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SURGICAL TECHNIQUE

Surgical treatment of "terrible triad of the elbow": technique and outcome

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Objective: To describe the authors' surgical technique and to evaluate the final functional outcome of surgical treatment of the "terrible triad of the elbow".

Methods: Eight patients identified with "terrible triad" injury patterns, including posterior elbow dislocation, radial head fracture and coronoid fracture, were available for a minimum of 11 months follow-up. Evaluation of functional outcome was based on Mayo elbow performance, Broberg-Morrey scores, and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. Complications were also recorded.

Results: Five elbows redislocated while in a splint after manipulative reduction. Three had residual subluxation after operative treatment. The final mean extent of forearm movement was as follows: 21° of extension deficit (range, 5° to 45°), 126° of flexion (range, 110° to 140°), 75° of supination (range, 45° to 90°), and 71° of pronation (range, 30° to 90°). The mean Mayo, Broberg-Morrey, and DASH scores were 78.0 ± 13.4, 76.0 ± 14.0, and 28.0 ± 24.7, respectively.

Conclusions: When an elbow joint is affected by the terrible triad, it is very unstable and prone to numerous complications. With operative treatment, the surgeon should attempt to perform internal fixation of the coronoid fracture, to regain normal radiocapitellar contact (either by preserving the radial head with open reduction and internal fixation (ORIF) or by replacing it with a prosthesis), and to repair the lateral collateral ligament (LCL). Thus early functional recovery and a successful final functional outcome can be achieved.

Key words: Dislocations; Elbow joint; Radius fractures

Introduction

The method of treatment of elbow dislocation varies according to the pathology of bone and ligament injuries. With simple elbow dislocation good results can be achieved by conservative treatment, but complex fracture-dislocations of the elbow require intensive treatment and frequently have unsatisfactory outcomes. The syndrome of "terrible triad of the elbow", which was first described by Hotchkiss in 1996[1], is a severe pattern of elbow fracture-dislocation injury that consists of posterior dislocation of the elbow associated with fractures of the radial head and the coronoid process of the ulna. In the past, most of these injuries were treated by manipulative reduction and cast immobilization. However, conservative treatment often leads to failures due to repeated residual dislocation of the ulnohumeral joint[2]. Since the importance of each component in stabilizing the elbow complex has been well illuminated in several studies, this severe pattern of elbow fracture-dislocation injuries is most often now treated by surgical intervention. Ulnohumeral articulation can provide up to 75% of varus and valgus resistance[3,4]. In one study by Closkey *et al.*, fractures involving greater than 50% of the coronoid resulted in axial instability[5]. Hull *et al.* found a trend towards a decreasing load resisting varus displacement after removal of more than 50% of the coronoid[6]. With regard to valgus stability, the radial head is thought to be important as a secondary stabilizer where the medial collateral ligaments have been disrupted[7]. In addition to the bony contributions, the ligaments are also important in elbow stability, particularly the lateral collateral ligament (LCL) complex. With regard to varus stability, O'Driscoll *et al.* described the relationship of the radial head and the LCL complex and its role as a secondary stabilizer in posterolateral rotatory stability[8]. The end result is that three structures, namely the coronoid process, radial head, and LCL complex, provide the bulk of the resistance. Although surgical treatment has been implemented, the short-term and

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long-term results are still relatively unsatisfactory, with a high rate of complications, including stiffness, instability, pain, and heterotopic ossification. This injury is relatively uncommon, and there are few reports in the current literature, in particular few that detail the final functional results. Our purpose is to describe our surgical technique and to evaluate the functional outcome of complex injury in our institute.

Materials and methods

General information

Between July 2006 and November 2008, a total of 14 patients diagnosed with an elbow fracture-dislocation were identified in our hospital's database. Their charts and radiographs were reviewed. Following evaluation of the radiographs, eight patients (two women and six men) were found to meet the criteria of terrible triad, namely radial head fracture, coronoid fracture, and posterior dislocation of the elbow. All patients' treatment and injury details are presented in Table 1. All of them presented for follow-up, which consisted of radiographic and functional evaluation of the elbow. Their mean age was 39 years (range, 20–52). Six dominant arms were involved. Five patients sustained the injury as a result of falling from a height and three were involved in traffic accidents. One patient had a Grade 2 open wound according to the classification of Gustilo and Anderson[9]. Two had an ipsilateral fracture of the distal radius, and two had multiple other injuries. The fractures of the radial head were classified, according to the system of Mason[10], as type II (involving part of the head) in seven patients and type III (a comminuted fracture involving the entire head) in one patient. The fractures of the coronoid process were classified, according to the system of Regan and Morrey[11], as type I (involving the tip of the coronoid) in two patients, and as type II (more than a small fleck but <50% of the height of the coronoid) in six.

Seven patients were initially treated by manipulative reduction and immobilization in a posterior plaster splint with 90° of elbow flexion except for one patient (case 6) who underwent emergency surgery. Five elbows redislocated in their splints. All eight patients eventually underwent operative treatment. Seven elbows were accessed via a lateral approach between the extensor carpi radialis longus and the extensor carpi radialis brevis, which allows better visualization of the proximal radius and ulna and repair of the LCL. Only one elbow (case 3) were accessed via a posterior approach, which was extended distally along the crista ulnae as an ipsilateral ulna shaft fracture required fixation with a plate. Six patients underwent open reduction and internal fixation of their radial head fractures with Herbert screws and one (case 6) was treated by partial radial head resection. In one patient (case 3), the radial head fracture was too comminuted to be repaired, so we chose a titanium radial head prosthesis (Wright Medical Group, Arlington, TN, USA). In only three patients was the origin of the LCL complex reattached to the lateral epicondyle. Six of the coronoid fractures were repaired, including five fixed with Herbert screws and one (case 6) with Kirschner wires. Two of these patients underwent additional fixation of the humeroradial joint with smooth Steinmann pins. All injured extremities were immobilized with a posterior plaster splint with the elbow joint held in 90° of flexion and the forearm in neutral rotation for an average of three weeks (range, 2–5). No preventive therapy for heterotopic ossification was used. All patients were followed up by the treating surgeons. Functional elbow movement exercises were implemented after removal of the plaster splint. Standard anteroposterior (AP) and lateral radiographs of the elbow were taken. At the most recent follow-up, elbow flexion, extension, pronation, and supination were measured using a goniometer. Grip strength was evaluated using a dynamometer. The radiographs were reviewed to evaluate maintenance of the reduction, post-traumatic arthritic changes, and development of heterotopic ossification.

Evaluation

At follow-up, the patients were evaluated with a questionnaire, physical examination, and radiographs. The objective outcome was calculated according to the Mayo Elbow Performance and Broberg-Morrey scores. According to the system of Mayo, scores of 90–100 are classified as excellent, 75–89 as good, 60–74 as fair, and 0–59 as poor[12]. As to the system of Broberg and Morrey, 95–100 is excellent, 80–94 good, 60–79 fair, and 0–59 poor[13]. Subjective functional outcomes were measured by the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire[14]. This questionnaire is graded from 0 to 100, with a higher score indicating a greater level of disability. Heterotopic ossification was graded by the classification of Brooker[15] and degenerative joint changes were classified as described by Broberg and Morrey[13]. According to this system, a normal elbow is evaluated as grade 0, an elbow with slight joint-space narrowing with minimum osteophyte formation as grade 1, an elbow with moderate joint-space narrowing and moderate osteophyte formation as grade 2, and an elbow with severe degenerative change and gross destruction of the joint as grade 3. Statistical analysis was performed with Student's paired *t*-test. Each data set was assessed with the Kolmogorov-Smirnov test of normality to permit use of the *t*-test. If not, non-parametric test was used. All statistical testing was

Table 1 Treatment and injury details

Patient No.	Age(years)/ sex	Injured side	Mason classification	Treatment of the radial head	Coronoid fracture type	Treatment of coronoid	Associated injury	Complications and additional procedures	Follow-up (months)
1	45/Male	Right	II	ORIF with Herbert screw	II	Fixation	None		18
2	46/Male	Right	II	ORIF with Herbert screw	I	Neither fixed nor debrided	None	Kirschner wires broke and were removed	16
3	48/Male	Left	III	Replaced	I	Neither fixed nor debrided	Ipsilateral radial, ulnar, tibial plateau and calcaneal fractures	Residual subluxation	11
4	25/Female	Right	II	ORIF with Herbert screw	II	Fixed	Ipsilateral tibial, fibular and ankle fractures	Residual subluxation, heterotopic ossification	12
5	52/Male	Right	II	ORIF with Herbert screw	II	Fixed	None	Heterotopic ossification	35
6*	42/Female	Right	II	Partial excision	II	Fixed with Kirschner wires	None	A fixation plate in the olecranon was removed	19
7	33/Male	Left	II	ORIF with Herbert screw	II	Fixed	Ipsilateral distal radial and proximal ulnar fractures	Residual subluxation	28
8	20/Male	Right	II	ORIF with Herbert screw	II	Fixed	Ipsilateral distal radial fracture		23

*, open injury; ORIF, open reduction and internal fixation.

Table 2 Functional outcomes

Patient NO.	Extension /flexion deficit	Pronation/supination	Score (MEPS)	Broberg-Morrey score	**DASH**
1	20°/130°	80°/85°	80 (good)	83 (good)	13
2	20°/125°	65°/70°	80 (good)	78 (fair)	19
3	45°/110°	30/45°	55 (poor)	51 (poor)	72
4	25°/125°	80°/80°	70 (fair)	73 (fair)	46
5	5°/140°	90°/90°	95 (excellent)	95 (excellent)	0
6	10°/130°	80°/85°	90 (excellent)	88 (good)	9
7	20°/130°	80°/80°	85 (good)	80 (good)	21
8	25°/125°	65°/65°	70 (fair)	63 (fair)	51

MEPS, Mayo Elbow Performance Scale; DASH, Disabilities of the Arm, Shoulder and Hand.

performed with SPSS 11.0 software (SPSS, Chicago, IL, USA). Statistical significance was set at $P < 0.01$.

Results

Range of motion

The patient's functional outcomes are presented in Table 2. The final mean extent of forearm movement was as follows: 21° of extension deficit (range, 5° to 45°), 126° of flexion (range, 110° to 140°), 75° of supination (range, 45° to 90°), and 71° of pronation (range, 30° to 90°). When compared with the contralateral unaffected arm, the affected arms had obviously increased extension deficits, decreased flexion and arcs of movement (Table 3, Fig. 1).

Outcome evaluation

The details are presented in Table 2. According to Mayo's classification[12], the average elbow performance score was 78 points (range, 55–95). There were two excellent, three good, two fair, and one poor result. According to Broberg and Morrey's system[13], the average score was 76 (range, 51–95 points). There were one excellent, three good, three fair, and one poor result. Grip strength averaged 72% of the contralateral extremity (range, 0% to 120%). The average DASH score[14] was 31 (range, 0–72). Of the eight patients in the series, the result of treatment was unsatisfactory in three. Two patients had an ipsilateral fracture in the upper extremity, two had multiple injuries, and two had residual subluxation after surgery. The three patients who scored more than 45 were compared to the remaining five. The former were more likely to have radiographic evidence of residual subluxation (67% *vs.* 20%, *P*, 0.464), and concomitant orthopaedic injuries (67% *vs.* 40%, *P*, 1.00). However, none of these factors were significant at the 95% confidence level.

Radiographic evaluation

After manipulative reduction five elbows redislocated in the splint. At the most recent follow-up, two patients (25%) had minor incidental heterotopic ossification, both rated as grade 1. Three had arthritis of the elbow, grade 1 in two patients and grade 2 in one. In addition, three patients were noted to have residual subluxation; none of them underwent subsequent surgery. Elbow arthritis was more severe among the three patients with residual subluxation after operative fixation, one being grade 0, one grade 1, and one grade 2.

Complications

Two patients required further operative procedures. One patient's Kirschner wires, which had been used for provisional fixation of the humeroradial joint, broke (case

Table 3 Statistical analysis of differences between the affected and the contralateral unaffected arm

Range-of-movement measure	Affected arm	Unaffected arm	*P* value (Kolmogorov-Smirnov test)	*t* value	*P* value
Extension deficit	21.25 ± 11.88	0.63 ± 4.17	0.2363	5.74	0.0007
Flexion	126.88 ± 8.43	139.00 ± 2.07	0.0027	–	0.0078
Arc of motion	105.63 ± 20.08	138.38 ± 7.29	0.0610	–	0.0078
Pronation	71.25 ± 18.66	86.50 ± 2.20	0.0079	–	0.0156
Supination	75.00 ± 14.64	86.25 ± 2.6	0.0233	–	0.0313

Each data set was assessed with the Kolmogorov-Smirnov test of normality to permit use of the *t*-test. Where $P < 0.1$, the non-parametric test was used, so there are no *t-test* values in the last four rows.

Figure 1 A 52-year-old male patient with terrible triad of the elbow. (A, B) AP and lateral radiographs and (C, D) 3D CT reconstruction images reveal a radial head fracture (Mason type II), ulnar coronoid process fracture (Regan-Morrey type II) and posterior dislocation of the elbow joint, and a small fragment of bone adjacent to the trochlea of the distal part of the humerus is a radial head fracture fragment. (E, F) AP and lateral radiographs taken 30 months postoperatively reveal achievement of a reduced and stable elbow joint. The radial head fracture was fixed with two Herbert screws, whereas the ulnar coronoid process fracture was fixed with a hollow nail. Slight heterotopic ossification and mild degenerative joint changes can be seen.

2), the breakage being discovered on the radiograph 40 days after the initial surgery. Under fluoroscopy, we removed the proximal parts of the broken Kirschner wires, and buried the ends of the distal parts in the radial head to prevent interlocking of the humeroradial joint. Another patient (case 6) experienced pain and extension deficit due to a plate placed in the olecranon. He recovered well after removal of the plate. None of our patients had delayed union, nonunion, infection or ulnar neuritis.

Discussion

In complex fracture-dislocations of the elbow, it is almost impossible to achieve stability with conservative treatment[16]. Although the coronoid is a small bony prominence, it plays a significant role in elbow stability. Regan and Morey described their experience with coronoid fractures and concluded that all fractures of type II and III associated with instability should be surgically repaired[11]. The size of the fractured fragment correlates with the incidence of instability. Using a kinematic model, Beingessner *et al*. demonstrated that type II and III coronoid fractures decrease elbow stability, even after radial head replacement and lateral ligament repair[17]. Fractures involving 50% of the coronoid can result in elbow instability even if other structures are intact. In the terrible triad pattern, the fracture of the coronoid process is usually small. CT studies have shown that the height of the fracture fragment in the terrible triad is approximately 35% of the mean height of the coronoid process, the mean height is 19 mm, and, just as in our series, no patient could be classified as having a type III fracture[18]. During surgery, the coronoid fragment must be carefully evaluated and internal fixation implemented[19–21].

As for radial head fractures, radiocapitellar contact is critical to elbow and forearm stability. When a fracture of

the radial head is displaced and unstable, it is usually accompanied by another fracture or ligamentous injury[22]. It is very important to fix even partial radial head fractures, especially those involving the anterolateral portion of the head, in order to to prevent posterior or posterolateral subluxation. However, a subsequent paper has reported unpredictable results after internal fixation of comminuted fractures with more than three articular fragments, such fractures usually being associated with early failure, later nonunion, and loss of forearm rotation[23]. Simple radial head fractures can be reduced and fixed with temporary K wires; then a screw can be inserted and buried in the head. As to comminuted fractures, we prefer prosthetic replacement.

Another important structure in terrible triad injuries is the LCL. Seki *et al.* reported that the lateral ligament contributes to lateral elbow stability and resists posterolateral instability[24]. The LCL, extensor origin and posterolateral capsule, all of which are usually injured in terrible triad, should be repaired[1]. However, Forthman *et al.* have suggested that repair of the medial collateral ligament is unnecessary, provided the articular fractures and LCL are repaired or reconstructed[25]. Just as in our series, no patient underwent such a procedure in their study. Even when all the injured structures have been repaired, elbow instability may still persist; the use of an articulated external fixator may permit concentric stability and reduction of the humero-ulnar articulation. However, particular attention should be paid to several details in technique.

The functional results of this series are somewhat disappointing. While five patients achieved a good or excellent result according to the Mayo elbow score, only four did so by the Broberg-Morrey criteria. Three out of the eight patients (37.5%), whose functional DASH score were all higher than 45, were dissatisfied with their surgical results. The poor correlation of these various scoring systems has been documented previously, questionnaire based scales, such as the DASH, being more consistent[26]. The DASH may be a more accurate representation of the results, as it takes into account many of the everyday tasks that require use of the elbow. This discordance becomes evident on observing that, of the three patients with unsatisfactory results on the DASH, one was classified as "good" and one as "fair" on the Mayo scale, two as "fair" on the Broberg-Morrey score, and only one was classified as "poor" on both the Mayo and Broberg-Morrey scales. The unsatisfactory results seen in three patients may have been associated with higher energy injuries. Their higher incidence of associated injuries is indicative of more serious trauma. These patients are more likely to have residual subluxation after operative treatment than patients with better results, suggesting more severe injuries with extensive soft tissue disruption.

A decrease in the flexion-extension arc of movement often leads to a poor functional outcome. The majority of the activities of daily living require a 100° arc of flexion-extension[27]. When the arc of movement of the affected arm was compared with that of the contralateral unaffected arm by Student's *t*-test or the non-parametric test for paired samples, a significant decrease was found in our series (Table 3). Limited flexion and/or extension are likely to be significant contributors to a decrease in function and in quality of life, as the ability to perform activities such as tying shoelaces, getting dressed, and eating is likely to be impaired. Similarly, the majority of the activities of daily living require an arc of forearm rotation from 50° supination to 50° pronation[27]. The average rotation arc of the three patients with poor DASH was 113°, with one patient having a rotation arc of less than 100°, whereas the smallest rotation arc in the better functioning group was 160°. Most of these patients had full or nearly full rotation, although there was no significant statistical difference in the range of forearm rotation when compared with the contralateral unaffected arm. Reduced grip strengths were also direct contributors to the lower DASH scores, and these patients were unable to carry out the same activities with their arms as before their injuries, particularly in the case of injury to the dominant side.

The results of this series are similar to those previously reported. In the series of Pugh *et al.*, 15 out of 36 patients achieved an excellent result on the Mayo score, only one patient scoring poorly[16]. This is encouraging, but may not represent all the morbidity associated with the injury, because these researchers did not use question-based functional outcome measures, such as the DASH. Ring *et al.* reported a case series of 11 patients with terrible triad injuries[28]. In this series, small coronoid fractures were not repaired. Radial head fractures were repaired in only five patients and the lateral ligamentous structures in only three. The average Broberg-Morrey functional score in their series was 76. This result is remarkably similar to our results, but excluding the three patients who failed with the original treatment, only four patients achieved satisfactory results at follow-up, in all of whom the radial head had been retained with internal fixation, and in two of whom the lateral ligaments had been repaired. Egol *et al.* reported that 13 out of 29 patients had poor DASH results and were dissatisfied after a minimum of 1-year follow-up, even though hinged external fixation was used in their series[19]. McKee *et al.* reported 36 patients who were treated with a standard surgical protocol including fixation or replacement of the radial head, fixation of the coronoid fracture, and repair of associated capsular and

lateral ligamentous injuries[29]. Fifteen excellent and 13 good results were obtained. Only eight patients had complications and required revision surgery.

This is a retrospective study, and lacks baseline functional data for the patients. Because of our limited numbers, there may not have been sufficient power to detect significant differences. Larger samples are required if future investigations are to detect any actual differences. The patients in this series were treated by different surgeons who had varied training, experience, and familiarity with elbow trauma. That standard treatment protocols were not used is the major weakness of our series. Surgical reattachment of the LCL complex to the lateral epicondyle was not initially used, but later in our learning curve, once biomechanical studies had demonstrated that it is helpful to elbow stability[8,24], most of the patients underwent such a procedure.

In conclusion, we suggest that the radial head must be repaired or replaced, substantial coronoid fractures must be subject to internal fixation, and soft-tissue injuries must also be treated in terrible triad of elbow injuries. The next critical step is to assess the stability of the elbow intraoperatively. Our limited experience suggests that transfixation of the humeroradial joint should also be helpful if stability of the elbow has not been achieved. Thus, a successful eventual functional outcome may be achieved in addition to early functional recovery.

Disclosure

The corresponding author, Li-xin Huang, representing all authors, certifies that this research did not involve any financial or personal relationships with other people or organizations that might have potential conflicts of interest. No funds were received in support of this research.

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