures are at risk during this procedure, and additional release is frequently required. The anterior incision is made in a curvilinear S-shape across the antecubital skin crease, which is followed by protection of the neurovascular structures (medial and lateral antebrachial cutaneous nerves, brachial artery, median nerve, radial nerve, and musculocutaneous nerves). The interval between the common flexor origin and biceps tendon is then developed, and the brachialis muscle is dissected from the capsule. The anterior capsule is excised after adequate exposure. This procedure is predominantly indicated for isolated flexion contractures or anterior heterotopic bone [80–82].

The posterior approach [83] should be reserved for extensive releases. A posterior midline incision is used in this procedure. After the medial border of the triceps is released, the extensor mechanism is reflected and the anconeus muscles are released from the ulna. The ulnar nerve is mobilized and the posterior band of the medial collateral ligament is released [84]. As most case series combine the results of different approaches, comparison of results between different procedures is difficult. However, the results of the respective approaches demonstrate durable improvement in elbow motion [10, 75, 76, 79, 85, 86].

With regard to heterotopic ossification, open capsular release can be performed after the removal of heterotopic bone [87]. Complete ankylosis of the elbow due to heterotopic ossification requires a unique approach [8]. This approach is challenging when mature heterotopic bone encases the elbow joint, which makes it difficult to recognize the demarcation of the heterotopic bone and the original bone. For this reason, the articulation may be difficult to identify, especially on the posteromedial part of the ulnohumeral joint. An osteotome is needed to remove the heterotopic bone in layers, which is done with great care to avoid iatrogenic injury. After the heterotopic bone is resected and capsular release has been performed, the elbow is manipulated to maximize elbow motion. In case the elbow tends to subluxate or dislocate after release, hinged external fixation should be considered. Although the majority of patients with complete ankylosis secondary to heterotopic bone show good results after treatment, recurrence of severe contracture is seen in a subset of patients [8, 23].

Arthroscopic contracture release

Arthroscopic capsular release of the elbow allows debridement, synovectomy, removal of adhesions and osteophytes, and capsular release [88–92]. Arthroscopic release is challenging due to the proximity of neurovascular structures and restricted work space [93, 94]. Reported complications include nerve injury, infection, inadequate release, recurrence of stiffness, ectopic bone formation, and persistent drainage [95]. Arthroscopic capsular release is usually only considered for simple elbow contractures [1], which has been defined as elbow contractures with an arc of motion equal to or greater than 80°, no or minimal prior surgery, no prior ulnar nerve transposition, no or minimal internal fixation or hardware in place, no or minimal heterotopic ossification, and normal osseous anatomy [4]. However, with greater experience, more complex contracture releases can be performed. The demanding technique for arthroscopic elbow capsule release developed rapidly from stripping the capsule to capsulotomy and capsulectomy [96], which has shown to be safe and effective in patients with a posttraumatic elbow contracture [97–100].

Interposition arthroplasty

Interposition arthroplasty is indicated if the articular anatomy cannot be restored and reconstruction of the articular surface is necessary [49, 101–104]. It is used in younger patients as an alternative to prosthetic replacement. A posterior skin incision or prior incision is used to obtain a wide surgical exposure. The general concept is to reshape the distal humeral and ulnar articular surface through a recontouring osteotomy in order to create a new congruent joint [105]. The interposition graft is secured to the distal humerus and the collateral ligaments are reconstructed. A hinged elbow external fixator is applied to protect the interposed graft. Complications include neuropathy, discomfort at the donor site, muscle hernia, pin-site infection, and long-term failure [103, 105]. Although the majority of the patients seem content after this procedure, some consider interposition arthroplasty as a salvage procedure as it does not completely relieve pain and restore elbow motion [7, 49, 102]. Failed interposition arthroplasty may be converted to a total elbow arthroplasty.

Total elbow arthroplasty

Total elbow arthroplasty may be considered in less active and older patients if no other treatment options are available [5, 11, 48, 106–108]. The semiconstrained implant is recommended in patients with complete ankylosis and elbow stiffness [27]. Specific surgical techniques depend on the implant used, prior incisions, and the preference of the surgeon. In all cases, the ulnar nerve must be identified, released, or transposed if needed; soft tissues should be aggressively released; and bone needs to be adequately resected for optimal biomechanical conditions [11, 109]. The most recognized complications include periprosthetic fracture, loosening, mechanical failure, infection, triceps disruption, and nerve palsy [110]. Although complications are frequent, careful preoperative planning and enhanced techniques lead to improvement of function and relief of pain in a subset of patients with posttraumatic ankylosed and stiff elbows [5, 11, 48, 106, 111].

Partial elbow arthroplasty

Partial elbow replacement is rarely used for posttraumatic elbow stiffness. It might be considered in patients with loss of cartilage of the radiocapitellar joint and preserved ulnohumeral articulation [112]. Capitellar resurfacing arthroplasty may be used if radial head arthroplasty is indicated and the quality of the capitellar surface is poor. In addition, distal humeral hemiarthroplasty may be considered in case of nonunion or malunion of fractures of the distal humerus [38, 113].

Postoperative management

Postoperative management and rehabilitation programs aim to regain elbow motion, restore muscle strength, and reincorporate the arm into daily activities of living [114] and should be continued until no further improvements are made.

Most surgeons start mobilization within 48 h after open capsular release. Continuous passive motion may improve elbow motion postoperatively [81, 82]; however, its benefit in the postoperative management of elbow contracture release remains subject of discussion [115]. In addition, static progressive or dynamic splints can be used after contracture release to support the recovery of elbow motion [8, 10, 67, 71, 72, 77, 78, 82].

After interposition arthroplasty, local anesthetics are used for 24 to 48 h after surgery to allow continuous passive motion. When the external fixator is removed after 4 to 8 weeks, the elbow is examined and gently manipulated under anesthesia to determine the firmness of the end-points, elbow joint stability, and expected elbow flexion arc. Then, progressive static splints may be used to support the rehabilitation [105].

The postoperative management after total elbow arthroplasty depends on several factors, such as the implant type, status of the ulnar nerve and triceps, and overall joint stability [116]. Splinting to regain motion is seldom indicated. When the ulnar nerve is in anatomical position, flexion could lead to compression of the nerve, which should be avoided. And in case the triceps is reflected in surgery, gravity-assisted extension is indicated for at least 4 weeks. Return to full activity with permanent restrictions can be recommended after 12 weeks [5, 108].

Conclusions

Although there have been some advances in the understanding of the pathogenesis of posttraumatic elbow contractures, the overall evidence is limited and sometimes contradictory. An improved understanding of the pathologic basis of the causes underlying posttraumatic elbow stiffness may help the development of new prevention strategies. However, current nonoperative and operative treatment regimens are considered safe and effective in patients with a posttraumatic stiff elbow, but the level of evidence of current treatment and rehabilitation programs is low. Future research will need to compare the respective treatment options (e.g., open versus arthroscopic capsular release) prospectively.

Compliance with ethical standards

Conflict of interest Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, and patent/licensing arrangements) that might pose a conflict of interest in connection with the submitted article.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Human studies done by authors (but no animal studies) This article does not contain any studies with animal subjects performed by any of the authors. With regard to the authors' research cited in this paper, all procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

Animal studies done by authors (but no human studies) This article does not contain any studies with human subjects performed by any of the authors, with regard to the authors' research cited in this paper and all institutional and national guidelines.

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