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Does Timing of Surgery Affect Treatment of the Terrible Triad of the Elbow?

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Background: This study investigated the influence of surgical timing on the treatment of terrible triad of the elbow (TTE).

Material/Methods: After exclusion, 63 patients were enrolled in this study: 20 patients were classified into the emergency group (group A, within 24 h after injury), 26 into the early surgery group (group B, from 4 to 14 days after injury), and 17 into the delayed surgery group (group C, more than 14 days after injury). All patients underwent the same approach, and elbow motion and complication rates were recorded and compared.

Result: Fifty-eight patients were followed up (mean 20.5±1.9 months), and 5 patients had lost partial final data. At 1 month after the operation, elbow motion in group A was higher than in group B and group C ($P<0.01$); however, 3 or more months later, there was no distinct difference between group A and group B ($P>0.05$), while both group A and group B showed better outcomes than group C at all time points ($P<0.05$). Moreover, group A and group B had better higher elbow motion, MEPS, excellent and good rate than group C at the final clinical visit (all $P<0.05$). No postoperative pain or complication rate differences were found among the 3 groups except for elbow stiffness (2 in group A, 3 in group B, and 7 in group C) ($P<0.05$) which required reoperation to enhance elbow function.

Conclusions: Emergency or early operation for TTE patients were more effective than delayed operation.

MeSH Keywords: **Anastomosis, Surgical • Elbow • Recovery of Function**

Abbreviations: **TTE** – terrible triad of the elbow; **CML approach** – combined anteromedial and lateral approach; **LCLC** – lateral collateral ligament complex; **MCL** – medial collateral ligament; **MEPS** – Mayo Elbow Performance Score; **VAS** – visual analogue scale

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Background

Elbow dislocation associated with radial head and coronoid process fractures was termed "the terrible triad of the elbow" (TTE) by Hotchkiss decades ago [1]. Fracture dislocations of the elbow are difficult injuries to manage and historically have had a consistently poor outcome [2–5]. TTE almost always renders the elbow unstable, making surgical fixation necessary. The primary goal of surgical fixation is to obtain a stable joint that permits early motion, and these studies emphasized that sufficient elbow stability and congruency must be achieved to allow for early motion and to prevent arthritis, both of which are important for obtaining good overall results [6]. Most cases are managed surgically; open reduction and inter fixation of coronoid process fixation, radial head fixation or arthroplasty, and repair of the lateral collateral ligament complex (LCLC) have been the standard surgical protocol treatments [3,7]. Nowadays, the treatment of TTE continues to evolve, as it is still associated with many postoperative complications like elbow stiffness, elbow dislocation or subluxation, heterotopic ossification, and osteoarthritis [8,9]. It is accepted that if the elbow joint immobilization persists for more than 2 weeks, the rate of elbow stiffness will increase greatly. A high rate of ankylosis after surgical repair of elbow injuries has been reported in numerous papers, especially in patients with TTE [10–12]. Anneluuk et al. consider that the TTE patients receiving acute treatment (within 2 weeks after injury) have better outcomes than patients receiving subacute treatment (3 weeks or more after injury) [13]. The present study explored whether the timing of surgery has an influence on the treatment of TTE. We hypothesized that the sooner the operation is performed, the better outcome will be achieved.

Material and Methods

We conducted a retrospective cohort study among patients with TTE injury treated in our hospital between 1 January 2009 and 31 December 2015. On the basis of surgery timing, we divided them into 3 groups: in group A (emergency surgery group) patients were operated on within 24 h after injury; in group B (early surgery group) patients were operated on from 4 to 14 days after injury; and in group C (delayed surgery group) patients were operated on more than 14 days after injury. After 24 h, the injured joint was very swollen, and at the third day, the soft tissue was the most swollen. During this period, surgeons always use mannitol or dexamethasone to help reduce swelling. Thus, patients in group B were operated on more than 3 days after injury. We had gained consent from every patient before treatment. The inclusion criteria were: (1) patients were over 18 years old and willing to cooperate with us for treatment and postoperative observation; (2) patients with no past history of elbow joint injury, and the elbow function was previously normal; (3) patients without other fractures that may have influence on elbow motion, such as distal humerus fracture and olecranon fracture; (4) patients were not associated with other diseases that may have influence on elbow motion after surgery; (5) patients underwent the same combined lateral and medical approach (CML approach); (6) only Kirschner wires or screws combined with suture anchors were used for fixation; and (7) follow-up more than 18 months. According to the Regan-Morrey classification standard, ulna coronoid process fractures were classified into the following types: type I (10 cases), type II (40 cases), and type III (13 cases) [14]. Mason-Johnston classification was used for radius head fracture: type I (12 cases), type II (34 cases), and type III (17 cases) [15]. The mechanisms of injury were traffic accident (21 cases), falling from a height (32 cases), and falling injury (10 cases). Approval for this study was obtained from the authors' Institutional Review Board, and we obtained consent from every patient before the study began.

Operative technique and protocol

All patients were initially treated with closed reduction and cast immobilization in the Emergency Department and none of them were associated with nerve lesion symptoms before the operation. All of them were operated by the same group of experienced elbow joint surgeons. The repair procedure was conducted initially with internal fixation (ulna coracoid process fracture first and radial head fracture second), followed by repair of the LCLC, then repair of the MCL of the elbow joint if necessary. All patients with open wounds underwent debridement and suturing.

Surgery procedure

Surgery approach: After all perioperative preparation had been completed, an anteromedial incision (over-the-top approach) was initially used to expose the coronoid process; this approach originates from the medial condyle of the humerus, making a 12~15 cm incision along the axis of the pronation teres, being cautious about the medial cutaneous nerve of the forearm in separation, splitting the pronation teres, exposing the fulcrum of the humeral muscle, then peeling half of the proximal part of the pronation teres until the coronoid fracture bone appeared. The radial head fracture was addressed through a lateral approach (Kocher approach); this incision originates 8~12 cm above the lateral condyle of the humerus to 8~10 cm below the olecranon. Surgeons entered the interval between the flexor carpi ulnaris and the elbow muscle to reach the LCLC and radius head fracture. To treat Regan-Morrey type I fractures, a suture was used for fixation. To treat type II or type III fractures, titanium screws or Kirschner wires were used for fixation. All radius head fractures were fixed with screws or screws combined with Kirschner wires. The lateral collateral ligament complex (LCLC) was repaired with suture anchors or trans-osseous sutures. After all the structures were repaired, elbow valgus

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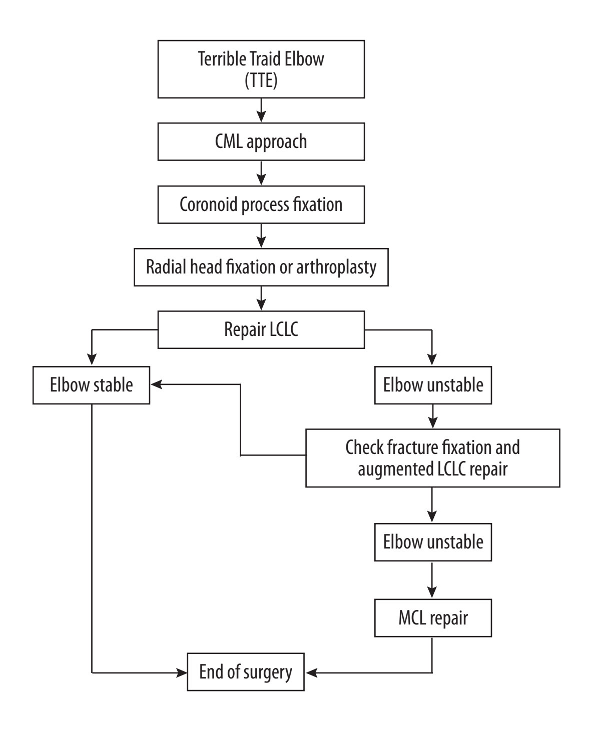

Figure 1. Schematic diagram of surgical procedure.

stability was then tested. If instability was found, repair of the medial collateral ligament (MCL) was done with suture anchors or direct sutures using number 1 or 2 sutures. No hinged external fixator was used for any patient [16] (Figures 1, 2).

Postoperative care

Postoperative drainage lasts 1~3 days and continues until flow volume is less than 20 ml. Antibiotics were regularly used for 3 days or more to prevent infection. Indomethacin (25 mg) was administered 3 times a day for the last 6 weeks to prevent heterotopic ossification formation. The elbow joint was bent at 90° and fixed with plaster or a brace in neutral position for all patients. The physiotherapy protocol had been followed by everyone before it was conducted. One to 2 weeks after the operation, plaster casts were removed, and patients started negative exercise, with brace support during non-exercising time, and limiting elbow joint extension to more than 30° within 1 month after the operation. About 1 month after the operation, patients were gradually encouraged to perform active exercise [17].

Follow-up and therapeutic evaluation

Pain at the third day after the operation was evaluated via VAS (visual analogue scale) score. Patients were followed up clinically and radiographically at postoperative months 1, 3, and 6 moths, including elbow flexion, and extension, pronation, and supination, and then once every 3~6 months. Data on bone fracture healing and heterotopic ossification recorded by X-ray were collected for each patient during the follow-up as well. At the final follow-up, according to the Broberg-Morrey classification for evaluating the degree of elbow degeneration, level 0 means normal, level 1 means the space of the elbow joint contracted slightly with little osteophyte formation, level 2 means the space of the elbow joint contracted moderately with partial osteophyte formation, and level 3 means severe degenerative changes of the elbow joint associated with joint destruction [18]. Motion range of elbow joint flexion and extension and forearm rotation for each patient were assessed, and the Mayo Elbow Performance Score (MEPS) was determined for each patient, including pain (45 points), range of motion of the elbow joint (20 points), elbow stability (10 points), and ability to perform activities of daily living (25 points). A final score of more than 90 points was regarded as excellent, 75~89 was good, 60~74 was acceptable, and less than 60 was poor [2].

Statistical analysis

SPSS 22.0 software was used for the statistical analyses. Descriptive statistics for continuous variables are reported as mean ±SD. One-way ANOVA was used to compare continuous variables among 3 groups, and the Levene test was used to assess the homogeneity of variances. If the data were not normally distributed, the non-parametric Kruskal-Wallis test was applied instead. The chi-square test or Fisher's exact test was used to compare the categorical variance, as appropriate, and $P<0.05$ were considered to be statistically significant.

Results

After appropriate exclusion, 36 males and 27 females, ranging from 25 to 65 years old, were enrolled in this study. Twenty patients were classified into group A (4–22 h after injury), 4 patients had an open wound around the elbow joint, 26 were classified into group B (4–14 days after injury), and the remaining 17 patients were classified into group C (from 15 to 34 days). No distinct differences were found in demographic characteristics, such as age, height, weight, cause of injury, and fracture classification. (Table 1). All patients underwent CML approach and had follow-up more than 18 months, with a mean of 20.6±1.9 months (range, 18–24 months). Two patients in group A (n=20) and 3 patients in group B (n=26) had lost partial final follow-up data.

Elbow function outcome

There were no distinct differences in preoperative elbow motion (50.2±10.1 to 52.8±12.3 to 54.1±13.3, P=0.736) and forearm rotation (50.0±14.5 to 53.4±10.1 to 51.8±11.8, P=0.859) among the 3 groups (Tables 2, 3). But at 1 month after surgery,

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Figure 2. (**A, B**) Preoperative elbow radiographs showing distinct elbow dislocation: (**C, D**) two-dimensional CT confirming radial head fracture and coronoid fracture: (**E, F**) postoperative elbow radiographs showing joint congruency, radial head fracture and coronoid fracture were fixed with screws.

patients in group A showed better elbow flexion-extension and forearm rotation recovery than those in group B, and patients in group A and group B achieved better outcomes than group C patients (range of elbow flexion-extension 92.4±23.8 to 76.8±20.0 to 61.5±25.2, $P<0.01$; forearm rotation 97.4±10.8 to 86.1±14.2 to 70.5±13.8, $P<0.01$). While on the basis of the data collected at 3 or more months postoperative, there was no distinct difference between group A and group B (all $P>0.05$), both groups still had better outcomes than in group C (all $P<0.01$).

In addition, at the final clinical visit, the total MEPS score in group A and group B was higher than group C (91.6±4.9 *vs.* 90.6±5.2 *vs.* 83.2±7.8 $P=0.002$ <0.05), which indicates that operations performed earlier were associated with regaining better elbow function (Table 4).

Postoperative complications and radiographic outcomes

In this study, the 4 patients in group A who had with open elbow joint wounds had internal fracture fixation and ligament repair after complete debridement, and no patient had wound

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Table 1. Perioperative data among three groups.

Item	Group A	Group B	Group C	p Value
Sex (Male/Female)	12/8	19/7	5/12	0.017
Age (years)	39.8±8.6	42.3±7.3	45.2±10.4	0.023
BMI (kg/m^2)	22.1±2.2	21.8±1.5	20.6±1.9	0.556
Injury reason				
Traffic accident	7	11	3	0.308
Falling from height	10	13	9	
Falling injury	3	2	5	
Left/Right side	15/5	9/17	11/6	0.007
Regan-Morrey types				
I	3	2	5	0.261
II	11	20	9	
III	6	4	3	
Mason-Johnston types				
I	3	5	4	0.262
II	8	15	11	
III	9	6	2	

Table 2. Change of flexion-extension of elbow joint among three groups.

Group	Before surgery	1 month postoperative (mean ±SD)	3 months postoperative (mean ±SD)	6 months postoperative (mean ±SD)
Group A	50.2±10.1$^{a)}$	92.4±23.8	104.6±22.0	111.3±18.5
Group B	52.8±12.3	76.8±20.0$^{1)}$	105.8±25.2$^{3)}$	109.6±17.3$^{3)}$
Group C	54.1±13.3	61.5±25.2$^{2)}$	75.3±24.8$^{2)}$	88.3±19.6$^{2)}$
$^{\#}$P value	0.736	<0.01	<0.01	<0.01

$^{\#}$ Comparison among all the three groups, all p<0.01; $^{a)}$ Compare with before surgery between three groups, all p>0.05; $^{1)}$ Compare group B to group A, p<0.05; $^{2)}$ Compare group C to the two groups above, p<0.01; $^{3)}$ Compare group B to group A, all p>0.05.

Table 3. Change of forearm rotation(pronation and supination) among three groups.

Group	Before surgery	1 month postoperative (mean ±SD)	3 months postoperative (mean ±SD)	6 months postoperative (mean ±SD)
Group A	50.0±14.5$^{a)}$	97.4±10.8	122.6±18.7	140.8±20.2
Group B	53.4±10.1	86.1±14.2$^{1)}$	120.8±20.5$^{3)}$	142.3±19.6$^{3)}$
Group C	51.8±11.8	70.5±13.8$^{2)}$	98.3±20.1$^{2)}$	118.2±24.8$^{2)}$
*P value	0.859	<0.01	<0.01	<0.01

* Comparison among all the three groups, all p<0.01; $^{a)}$ Compare with before surgery between three groups, all p>0.05; $^{1)}$ Compare group B to group A, p<0.05; $^{2)}$ Compare group C to the two groups above, p<0.01; $^{3)}$ Compare group B to group A, all p>0.05.

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Table 4. Elbow motion and forearm rotation, MPES score at the final follow up.

Variable*	Group A (mean ±SD)	Group B (mean ±SD)	Group C (mean ±SD)	p Value
Flexion (°)	123.8±16.5	124.9±19.2	108.4±21.0	0.019
Extension (°)	10.4±7.8	12.6±7.4	17.3±11.2	0.065
Range of flexion and extension (°)	113.1±22.6[1)]	112.0±25.2	91.0±29.8[2)]	0.020
Pronation (°)	73.0±5.6	71.5±9.0	61.2±10.3	<0.01
Supination (°)	74.6±7.7	78.0±7.9	68.6±7.7	<0.01
Forearm rotation (°)	147.0±11.8[1)]	149.5±14.2	129.8±17.4[2)]	<0.01
MEPS score	91.6±4.9[1)]	90.6±5.2	83.1±7.8[2)]	0.002
Excellent	15 (83.3%)	18 (78.2%)	7 (41.2%)	0.006
Good	3 (16.7%)	5 (21.8%)	8 (47.0%)	
Acceptable	0	0	2 (11.8%)	

* Two patients in group A and three patients in group B lost the final data; [1)] Compare group A to group B, all p>0.05; [2)] Compare group C to the other two groups, all p<0.05.

Table 5. Postoperative data among three groups.

	Group A	Group B	Group C	p Value
Fracture delayed union	2	3	0	–
Fracture nonunion	0	0	2	–
Ulnar nerve symptom	3	6	2	0.701
Heterotopic ossification	4	6	5	0.812
Elbow joint stiffness	2	3	7	0.018
Broberg-Morrey classification				
0	16	18	10	0.338
1	3	6	4	
2	1	2	3	
3	0	0	0	
VAS score	4.1±1.1	4.3±1.0	4.4±1.4	0.148

infection or required a second debridement operation. No postoperative pain difference was found among the 3 groups (P=0.148>0.05); 3 patients in group A, 6 patients in group B, and 2 patients in group C had ulnar nerve lesions after surgery, all the patients' symptoms disappeared within 4 months (from 2 weeks to 4 months), and no patient needed to accept release or anterior transposition of the ulnar nerve operation. Most coronoid and radial head fractures had solid osseous union at follow-up; only 2 patients in group A and 3 patients in group B had delayed union of the radius head, and 2 patients in group C had nonunion of the radius head. In addition, 4 patients in group A, 6 patients in group B, and 5 patients in group C had heterotopic ossification formation at the final follow-up (P=0.812 >0.05). Two patients in group A, 3 patients in group B, and 7 patients in group C had elbow joint stiffness and required a reoperation to improve elbow function. According to Broberg-Morrey classification, among the 3 groups, 44 patients were grade 0, 13 patients were grade 1, 6 patients were grade 2, and no patients were grade 3 (Table 5).

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Discussion

The terrible triad of the elbow (TTE) causes extensive damage to the ligaments and osseous structures, which causes acute elbow instability [6,12,16,17,19]. Almost all TTE patients need surgical treatment; however, although even the most experienced experts do their best to repair or rebuild injured structure, the clinical results are still not ideal [8,15,19]. Few articles address the treatment of terrible triad injuries specifically, surgical timing in particular. Our findings clearly show that TTE patients who had acute treatment (within 2 weeks) had better flexion-extension arc and forearm rotation arc than did patients who had delayed treatment (more than 2 weeks later). Certainly, it is better to have comparison of elbow motion and forearm rotation in the first days after surgery. However, according to long-term follow-up results, the difference is still distinct. The relatively higher average MEPS scores and better Broberg-Morrey outcome in group A and group B reflect the function recovery as well as the successful restoration of strength and stability, irrespective of the timing of surgery. Thus, we found that the surgical timing had an influence on the treatment of TTE patients. There is no significant difference between emergency surgery (within 24 hours) and early surgery (within 2 weeks) for TTE patients.

Surgical timing choice

Some authors have investigated the effect of timing of elbow joint surgery. Anneluuk was the first to compare the outcome of early operation and delayed treatment for TTE patients. He divided patients into an early operation group (mean 6 days after injury, range 1–13 days) and a delayed operation group (mean 7 weeks after injury, range 3–13 weeks after injury). All patients were treated with radial head replacement and lateral collateral ligament repair, and fixation of the coronoid fracture. He found that the former group had better flexion-extension and forearm supination of function recovery than the latter group, but there was no obvious difference in forearm pronation between the 2 groups [12]. He then compared the data with the data that Pugh-McKee collected, and concluded that there was no difference in the outcome of the early surgical group (patients operated on within 2 weeks), but the outcome of the delayed surgical group was poor [12,19]. Pugh et al. and Mckee et al. reported on large samples of TTE patients who had early operations and concluded that TTE patients operated on with standard surgical protocol in the early period could achieve good function recovery [3,19].

In our research, we divided all the patients into 3 groups according to the surgery timing and followed them for more than 18 months. Our continuous observation found that the emergency group (group A) had higher flexion-extension and forearm rotation than the other 2 groups in the early postoperative period. However, over time the differences decreased between the emergency group (group A) and the early group (group B). By about 3 months after the operation, there was no distinct difference between the 2 groups, but both groups displayed better outcomes than in the delayed surgery group (group C) at all time points.

This phenomenon may be related to the change of soft tissue structure after injury, as TTE is a typical severe injury of bone and soft tissue of the elbow joint. In the early period after injury, hematomas form around the fracture, soft tissue is congestive and gradually swells, cell disruption and vascular and nerve injury aggravate the damage of tissue ischemia and hypoxia, and more bone tissue and soft tissue becomes necrotic; all these factors cause aseptic inflammation. Consequently, the injured part swells, body temperature rises, and pain increases. Cell degeneration and necrosis appear within 24–48 h, releasing inflammatory mediators and aggravating tissue edema and necrosis. Because the elbow joint is immobilized, over time the hematoma becomes absorptive, the joint capsule becomes contracted, and the muscles gradually become atrophic; all of which worsen the joint dysfunction. In emergency surgery, we can break the chain that causes joint dysfunction over time, decreasing intra-articular pressure and alleviating tissue damage, quickly avoiding joint capsular contracture, muscle atrophy, and fibrous tissue formation, and thus stopping the process of malignant development. In addition, in the early period, the soft tissue boundaries are easy to identify, which is beneficial to anatomical reduction and internal fixation. After all bone and soft tissue structures are well-repaired, patients can perform functional exercise earlier and regaining their previous elbow function sooner. In the early operation group (group B) and delayed operation group (group C), patients had different degrees of preoperative tissue adhesion, joint capsular contracture, and muscle atrophy, and patients needed more time to recover elbow function. As patients continued to perform functional exercise, the outcomes in group A and group B gradually became more similar, possibly because elbow joint damage in the 2 groups was still within the reversible damage range. Nevertheless, tissue injury in group C had turned into irreversible damage perioperatively. Even worse, for old injuries, adhesion between tissues was serious and the boundary between soft tissue was blurred, and sometimes it was difficult to recognize the injured structure; these factors can affect accurate anatomic reduction in surgery. Consequently, it was inevitable that patients who had a delayed operation achieved lower elbow function and had longer recovery times.

Treatment of TTE, which is a well-known and complex bone and ligament injury, is a challenge for many doctors. When TTE patients do not undergo surgery in the Emergency Department, or if they have an open wound around the elbow joint, some doctors prefer to have a further repair operation until the

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swelling goes down or the wound had been partially healed. According to our experience, open TTE patients always have medial wounds. According to Gustilo classification system, the wound was type I or IIA, which indicated that it had low risk rate of infection. In our research, 4 patients in group A had open wounds. We had complete debridement initially and then performed repair operation. No patients suffered postoperative wound infection, and all patients eventually regained good elbow function. Certainly, if open TTE patients also have a severe soft tissue contusion and are very likely to be infected, we advise first performing complete debridement, and then perform the repair operation later (if possible, not exceeding 2 weeks).

Conclusions

In summary, emergency or early operation for TTE patients resulted in better function recovery than a delayed operation. Open TTE patients should initially receive complete debridement, and the decision to perform or delay the repair operation is made according to the wound condition. Closed TTE patients should have an early operation.

Study limitations

First, we needed more cases to support our conclusion. Second, the patients were operated on by different orthopedic surgeons, although they used the same approach and were fully experienced, there was still a difference. If more details are included, perhaps a more detailed conclusion can be drawn.

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