

# What Factors Are Associated With Elbow Stiffness After Operation of Terrible Triad Injury

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## Research article

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# Abstract

**Background:** The elbow stiffness is a common complication after operation of terrible triad injury (TTI) and significantly impair the patients' activities of daily living, while the risk factors have yet to be clearly identified. The goal of this study was to examine the patient-related, injury-related, and treatment-related factors for elbow stiffness after operation of terrible triad injury.

**Methods:** Between January 2013 and December 2019, 71 patients at two tertiary-care referral centers underwent operation of terrible triad injury were respectively reviewed. Range of motion (ROM), Mayo elbow performance scores (MEPS), Broberg-Morrey scores were used for functional evaluation. According to the ROM, the patients were categorized into stiffness group and non-stiffness group. The former had  $< 100^\circ$  of extension-flexion ROM and the latter had  $> 100^\circ$ . The patient-related, injury-related, and treatment-related factors were extracted from the medial records. The multivariate logistic regression were performed to identify the independent factors.

**Result:** At a mean follow-up of 35.9 months (12-68 months), 13 patients were classified into the stiffness group and 58 patients in the non-stiffness group. The stiffness group had significant worse functional scores compared to the non-stiffness group. Patients in the stiffness group were more likely to be Mason type III fracture, high-energy injuries, to have longer time between injury and surgery, ipsilateral upper limb injuries, and other fractures in body. However, multivariate logistic regression analysis revealed that time between injury and surgery  $> 7$  days, concurrent ipsilateral upper limb injuries and high-energy injury were independent factors that increased the risk of elbow stiffness after operation of terrible triad injury.

**Conclusions:** The patients underwent operation for terrible triad injury should be informed the probability of elbow stiffness when concurred ipsilateral upper limb injuries and operations should be conducted without delay. Knowledge of these risk factors will be helpful for guiding prophylaxis and early intervention in patients with high risk of elbow stiffness after operation of terrible triad injury.

## Introduction

The terrible triad injury (TTI) is a complex injury and defined as dislocation of the elbow along with fractures of the coronoid process and the radial head. This kind of injury is not common and accounts for only 4% of radial head fractures and 31% of elbow dislocation in adult [1]. The incidence of this injury makes peak in male and in the fourth decade of life [2].

The destruction of the valgus buttress of the radial head, the anterior buttress of the coronoid and the posterolateral stabilization of the lateral ulnar collateral ligament results in severe instability of elbow and remains a thorny problem for treating, even in experienced elbow surgeons [3, 4]. The conservative treatment usually led to poor results and evolve to re-dislocation, delayed consolidation, chronic instability, osteoarthritis, or severe stiffness because of prolonged immobilization [5, 6]. As a result, a change in treatment to early surgery has been widely accepted. Specially, in recent years, with the increased knowledge of elbow biomechanics, the advancement of fixation techniques, and the

application of standardized surgical protocols, the satisfactory outcomes have been reported by many studies [7–9]. However, the complication rate after operative treatment of TTI was reported as high as 50% [4, 5], especially the elbow stiffness, which obvious impairs the patients' activities of daily living [10–12]. Morrey reported that an arc of elbow motion between 30° and 130° is required for 90% of daily activities and loss of 50° arc of motion would result in up to 80% of functional loss [13]. In a recent study, Ostergaard et al [14] studied the factors associated with reoperation after surgical treatment of TTI and found that elbow stiffness was the main cause of reoperation, accounting for nearly 21%. Therefore, it is important to identify the risk factors after operation of these injuries and independent risk factors would be valuable in the pre-operative setting, initial patient consultation and prognostication. But, to our knowledge, there was no published literature evaluating factors associated with elbow stiffness after surgical treatment of TTI. Therefore, the goal of the present study was to determine the risk factors potentially associated with elbow stiffness in patients with operation of TTI.

## Materials And Methods

### Patients

We evaluated the patients who suffered TTI and underwent operation between January 2013 and December 2019 at two tertiary-care referral centers respectively. The inclusion criteria were set as follows: patients over 18 years old, without elbow fracture history, and with a normal function of the elbow previously as well as follow-up more than 12 months. The exclusion criteria were open physis, TTI accompanied by compartment syndrome, old fractures or neuro-muscular disorders. This study was approved by the Institutional Review Board of our hospital.

We found 71 patients underwent operation for the terrible triad injuries. There were 15 females and 56 males and the patients' mean age were 39.7 years (range, 19–71 years). Thirty-six of the patients had left sided fractures and 35 patients had right sided fractures.

### Data Collection

The electronic medical records information was collected by investigators other than the operating surgeons. The collected data was classified into patient-related, injury-related and treatment-related factors. The patient-related factors included gender, age, affected side, body mass index (BMI), underlying diseases (e.g., hypertension and diabetes mellitus). In addition, the smoking status and alcohol abuse were also recorded. The injury-related factors included mechanism of injury, type of radial head fracture and coronoid process fracture, presence of ipsilateral upper limb injuries, other fractures in body and presence of open fracture. The ipsilateral upper limb injuries were defined as fractures or nerve injuries accompanied by TTI (Fig. 1–3). In order to evaluate the severity of the fracture, Mason classification was used for radial head fracture while Regan-Morrey classification for ulna coronoid process fracture. We classified the mechanism of injury into high-energy injury and low-energy injury. The former included

vehicle accidents and falls from more than two-meter heights, while the latter included simple falls and sports injuries. Based on the operative records, the treatment-related factors were examined, including time between injury and surgery, surgical incision, the treatment modalities of radial head fracture (replacement or reconstruction or nonoperative) and coronoid process fracture (fixation or nonoperative), the management of medial collateral ligament (repair or no repair). Besides, surgical time and drainage tube use were also recorded. Referring to the previous literature [15], the time between injury and surgery was classified < seven days and > seven days.

All patients were followed up from 12 to 84 months. The elbow's range of motion, Mayo Elbow Performance Scores (MEPS) and Broberg-Morrey scores were used for post-operatively functional evaluation.

According to the range of elbow motion [13], the patients were classified as stiffness group (rang of elbow motion < 100°) and non-stiffness group (rang of elbow motion > 100°). The patient-related, injury-related and treatment-related factors were compared between the two groups.

## Statistical analysis

The SPSS software (SPSS v25, SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Univariate logistic regression was utilized to evaluate the correlation between potential risk factors and elbow stiffness. Continuous data were given as mean  $\pm$  standard deviation (SD) and compared with t-test between the two groups. Kolmogorov–Smirnov test was utilized to evaluated absence of normal distribution of continuous data, using the Mann-Whitney U test for the statistical analysis. Categorical data were expressed as percentage or rate and compared with chi-square test or Fisher's exact test. Then, a multivariant logistic regression analysis was used to produce odd ratios (OR) of independent variables and 95% confidence interval (CI). The statistical significance was set at  $p < 0.05$ .

## Results

Thirteen of 71 patients in the present study were identified as elbow stiffness with a mean range of motion 74.6° (stiffness group), while the remaining 58 cases with a mean range of motion 116.9° comprised the non-stiffness group. A significant difference could be found regarding the range of motion ( $p < 0.001$ ). There were also significant differences in MEPS score ( $p < 0.001$ ) and Broberg-Morrey score ( $p < 0.001$ ) between the two groups. The mean follow-up duration was 35.9 months (12–68 months) and no significant difference was found between the two groups. In addition, six patients underwent arthrolysis due to severe elbow stiffness.

When compared the patient-related variables between the two groups, we found no significant difference in age, gender, affected side, body mass index, alcohol abuse, smoking, and underlying diseases (Table 1). Regarding injury-related variables, no differences were observed in relation to the coronoid fracture type ( $p = 0.353$ ) and open or closed fractures ( $p = 0.335$ ). However, there was a high proportion of patients with ipsilateral upper limb injuries and other fractures in body in the stiffness group. Patients in

the stiffness group also had a high rate of high-energy injury and Mason type III fractures compared with the non-stiffness group. Analysis of the treatment-related factors showed no significant differences between the two groups in the surgical time, surgical incision, medial collateral ligament repair or not as well as the treatment modalities of radial head and coronoid process fractures. Nevertheless, there was a higher rate of patients with time between injury and surgery > seven days in the stiffness group.

Table 1  
The characteristics of patients with surgical treatment of terrible triad injury

Characteristics	Stiffness group (n = 13)	Non-stiffness group (n = 58)	p
Patient-related variables			
BMI, kg/m <sup>2</sup> (mean ± SD)	26.7 ± 3.45	26.2 ± 4.00	0.701 <sup>(1)</sup>
Age, years(range)	43.9(27–64)	38.8(19–71)	0.137 <sup>(2)</sup>
Side (n, %)			0.387 <sup>(3)</sup>
Left	8 (61.5%)	28 (48.3%)	
Right	5 (38.5%)	30 (51.7%)	
Gender (n, %)			0.274 <sup>(4)</sup>
Male	12 (92.3%)	44 (75.9%)	
Female	1 (7.7%)	14 (24.1%)	
Underlying diseases (n, %)			
Hypertension	1 (7.7%)	7 (12.1%)	1.000 <sup>(4)</sup>
Diabetes mellitus	1 (7.7%)	2 (3.4%)	0.460 <sup>(4)</sup>
Smoking (n, %)	2 (15.4%)	4 (6.9%)	0.301 <sup>(4)</sup>
Alcohol abuse (n, %)	2 (15.4%)	3 (5.2%)	0.224 <sup>(4)</sup>
Injury-related variables			
Open fracture (n, %)	1 (7.7%)	1 (1.7%)	0.335 <sup>(4)</sup>
Ipsilateral upper limb injuries (n, %)	7 (53.8%)	6 (10.3%)	0.001 <sup>(4)</sup>
Other fractures in body (n, %)	4 (30.8%)	3 (5.2%)	0.018 <sup>(4)</sup>
Injury mechanism (n, %)			0.002 <sup>(4)</sup>
ROM range of motion			
MEPS mayo elbow performance scores			
Continuous variables were expressed as mean ± standard deviation or median (minimum–maximum) according to normality of distribution and categorical variables as frequency (percentage).			
(1) Independent samples t test, (2) Mann-Whitney U test, (3)Chi-square test,(4)Fisher's exact test			

Characteristics	Stiffness group (n = 13)	Non-stiffness group (n = 58)	<i>p</i>
High-energy	9 (69.2%)	13 (22.4%)	
Low-energy	4 (30.8%)	45 (77.6%)	
Radial head fracture type (Mason classification) (n, %)			0.047 <sup>(4)</sup>
Type I	1(7.7%)	6(10.3%)	
Type II	2(15.4%)	29(50.0%)	
Type III	10(76.9%)	23(39.7%)	
Coronoid fracture type (n, %) (Regan–Morrey Classification)			0.353 <sup>(4)</sup>
Type I	3(23.1%)	26 (44.8%)	
Type II	8(61.5%)	27 (46.6%)	
Type III	2(15.4%)	5 (8.6%)	
Treatment-related variables			
Time between injury and operation,days (n, %)			0.015 <sup>(3)</sup>
< 7 days	3 (23.1%)	35 (60.3%)	
> 7 days	10(76.9%)	23(39.7%)	
Surgical time,minutes (range)	164.6(90–240)	141.7 (60–285)	0.180 <sup>(2)</sup>
Drainage tube (n, %)	7 (53.8%)	32 (55.2%)	0.931 <sup>(3)</sup>
Surgical incision (n, %)			0.342 <sup>(4)</sup>
Lateral approach	6 (46.2%)	34 (58.6%)	
Combined lateral and anteromedial approach	4 (30.8%)	9 (15.5%)	
Anterior medial approach	0 (0.00%)	6(10.3%)	
ROM range of motion			
MEPS mayo elbow performance scores			
Continuous variables were expressed as mean ± standard deviation or median (minimum–maximum) according to normality of distribution and categorical variables as frequency (percentage).			
(1) Independent samples t test, (2) Mann-Whitney U test, (3)Chi-square test,(4)Fisher's exact test			

Characteristics	Stiffness group (n = 13)	Non-stiffness group (n = 58)	<i>p</i>
Posterior approach	3 (23.1%)	9 (15.5%)	
Medial collateral ligament repair (n, %)	1 (7.7%)	6 (10.3%)	1.000 <sup>(4)</sup>
Radial head fixation (n, %)			0.490 <sup>(4)</sup>
No fixation	2 (15.4%)	5 (8.6%)	
Reconstruction	8 (61.5%)	31(53.4%)	
Replacement	3 (23.1%)	22 (37.9%)	
Coronoid fixation (n, %)	9 (69.2%)	34 (58.6%)	0.479 <sup>(3)</sup>
Follow-up, months (mean ± SD)	35.2 ± 15.5	36.1 ± 15.5	0.852 <sup>(1)</sup>
ROM (flexion-extension) (°) (mean ± SD)	74.6 ± 17.4	116.9 ± 8.0	< 0.001 <sup>(1)</sup>
MEPS scores (range)	79.6 (70–95)	94.6 (85–100)	< 0.001 <sup>(2)</sup>
Broberg-Morrey scores (range)	82.8 (74–87)	91.6 (81–100)	< 0.001 <sup>(2)</sup>
ROM range of motion			
MEPS mayo elbow performance scores			
Continuous variables were expressed as mean ± standard deviation or median (minimum–maximum) according to normality of distribution and categorical variables as frequency (percentage).			
<sup>(1)</sup> Independent samples t test, <sup>(2)</sup> Mann-Whitney U test, <sup>(3)</sup> Chi-square test, <sup>(4)</sup> Fisher's exact test			

In the univariate analysis, ipsilateral upper limb injuries, other fractures in body, and time between injury and surgery as well as injury mechanism were all associated with elbow stiffness (Table 2). However, the outcome of the multiple logistic regression analysis indicated that the association between other fractures in body and elbow stiffness was no longer significant. On the contrary, the ipsilateral upper limb injuries (OR 11.87, 95% CI 1.46–96.43  $p = 0.021$ ), time between injury and surgery (OR 9.63, 95% CI 1.34–69.39  $p = 0.025$ ) and injury mechanism (OR 8.42, 95% CI 1.24–56.98  $p = 0.029$ ) were still significantly associated with elbow stiffness after surgery treatment of TTI.

Table 2

Association of potential risk factors and elbow stiffness after surgical treatment of terrible triad injury  
(Multiple Logistic Regression Analysis)

	Univariate		Multivariate	
	Odds ratio (95% CI)	<i>p</i> -value	Odds ratio (95%CI)	<i>p</i> -value
Ipsilateral upper limb injuries	12.37 (2.98–51.40)	0.001	11.87 (1.46–96.43)	0.021
Other fracture in body	8.15 (1.56–42.62)	0.018	5.92 (0.52–67.22)	0.151
Time between injury and surgery (days)	5.07 (1.26–20.43)	0.015	9.63(1.34–69.39)	0.025
Injury mechanism	9.61 (2.50–37.02)	0.002	8.42 (1.24–56.98)	0.029
Radial head fracture type (reference: Mason I)				
Mason II	2.42 (0.19–31.15)	0.499	1.78 (0.03–124.24)	0.789
Mason III	0.38 (0.04–3.61)	0.402	0.40 (0.01–17.54)	0.629
CI: confidence interval.				

## Discussion

The management of the terrible triad injuries is still challenging. Although surgical treatment is effective for the vast majority of patients medically suitable for operation, the high incidence of complication should not be neglected [16–19]. With the increasing knowledge of elbow mechanism and pathology of terrible triad injury, many studies have presented good radiological and clinical results [7, 9, 20]. Unfortunately, elbow stiffness is still a common complication, which severely decreases the patients' quality of life [21–23]. Many factors may influence the treatment results of TTI, including the fracture type of radial head and coronoid process, the surgical incision, the time between injury and surgery and the degree of ligament injury [24–27]. Identifying the potential risk factors for elbow stiffness after surgery treatment of TTI may assist surgeons taking preventive measures and improving the treatment of these serious injuries, but there have been little studies published so far.

The most important findings of our study were that time between injury and surgery > seven days and the presence of ipsilateral upper limb injury increased the risk of elbow stiffness after surgical treatment of TTI. In the present study, the time from injury to surgery longer than seven days was associated with more than nine-fold increase in the risk of elbow stiffness. Different studies have evaluated the timing of elbow operation and stiffness. In a retrospectively study, Hong et al [15] examined the heterotopic

ossification after elbow fracture surgery and reported that the risk of heterotopic ossification increased 10.62 times when the time to surgery was more than seven days. In another study, Tunali et al [11] evaluated risk factors for stiffness after distal humerus plating and found that patients with the time to surgery > seven days were more likely (2.59 times) to suffer elbow stiffness. Similarly, Lindenhovius et al [28] compared the acute and subacute treatment of TTI and showed that earlier management could obtain a better flexion arc. In addition, Wigger et al [29] reported that the risk of post-traumatic elbow stiffness increased 1.12-fold for each additional day until the definitive operation was undertaken after the initial injury. In line with these studies, we observed that the longer time between injury and surgery could increase the risk of elbow stiffness after surgery treatment of TTI. This phenomenon could be attributed to the fact that the patients who underwent delayed surgery may have had more severe soft-tissue damage and needed more time for the swelling to subside so as to avoid the wound complications [30].

Concurrent ipsilateral upper limb injuries in this study were associated with nearly 12-fold increase in the risk of elbow stiffness when a considerable number of factors noted to be risk in previous studies were controlled. The ipsilateral limb injury has been considered as a risk factor for worse outcome in different orthopedic disorders [31, 32]. In relation specifically to terrible triad injury, the available evidence is scarce. In 2013, Wigger et al [29] investigated different factors associated with restrictive heterotopic ossification (HO) after elbow trauma and found that ipsilateral injury accounted for 37% of cases in restrictive HO group while only 28% in non-restrictive HO group. Although no significant difference was observed between the two groups, the trend was still worth noting that the ipsilateral injury potentially affected the range of elbow motion. Additionally, Allemann et al worked on the predictive factors of complication and adverse outcomes in 149 patients with isolated or combined fractures in ipsilateral upper limb [33]. They found that, compared with the isolated articular fracture group, the combined fractures group was more likely to occur joint contractures (25% vs 8.3%,  $p = 0.009$ ) and severe heterotopic ossifications (80.7% vs 13.6%,  $p < 0.001$ ). In another study, Dickens et al [34] reported that periarticular fractures on both sides of the elbow, which defined as bipolar fractures were significantly associated with decreased range of elbow motion and worse outcome in patients with open elbow fractures. In any case, the multiple injuries in the ipsilateral upper limb always reflected greater soft tissue injuries and a more serious injury. The serious soft tissue injuries and concurrent ipsilateral limb fractures, often requiring a delayed surgery, prolonged operation course and longer time of immobilization after operation, may explain the elbow stiffness after surgical treatment of TTI.

The present study has also supported the previous literatures reporting the association of high-energy injury and elbow stiffness. In a retrospective study, Zheng et al [35] retrospectively investigated 169 patients with elbow stiffness and noted that the risk of severe elbow stiffness was markedly higher in high-energy trauma group (OR 4.45,  $p = 0.03$ ). Dickens et al [34] reviewed 136 patients with open elbow fractures and found that high-energy injury was associated with limited range of elbow motion. This is not surprising, given the association between injury mechanism with the degree of osseous and soft tissue damage—that is, the higher the force, the more serious osseous and soft tissue injury and the more likely to develop elbow stiffness.

On the contrary, our study has not found support for the different managements of radial head fracture as a risk factor of elbow stiffness. Yan et al [36] analyzed 39 patients with terrible triad injury who were treated with either radial head reconstruction or radial head replacement and found that the rate of elbow stiffness was significantly higher in repair group than replacement group (21.1% vs 5%). In a recent study, Ostergaard et al [14] investigated 62 patients who had surgery for TTI and found that elbow stiffness was the most common indication for reoperation (21%) and radial head treatment was the only risk factor for reoperation. However, the most important difference with reports indicating a positive association of radial head treatment and elbow stiffness, is that the injury mechanism was controlled in our study. The high-energy injury often resulted in comminuted radial head fractures, which were difficult for open reduction and internal fixation and always required radial head replacement for early rehabilitation.

There are several limitations in our study. First of all, because of the retrospective nature of the study, selection bias was unavoidable. But, after carefully selected patients according to the inclusion and exclusion criteria, the readers could be able to identify which cases our results best apply. Secondly, the study was performed nearly a seven-year period in two hospitals and the operations were conducted by several different surgeons, all of which might result in potential selection bias. However, considering these operations were all performed by experienced surgeons in the tertiary-care referral centers and the principle of dealing with terrible triad injury remaining constant, we believed that these were not a relevant limitation of the present study. Thirdly, the sample size of patients was relatively small, which would limit the number of risk factors evaluated. In future, a larger sample size, multi-center study with a high level of evidence should be conducted to further verify our findings. However, despite these limitations, to our knowledge, this is the first study to perform a detailed risk factor analysis for elbow stiffness after surgical treatment of TTI. Knowledge of these risk factors will be valuable in improving the treatment of terrible triad injury.

## Conclusion

In conclusion, there were various variables affecting elbow stiffness development after surgery treatment of terrible triad injury. Among these factors, the time between injury and surgery > seven days, concurrent ipsilateral upper limb injury and high-energy injury were found to increase the risk of elbow stiffness, while the treatment modality of radial head was not associated with the development of elbow stiffness. The findings in our study will be potentially helpful for guiding prophylaxis and early intervention when patients are at high risk of elbow stiffness after surgical treatment of terrible triad injury.

## Abbreviations

TTI

Terrible triad injury; ROM:Range of motion; BMI:Body mass index; MEPS:Mayo elbow performance scores; HO:Heterotopic ossification.

## Declarations

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## **Authors' Contributions**

Yingze Zhang and Jian Zhu contributed to the study conception and design. Material preparation, data collection and analysis were performed by Hongzhi Hu, Xiangtian Deng, Xiaodong Chen and Zhanchao Tan. The first draft of the manuscript was written by Jian Zhu and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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## **Availability of data and materials**

The data and materials contributing to this article may be made available upon request by sending an e-mail to the first author.

## **Ethical Approval and consent to participate**

This study was approved by the clinical research ethics committee of the Third Affiliated Hospital of Hebei Medical University and the number was 2020-040-01.

## **Consent to Participate**

Informed consent was obtained from all individual participants included in the study.

## **Consent to Publish**

Consent to publish was obtained from the patient detailed in this study.

## **Competing Interests**

All the authors declare that they have no conflict of interest with any organization that sponsored the research.

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## Figures



**Figure 1**

A 20-year-old male diagnosed with terrible triad injury associated with ipsilateral scaphoid fracture. a, b Initial radiographs of elbow (anteroposterior and lateral) showed a posterior elbow dislocation, with a radial head and coronoid process fracture. c, d The ipsilateral radiographs of wrist (anteroposterior and lateral) revealed the scaphoid fracture, with no significant displacement. e, f The contralateral radiographs of the wrist (anteroposterior and lateral) indicated the scaphoid was intact.



**Figure 2**

Postoperative radiographs (anteroposterior and lateral) of the same patient in Figure 1. a, b The radial head was reconstructed with screws and the coronoid fracture was not fixed due to small fragment. c, d The scaphoid fracture was managed by conservative treatment with a plaster.



**Figure 3**

Radiographs of a 47-year-old male after a fall from 2-meter-high ladder with an open fracture. a, b The anteroposterior and lateral X-ray of elbow showed elbow dislocation and radial head fracture. c, d CT scan revealed dislocation of the elbow, the fractures of radial head and coronoid process (terrible triad injury) associated with external condyle fracture of humerus. e, f Postoperative radiographs showed the fractures were reconstructed with K-wires due to the open wound.