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SYMPOSIUM: TRAUMATIC ELBOW INSTABILITY AND ITS SEQUELAE

Single-staged Treatment Using a Standardized Protocol Results in Functional Motion in the Majority of Patients With a Terrible Triad Elbow Injury

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Abstract

Background Terrible triad injuries of the elbow, defined as elbow dislocation with associated fractures to the radial head and coronoid, are associated with stiffness, pain, and loss of motion. Studies to date have consisted of small sample sizes and used heterogeneous surgical techniques, which render comparisons difficult and unreliable.

Questions/purposes In a group of patients treated under a standard surgical protocol, we sought to determine the early dislocation rate, the range of motion in those not undergoing secondary procedures, the frequency and types of secondary surgical interventions required, the difference in motion between those undergoing secondary surgery and those who did not, and the frequency of heterotopic ossification and patient-reported stiffness.

Methods Patients underwent a surgical protocol that involved fixing the coronoid, fixing the radial head if possible, otherwise performing radial head arthroplasty, and repairing the lateral ligamentous structures. Patients were excluded if ipsilateral upper extremity fractures from the humerus to the distal forearm were present. Fifty-two patients had a minimum followup of 6 weeks and were included for the early dislocation rate, and 34 of these (65%) had a minimum of 6 months followup and were included for the rest of the data. Eighteen of the 52 (35%) were considered lost to followup because they were seen for less than 6 months postsurgically and were excluded from further analysis. Chart review was performed to determine the presence of early dislocation within the first 6 weeks after surgery, range of motion in patients not requiring a secondary procedure, the frequency and types of secondary procedures required, the range of motion before and after a secondary procedure if it was required, and postoperative stiffness. Postoperative radiographs were analyzed to determine the presence and severity of heterotopic ossification.

Results One of 52 patients sustained a dislocation within the first weeks of surgery (1.9%). Those not undergoing a secondary procedure were able to achieve a flexion arc of 110° and a supination-pronation arc of 148°. Nine of 34 patients (26%) underwent a secondary surgical procedure with stiffness, heterotopic ossification, and ulnar neuropathy being the most common surgical indications. Before secondary surgical procedures, patients had a flexion arc of 57° and a supination-pronation arc of 55°, which was less than those only requiring primary surgery alone ($p < 0.001$). After secondary surgery, patients were able to achieve a flexion arc of 96° and a supination-pronation arc of 124°, which was not different from those who did not undergo reoperation ($p = 0.09$ and $p = 0.08$, respectively). Twenty-eight of 34 patients demonstrated evidence of heterotopic ossification on radiographs, whereas 20 patients, including all nine undergoing secondary procedures, reported stiffness at the elbow.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Conclusions Using a standardized surgical protocol, a low early dislocation rate was observed, although stiffness remains a challenge. Many patients who initially do not attain functional range of motion can usually attain this after secondary procedures aimed at removing the heterotopic ossification.

Level of Evidence Level IV, therapeutic study. See guidelines for authors for a complete description of levels of evidence.

Introduction

An elbow dislocation with associated radial head and coronoid fractures is referred to as a "terrible triad" injury and has a reputation for being a challenging condition to treat [7], because it can cause stiffness, instability, posttraumatic arthrosis, and pain [23]. Better results have been reported using a biomechanically sound standard treatment protocol [1] that includes coronoid repair, radial head open reduction and internal fixation (ORIF) or replacement, and lateral collateral ligament (LCL) repair. Medial collateral ligament (MCL) repair and/or external fixation are required for those with persistent instability [19].

The terrible triad is a relatively rare injury [27] and most published series are small. Although outcomes have improved with standardized protocols, the infrequency and complexity of this injury type [27] has left published series with small sample sizes and heterogeneous surgical approaches. A recent review article summarized 137 cases from five studies with the largest single study reporting on 36 patients [9, 11, 17, 23, 30, 31].

We therefore sought to evaluate a single institution's results using a standard protocol. Specifically, we evaluated (1) the early dislocation rate after surgical intervention; (2) the ROM achieved in those who did not undergo secondary procedures; (3) the frequency of reoperation and the types of surgical interventions used in secondary procedures; (4) the difference in ROM achieved between patients undergoing secondary surgical procedures and those who did not; and (5) the frequency of radiographic heterotopic ossification and patient-reported stiffness.

Patients and Methods

Clinical Algorithm, Operative Technique, and Aftercare

Between January 1, 1995, and March 1, 2013, four fellowship-trained orthopaedic trauma surgeons at one institution treated 52 patients with 52 terrible triad injuries, defined as elbow dislocations with associated coronoid and radial head fractures. During that time, all were managed surgically. Of those, 52 (100%) had adequate radiographic and clinical followup at 6 weeks to ascertain the early redislocation rate, which was defined as dislocation within 6 weeks of the initial surgical procedure. Of these patients, however, 18 (35%) did not have followup longer than 6 months and were considered lost to long-term followup and excluded from all other data points. A total of 34 (65%) had adequate radiographic and clinical followup at 6 months to evaluate our other study endpoints, including the use of secondary procedures, ROM, and patient-perceived stiffness.

Patients who underwent surgery were managed similarly (Figs. 1, 2, 3). Large coronoid fractures were treated with screws, whereas small fragments were treated with suture repair of the anterior capsule. The radial head was treated with primary repair or arthroplasty in all elbows. The primary indication for radial head arthroplasty was to avoid tenuous radial head fixation in comminuted fractures, which would predispose to recurrent dislocation should the repair fail [1, 3]. The determination of a tenuous repair was established by the treating surgeon in each instance but was uniformly considered to be radial head fixation that was not anticipated to allow physiologic loads through a functional arc of motion without a substantial risk of early dislocation [29]. The radial head was evaluated first and if arthroplasty was chosen as treatment, the neck cut was performed to improve the access to the coronoid and then the coronoid was fixed. If repair was chosen, the fragments were carefully moved out of the way taking care not to disrupt the periosteum, and the coronoid was fixed first. The LCL complex and common extensor origin were then repaired. If, after this sequence, ulnohumeral instability was not achieved, then repair of the MCL was also performed. External fixation was never used. The elbow was taken through a ROM and stability was assessed both clinically and using fluoroscopy. Extension using gravity was assessed but the elbows were not forced into terminal extension so that the coronoid repair would not be disrupted. Valgus instability was not an indication for medial repair. Subluxation at the ulnohumeral joint at any point during the range was an indication for further intervention.

Postoperative rehabilitation protocols were similar in all patients. Patients were initially placed in a posterior plaster splint. The splint was removed on the first or second postoperative day, and active and active-assisted motion was started. Full ROM was allowed with the forearm in pronation or neutral with supination occurring with the elbow at 90° of flexion or greater. Terminal extension in supination was avoided for approximately 3 weeks. No patient received postoperative heterotopic ossification prophylaxis.

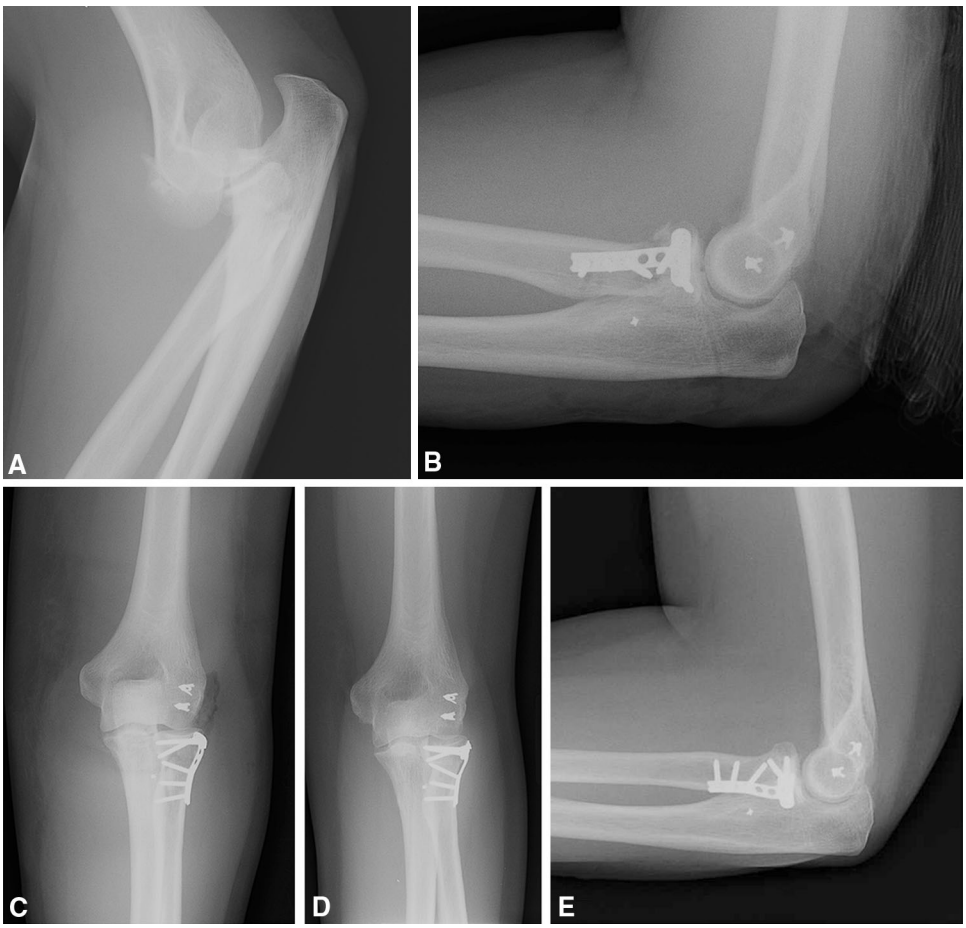

Fig. 1A–E Radiograph of a 48-year-old woman who sustained a terrible triad injury (**A**). She underwent ORIF of her radial head and coronoid and repair of her lateral ligaments 1 day after injury (**B**–**C**). At her final followup 331 days after injury, her ROM was from 20° to 130° of flexion with 90° of pronation and supination. Final radiographs (**D**–**E**) show a concentrically reduced joint with no heterotopic ossification.

Data Collection

All injuries involving a fracture or dislocation of the elbow were reviewed to identify terrible triad injuries of the elbow. Radiographs were reviewed to confirm the preoperative presence of an ulnohumeral dislocation, radial head fracture, and coronoid fracture. Those with associated ipsilateral upper extremity injuries including distal humerus fractures, Monteggia and Monteggia variant fractures, ulnar or radial shaft fractures, distal radius or ulna fractures, and distal radioulnar joint disruption were excluded. Cases with ipsilateral carpal pathology such as scaphoid fractures were included. Those without at least one postoperative radiograph were also excluded.

Of the 52 patients identified, 39 were men and 13 were women with an average age of 44 years (SD 13; range, 19–65 years). Sixteen were smokers. Twenty-four and 28 patients sustained right and left elbow injuries, respectively.

Patients underwent surgical intervention at an average of 4 days from injury (range, 0–15 days). Radial head arthroplasty was performed for 40 patients whose fractures were deemed too comminuted to be adequately fixed and radial head fixation was performed in 12 cases. The coronoid was repaired in 45 cases and was treated without fixation in seven cases. In 49 of the 52 cases, the LCL complex was repaired. In one patient, the MCL was also repaired. Two patients required repair of the common extensor origin and one required repair of a triceps tendon avulsion.

The 34 patients with followup longer than 6 months were divided into two groups: those requiring primary surgery only and those undergoing secondary surgery. The need for secondary surgery was defined as any subsequent surgical procedure on the ipsilateral extremity as a sequela of the initial injury and not related to new trauma. For the primary surgery only group, ROM at the last clinical followup date was recorded, including flexion, extension, supination, pronation, and the respective flexion-extension and supination-pronation arcs. For the secondary surgery group, the same data were collected at the last clinical visit before the secondary surgery as well as the last clinical visit after secondary surgery. For this group, the indications and diagnoses for secondary surgery and types of secondary surgery performed were gathered from preoperative documentation and operative reports. The difference in ROM after secondary surgery compared with before secondary surgery was then calculated as well as the difference between the final ROMs between the two groups.

Fig. 2A–I Radiographs of a 35-year-old man who sustained a terrible triad injury (**A**–**B**). He underwent radial head arthroplasty, coronoid fixation, and lateral ligament repair 11 days after injury (**C**–**E**). He showed early signs of heterotopic ossification 3 weeks after repair. The patient's elbow became ankylosed at 90° of flexion and neutral rotation (**F**–**G**) by 8 weeks. He underwent resection of heterotopic bone, synovectomy, ulnar neurolysis, and lateral ligament repair 114 days after his injury. At final followup 1 year after release, his motion was from 45° to 125° of flexion with 50° each of pronation and supination (**H**–**I**).

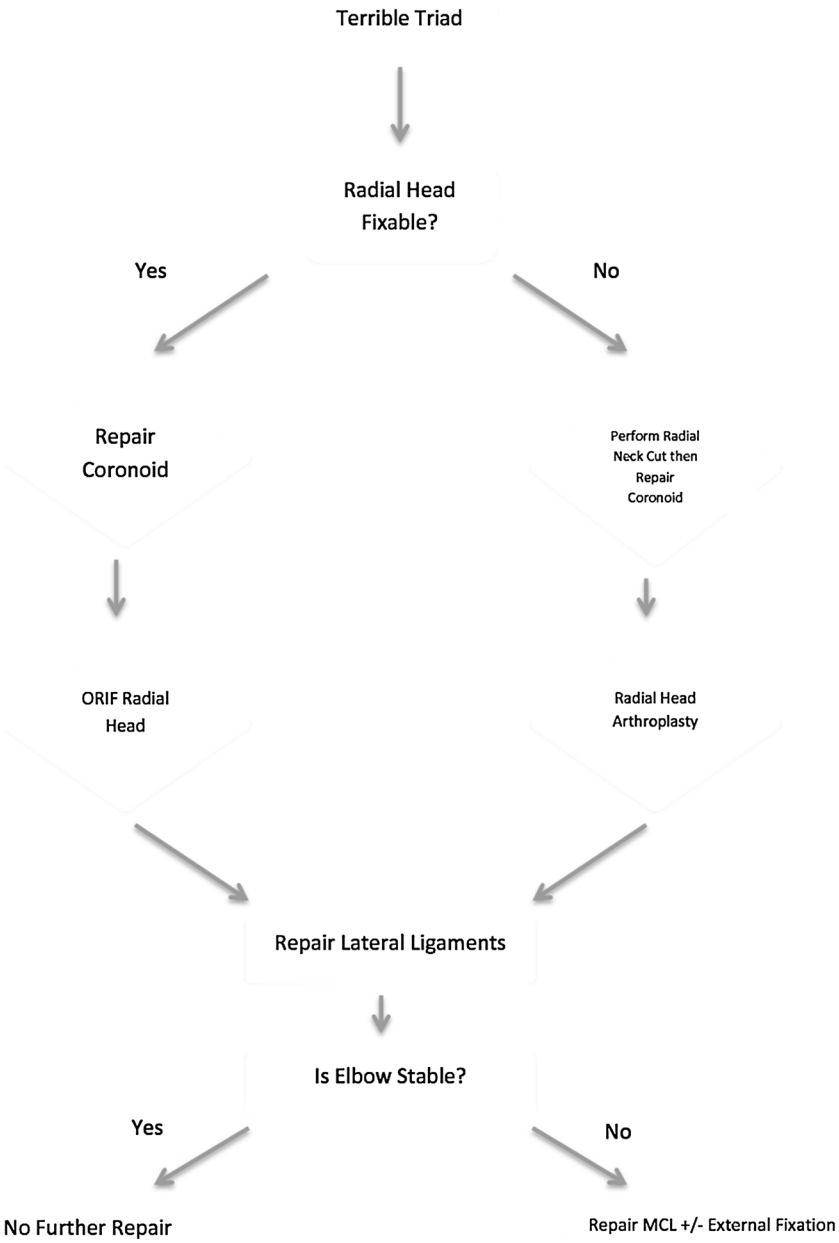

Fig. 3 Flowchart depicts the surgical protocol sequence.

Clinical stiffness was considered to be present once the chart reflected that the symptoms were problematic for patients at their 6-week postoperative visit or later. Any clinically reported stiffness before this was considered part of the normal recovery process. Radiographs were analyzed until the patient's last clinic visit, which was at an average of 57 weeks after surgery, and included presence of heterotopic ossification and the number of days from surgery to the first appearance of heterotopic ossification.

Statistical Analysis

Analysis was performed using statistical software (SPSS Version 21; SPSS Inc, Chicago, IL, USA). Group t-tests were used to evaluate statistical differences between the primary surgery only group and the secondary surgery group both preoperatively and postoperatively. Paired t-tests were used to evaluate the differences in ROM from preoperatively to postoperatively in the secondary surgery group.

Results

Early Dislocation Rate

Fifty-two patients with a minimum of 6 weeks of followup were analyzed for the presence of an early dislocation after surgery. Only one patient (1.9% of the 52) was found to

Table 1. ROM in the primary surgery group and the secondary surgery group before the second intervention and after the second intervention

Variable	Primary surgery only group	Secondary surgery group (before secondary procedure, after the index procedure)	Secondary surgery group (after the secondary procedure[s])
Flexion (degrees)	128	108	122
Extension (degrees)	17	51	26
Supination (degrees)	72	27	68
Pronation (degrees)	78	28	57
Flexion-extension arc (degrees)	110	57*	96†
Supination-pronation arc (degrees)	148	55*	124†

* Statistically significant difference compared with the primary surgery only group ($p < 0.05$); †no statistically significant difference compared with the primary surgery only group ($p > 0.05$).

Table 2. Radiographic analysis in both primary and secondary surgery groups

Variable	Primary surgery only group	Secondary surgery group
Last radiograph analyzed (number of days)	276	625
Number of cases with radiographic HO (%)	19/25 (76%)	9/9 (100%)
First radiographic appearance of HO (number of days)	68	55
Combined MCL/LCL calcification (%)	7/25 (28%)	3/9 (33%)
Isolated MCL calcification (%)	3/25 (12%)	1/9 (11%)
Isolated LCL calcification (%)	1/25 (7%)	1/9 (11%)

HO = heterotopic ossification; MCL = medial collateral ligament; LCL = lateral collateral ligament.

have a postoperative redislocation within the first 6 weeks after surgery. This occurred at 33 days and was a result of a fall directly onto the affected extremity resulting in failure of the LCL repair. The patient underwent secondary surgery, which included LCL reconstruction and removal of heterotopic ossification. This patient, however, was lost to followup and was excluded from subsequent analysis.

ROM in the Primary Surgery Only Group

Of the 34 patients with at least 6 months of followup, 25 (74%) did not undergo a secondary surgical procedure. These patients had a mean flexion of 128° and a mean extension of 17° (mean flexion-extension arc, 110°; SD 23°). Mean supination was 72° and mean pronation was 77° (mean supination-pronation arc, 148°; SD 37°; Table 1).

Secondary Surgery Group

Secondary surgeries were performed in nine of the 34 patients (26%). In all of these patients, stiffness and heterotopic ossification were the major indications for reoperation. One patient developed stiffness requiring release but underwent a total elbow arthroplasty instead as a result of a supracondylar fracture that had occurred from a fall before her planned release. Excision of heterotopic ossification was performed in all nine secondary procedures, and synovectomy was performed in three. Ulnar neurolysis and transposition were performed in seven patients. Lateral collateral ligament repair was performed in one elbow after contracture release. Other procedures performed once each included revision radial head arthroplasty, median nerve neurolysis, and biceps and triceps tenolysis.

Before the secondary procedure, the patients in this group had a mean flexion of 108° and a mean extension of 51° (mean flexion arc, 57°; SD 44°). Mean supination measured 27° and mean pronation was 28° (mean supination-pronation arc, 55°; SD 54°). Both the mean flexion arc and mean supination-pronation arc were inferior to those in the primary surgery-only group ($p < 0.001$ for both). After secondary surgery, patients achieved a mean flexion of 122° and mean extension of 26° (mean flexion-extension arc, 96°; SD 11°) at a mean followup of 84 weeks (range, 32–143 weeks). Patients attained a mean pronation of 57° and mean supination of 68° (mean supination-pronation arc, 124°; SD 23). Secondary surgery improved the mean flexion-extension arc by 39° ($p = 0.02$) and the mean supination-pronation arc by 69° ($p < 0.003$). After secondary surgery, with the numbers available, patients had a comparable flexion-extension arc ($p = 0.09$) and supination-pronation arc ($p = 0.08$) as those in the primary surgery only group (Table 1).

Heterotopic Ossification and Stiffness

Twenty-eight of the 34 patients demonstrated radiographic evidence of heterotopic ossification with the first signs appearing on radiographs at an average of 64 days postoperatively (Table 2). Ten patients demonstrated both MCL and LCL calcifications. Four demonstrated isolated MCL calcification and two demonstrated isolated LCL calcification. Twenty of the 34 patients (59%), including all nine patients undergoing secondary procedures, reported stiffness at the elbow.

Discussion

Terrible triad injuries of the elbow have historically been challenging injuries to treat and although initial treatment protocols were limited because of small sample sizes and high complication rates, recent studies have shown more predictable results [11, 16, 18, 22, 30]. The aim of this study was to evaluate the algorithm used at one high-volume trauma center, which relies on biomechanical and clinical principles of functional anatomy and how it relates to postoperative stability [1–6, 12, 13, 24] and early ROM. The results demonstrated that the early dislocation rate was very low, and those who did not undergo secondary procedures were able to obtain good functional ROM postoperatively. Although stiffness and heterotopic ossification were quite common and indicated secondary surgery in a large proportion of patients, most of those patients reliably gained functional ROM after the secondary surgery.

There are several limitations to this study that must be considered. First, this is a retrospective review, which limits the ability to control factors such as followup, standard motion measurements, and standardized timing for radiographs. The most important limitation of this study was the relatively high proportion of patients who were lost to followup (35%, 18 of 52 at 6 months or longer). Thus, the data presented here likely represent that of patients with a higher degree of compliance with postoperative protocols than those who did not return, and those who do not follow postoperative rehabilitation are expected to have less ROM and function. Given the long period of data collection, there is some inevitable variation in intraoperative technique (including radial head prosthetic design, suture material/technique, and perhaps others). Despite this, on careful review of all charts, it is apparent that a consistent general protocol (emphasizing the biomechanical importance of radial head repair or replacement, coronoid assessment and stabilization, and LCL complex integrity) was used with variations owing to the surgeon trying to tailor recovery to the patients' ability, motivation, and specific complaints. The retrospective nature of this study also prevented the collection of validated outcomes measuring tools such as the Disability of the Arm, Shoulder, and Hand Questionnaire, Mayo Elbow Performance Index, or the Broberg and Morrey rating system. Collection of these data would certainly enhance the standardization of classifying outcomes. Another limitation is that data were collected only within the study period and several of the patients in the primary surgery group were still being followed in the clinic and potentially could undergo secondary procedures for stiffness if monitored for a longer period of time. Even so, however, we believe these results to be valid because there was still a large population that was followed to completion of postoperative treatment. Also, the majority of patients in the region that require surgery for elbow stiffness are seen at our institution so it is unlikely that further surgery was performed on those with limited followup.

The results of this study show that early dislocation with initial definitive fixation is low (2%, one of 52 patients) and that the case in which this happened was likely a result of direct trauma from a fall. This result is similar to other studies such as that published by Egol et al that showed resubluxation in one of 29 patients [9]. In a study by Lindenhovius et al [17], 14 patients presented to them after 3 weeks postinjury with subluxation or dislocation of the ulnohumeral joint. Of these, five were treated operatively before presentation to their institution and two were treated with radial head excision. These results reinforce recent biomechanical literature that demonstrate that joint stability can be achieved with early fixation of the coronoid [4, 5, 25], repair or replacement of the radial head [8, 13–15, 28, 30], and repair of the LCL complex [20, 30].

Functional results from this study show that an average flexion-extension arc of 110° and a supination-pronation arc of 148° can be achieved in approximately 74% of patients (25 of 34 patients) but the remainder required secondary procedures for stiffness. Other published results similarly demonstrate an average flexion-extension arc of 100° to 119° and a supination-pronation arc of 128° to 141° [9, 11, 17, 23, 31]. The functional ROM of the elbow for most activities of daily living is thought to be 100° of flexion-extension and 100° of supination-pronation [22] and in a large majority of patients, this can adequately be achieved with a single surgical intervention.

There were several indications for secondary surgery for symptomatic patients with the most common procedures performed being excision of heterotopic ossification for stiffness (26%, nine of 34 patients) and ulnar neurolysis with transposition for ulnar neuropathy (21%, seven of 34 patients). Previous reports show that most common complications with these injuries include stiffness, instability, heterotopic ossification, and ulnar neuropathy [11, 18, 21–23, 25] (15%–25% [22]). The rate of secondary surgery in this study (26%) compares similarly to other studies, which publish a secondary surgical rate of 15% to 25% [9, 11, 17, 22, 23]. Other studies have noted ulnar neuritis requiring secondary ulnar nerve decompression at similar rates as well [9, 11, 17], although prophylactic release during the index procedure was variably performed. Routine decompression during the index procedure was not performed in our patients; however, with similar rates of secondary surgery compared with other studies in which prophylactic decompression was performed, it suggests that ulnar neuritis is more likely related to heterotopic ossification

postinjury. As such, we do not recommend routine initial prophylactic decompression of the ulnar nerve.

Patients requiring secondary surgery had less ROM before secondary surgery compared with those who only underwent the index procedure. After secondary surgery, however, the ROM achieved was not statistically different and also was within the functional ROM required for activities of daily living. These results are similar to previously published data regarding elbow ROM after capsulectomy for stiffness, which showed restoration of flexion-extension arcs to 103° to 109° [10, 26]. Although secondary surgical intervention must be tailored to the individual patient, these data suggest that patients who have vastly diminished ROM that impairs activities of daily living should be considered for secondary surgical procedures, which appear to significantly improve function.

Heterotopic ossification remains a challenging and inconclusive problem in the treatment of elbow trauma. Although present in many patients, it was not clinically relevant in most of them. Similarly, all patients had a similar injury pattern and some patients did not develop any heterotopic bone at all underscoring our lack of understanding of which patients are at risk and therefore should be treated. Our experience is that many patients are noncompliant with treatment and that it is difficult to predict which patients would benefit the most from it and we therefore do not give prophylaxis for heterotopic ossification. With regard to patient complaints of stiffness, this also was seen quite frequently throughout the course of care but again most of them had achieved a functional arc of motion. This reinforces the notion that a "normal" elbow is rarely achieved but that reasonable results within functional ROMs are attainable [22]. Patients can be counseled that even several months into postoperative recovery, stiffness may persist, but a good functional outcome that does not require further surgery is possible in the majority of cases.

Overall, this study represents a large collection of terrible triad elbow fracture-dislocations treated with a standard protocol consisting of radial head repair or replacement, coronoid or anterior capsular repair, LCL complex repair, early postoperative ROM, and no heterotopic ossification prophylaxis. No patients underwent external fixation, and MCL repair was rarely performed. The rate of recurrent instability is extremely low. The majority of patients reliably attained functional ROM arcs with this treatment protocol. Although the use of secondary surgery for contracture remains higher than desired, contracture release provides near functional ROM arcs in most patients who undergo it.

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