CLINICAL ARTICLE

Risk Factors of Elbow Stiffness After Open Reduction and Internal Fixation of the Terrible Triad of the Elbow Joint

Xiao He, MD[1,2], Quan Fen, MD[1,2], Jiarui Yang, MD[1], Yutian Lei, MD[3], Lisong Heng, MD[1], Kun Zhang, PhD[1]

[1]*Department of Orthopaedic Surgery, Hong Hui Hospital, Xi'an Jiaotong University and* [2]*Yan'an University School of Medicine and* [3]*Xi'an Jiaotong University, Xi'an, Yan'an, China*

Objective: To analyze the risk factors of elbow stiffness following open reduction and internal fixation of the terrible triad of the elbow joint.

Methods: A retrospective study was conducted of 100 patients with the terrible triad of the elbow joint, who had been treated at our hospital from January 2015 to December 2018. All patients were treated with a loop plate to repair the ulnar coronoid process. According to the severity of the injury, the radial head was either fixed or replaced, and the lateral collateral ligament was repaired with an anchor. According to the range of motion of the elbow during the last follow-up, the patients were divided into two groups. The stiffness group (displayed extension–flexion or pronation–supination <100°) consisted of 30 patients. The second group, named the non-stiffness group (exhibited extension–flexion and pronation–supination ≥100°), consisted of 70 patients. Related risk factors included age, gender, smoking, diabetes, whether the fracture is on the dominant side, mechanism of injury, fracture classification, time from injury to surgery, configuration of internal fixation of the radial head, postoperative immobilization time, and use of anti-heterotopic ossification drugs (oral indomethacin). Both *t*-test and chi squared test were used to analyze any significant differences. Only the variables with a $P < 0.05$ in the tests were retested into a logistic multiple regression in order to screen risk factors of elbow stiffness.

Results: All patients were followed up for 12–48 months (average, 25.7 months), and all patients exhibited bone healing. Multivariate regression analysis showed that high-energy injury (OR = 3.068, 95% CI 1.134–8.295, $P = 0.027$), time from injury to surgery > 1 week (OR = 2.714, 95% CI 1.029–7.159, $P = 0.044$), and postoperative immobilization time (OR = 3.237, 95% CI 1.176–8.908, $P = 0.023$) were independent risk factors of elbow stiffness after surgery for the terrible triad of the elbow.

Conclusion: High-energy injury, the time from injury to surgery > 1 week, and postoperative joint immobilization time > 2 weeks are the independent risk factors of elbow stiffness after surgery of the terrible triad of the elbow, which should be treated carefully in clinical treatment.

Key words: Elbow stiffness; Internal fixation; Risk factors; The terrible triad of the elbow

Address for correspondence Kun Zhang, PhD, and Lisong Heng, MD, Department of Orthopaedic Surgery, Honghui Hospital, Xi'an Jiaotong University, 555 Youyi East Road, Beilin District, Xi'an, Shaanxi, China 710054 Tel: 15029219698; Fax: 029-87894724; Email: zhangkunhhyy@163.com (Zhang); Tel: 13379259833; Fax: 029-87894724; Email: henglisonghhyy@163.com (Heng)

Grant Sources: This study was supported by the Key Social Development Projects of Shaanxi Science and Technology Administration (2017SF-197).
Disclosure: Each author certifies that he has no commercial or any other associations that might pose a conflict of interest in connection with the submitted article.
Received 25 August 2020; accepted 26 October 2020

Introduction

The "terrible triad" of the elbow joint refers to the dislocation of the elbow joint accompanied by fractures of both the ulnar coronoid process and the radial head, first presented by foreign scholar Hotchkiss[1] in 1996. It is a type of severe elbow fracture, often causing related complications. A stiff elbow joint is more common, and is defined as a joint that cannot reach its functional range of motion. Morrey *et al.*[2] considered the functional range of elbow joint to be flexion and extension of 100° (extension 30° to flexion 130°), rotation 100° (pronation 50°, supination 50°). In current times, people have higher requirements for the range of elbow joint functional activities. In 2011, Sardelli *et al.*[3] redefined the range of elbow joint functional activities as extension 23° to flexion 142° and 65° pronation to 77° supination. Studies have found that functional recovery after elbow joint fracture resection and internal fixation may be affected by a variety of factors, including gender, age, fracture type, internal fixation configuration, and injury-to-operation time. However, there is a lack of research on the methods of reducing the occurrence of elbow stiffness after surgery for the terrible triad of the elbow joint. This study collected data on patients with the terrible triad of the elbow joint, who were admitted to our hospital from January 2015 to December 2018, and retrospectively analyzed the risk factors of elbow stiffness after their surgery.

Materials and Methods

Inclusion Criteria and Exclusion Criteria

The inclusion criteria were as follows: (i) the initial diagnosis was the terrible triad of the elbow; (ii) unilateral elbow fracture; (iii) age >18 years old; (iv) patients without severe disease history of heart, brain, lung, or other important organs; (v) follow-up period greater than 1 year.

Exclusion criteria: (i) open fracture or accompanied by severe soft tissue injury or multiple fractures of the same upper limb; (ii) combined with other fractures or old fractures; (iii) fractures with vascular and nerve injuries or pathological fractures, congenital deformities, and other diseases that affect upper limb function; (iv) patients with mental disorders that could not be effectively treated. A total of 173 cases were collected and 73 cases were excluded after further screening. There were 30 cases of multiple fractures, 20 cases of open fractures, 13 cases of old fractures, and 10 cases of multiple fractures in the same upper limb. The remaining 100 cases met the inclusion criteria.

Treatment Method

General Treatment

Upon admission, all patients were examined by anterior and lateral X-rays of the elbow joint. The elbow joint was then reduced manually and fixed with a brace. Prior to surgery, a CT scan and three-dimensional reconstruction of the elbow joint were performed, in order to evaluate the injury and determine the basic operation plan.

Surgical Treatment

Thirty minutes prior to surgery, intravenous infusion of antibiotics was administered. All patients were under general anesthesia during surgery. The patient was recumbent in the supine position, with his/her forearm in front of the chest; an airbag tourniquet was applied at the root of the upper arm. All surgical incisions used the lateral approach. Upon exposing the surgical field of view, evaluation of the radial head fracture was performed in order to determine whether repair and reconstruction or replacement of the radial head was required. During the operation, in order to maintain the reduction of the elbow joint, the ulnar coronoid process was fixed with a loop steel plate. Then the choice of radial head repair, reconstruction, or replacement was selected according to the extent of the radial head fracture; finally, the lateral ligament complex was repaired with thread rivets. After completing the above operation, the elbow joint was moved passively (flexion, extension, pronation, supination) in order to confirm the stability of the elbow joint, and whether there was any obstruction or friction; also to determine the reduction of the fracture and the position of the implant *via* C-arm fluoroscopy. After determining that the stability of the elbow joint was restored, the tourniquet was relaxed, bleeding was thoroughly stopped, the incision was closed layer by layer, and the wound was wrapped in an aseptic dressing. The typical case is shown in figure 1.

Postoperative Treatment and Follow-Up

The use of antibiotics should not be administered untill after 24 h post-surgery. In order to actively eliminate swelling, and to relieve pain after the operation, it is helpful to exercise the metacarpophalangeal and interphalangeal joints as soon as possible to promote distal blood circulation. The drainage tube can be removed if the drainage volume is less than 30 mL after 24 h. All patients began passive functional exercise of the affected limb within 1 week after the operation. It is recommended that patients take indomethacin (25 mg, 3 times/day) orally for 3 weeks in order to prevent heterotopic ossification. Clinical follow-up and X-ray examination of the elbow joint were performed at 1, 2, 3, 6, and 12 months after the operation, and the patients were guided into exercise rehabilitation according to the clinical review results. At the final follow-up, the patient's elbow joint extension–flexion and rotation range of motion were recorded.

Grouping Criteria and Risk Factors

According to a study by Morrey *et al.*[2], the definition of elbow joint stiffness, the flexion, extension and rotation of the affected limb were recorded at the final follow-up. The patients were divided into two groups: a stiffness group (flexion–extension or rotation range of motion <100°) and a non-stiffness group (flexion–extension and rotation range of

TABLE 1 Comparison of clinical data among the two groups

Variable	Stiffness group (n = 30)	Non-stiffness group (n = 70)	*t*-value	*P*-value
Extension (°)	40.16 ± 6.67	10.44 ± 8.06	83.057	0.000
Flexion (°)	105.78 ± 13.40	139.16 ± 3.66	−89.702	0.000
ROM (flexion-extension) (°) (mean ± SD)	65.62 ± 18.61	128.72 ± 11.31	−97.098	0.000
Pronation (°)	39.64 ± 6.96	69.95 ± 6.66	−96.199	0.000
Supination (°)	42.14 ± 6.63	74.65 ± 8.28	−89.048	0.000
Rom (Rotation) (°) (mean ± SD)	81.78 ± 10.13	144.6 ± 14.48	−101.040	0.000
MEPS (mean ± SD)	63.47 ± 10.94	89.10 ± 8.33	−59.695	0.000

motion ≥100°). The comparison of elbow joint function between the two groups is shown in Table 1. The related risk factors of elbow stiffness after operation for the terrible triad in this study included: age, gender, smoking, diabetes, fracture type, whether the fracture is on the dominant side, energy of the force causing the injury, time from injury to operation, postoperative immobilization time, internal fixation configuration of the radial head, and whether to use anti-heterotopic ossification drugs (indomethacin).

Statistical Analysis

All statistical analyses were performed using IBM SPSS statistics version 22.0. Continuous variables such as age were statistically described by (M ± SD), and two independent sample t-tests were used for comparison between the two groups. Gender, fracture classification, injury energy, time from injury to operation, and other counting data were compared between the two groups using the χ^2-test. The factors were analyzed by univariate analysis, and then the factors with $P < 0.05$ were analyzed by logistic regression analysis. A value of $P < 0.05$ was considered statistically significant.

Results

General Results

A total of 100 cases were included in this study. There were 30 cases in the stiffness group, including 13 males and 17 females, aged from 20 to 65 years (mean 42.75 ± 8.47 years). According to the Regan–Morrey[4] method, the ulnar coronoid process fractures were classified into 13 cases of type I and 17 cases of type II. According to the Mason[5] method, the radial head fractures were classified as 10 cases of type I, 13 cases of type II, and 7 cases of type III. According to the cause of the injury, 20 cases were due to a high-energy injury (fall injury, car accident injury, sports injury), 15 cases of the dominant-side injury. Internal fixation materials used for the radial head injury: 13 cases of countersunk nails, 14 cases of plate fixation, and three cases of replacement; 18 cases of injury to operation time greater than 1 week, 16 cases of postoperative immobilization time greater than 2 weeks, and 10 cases without oral administration of anti-heterotopic ossification drugs. There were 70 cases in the non-stiffness group, including 33 males and 37 females, ranging in age from 20 to 65 years (mean 42.16 ± 9.76 years). According to the Regan–Morrey[4] method, the ulnar coronoid process fractures were classified into 30 cases of type I and 40 cases of type II. According to the Mason[5] method, the radial head fractures were classified as 20 cases of type I, 37 cases of type II, and 13 cases of type III. Based on etiology, 23 cases were due to high-energy injuries (fall injuries, car accident injuries, sports injuries), 30 cases of the dominant-side injury. Internal fixation materials for the radial head injuries: 23 cases of countersunk nails, 37 cases of plate fixation, and 10 cases of replacement; 20 cases of injury to operation time greater than 1 week, 15 cases of postoperative immobilization time greater than 2 weeks, and 10 cases without oral administration of anti-heterotopic ossification drugs. The basic information of the patients is shown in Tables 2 and 3.

TABLE 2 Demographic characteristics of the study population by patient

Characteristics	Data
Number of patients	100
Age (Mean ± SD, years)	42.34 ± 9.39
Gender (Males, %)	46,46%
BMI (kg/m^2) (mean ± SD)	22.24 ± 3.25
Comorbidities	
Diabetes (n,%)	9,9%
Tobacco (n,%)	37,37%
Energy level	
High-energy (n,%)	43,43%
Low-energy (n,%)	57,57%
Dominant side	
Yes (n,%)	45,45%
No (n,%)	55,55%
Time from injury to operation	
Within a week (n,%)	62,62%
More than a week (n,%)	38,38%
Postoperative immobilization time	
Within 2 weeks (n,%)	69,69%
More than 2 weeks (n,%)	31,31%
Anti-heterotopic ossification drugs use (n,%)	80,80%

Follow-Up Results

All patients were followed up for 12–48 months (mean 25.7 months). The wounds of all patients healed in one stage, there was no nerve or vascular injuries, and bone healing was achieved in all patients.

Outcome of Univariate Analysis

A univariate comparison between the stiffness group and the non-stiffness group found that damage energy (P = 0.002), time from injury to operation (P = 0.003), postoperative immobilization time (P = 0.002), postoperative use of anti-heterotopic ossification drugs (P = 0.029) demonstrated a statistically significant difference (Table 4). There was no statistically significant difference in factors such as age, gender, injury side, fracture type, etc. ($P > 0.05$, Table 4).

TABLE 3 Demographic characteristics of the patients by fracture

Fracture	Number
Regan-Morrey types	100
I (n,%)	43,43%
II (n,%)	57,57%
Mason types	
I (n,%)	30,30%
II (n,%)	50,50%
III (n,%)	20,20%
Material of radial head	
Countersunk nail (n,%)	36,36%
Mini steel plate (n,%)	51,51%
Artificial radial head (n,%)	13,13%

Outcome of Multivariate Logistic Regression Analysis

Logistic regression analysis was used to analyze the factors with $P < 0.05$.The results of multivariate analysis indicated that high-energy injury (OR = 3.068, 95% CI 1.134–8.295, P = 0.027), the time from injury to operation >1 week (OR = 2.714, 95% CI 1.029–7.159, P = 0.044), and postoperative immobilization time (OR = 3.237, 95% CI 1.176–8.908, P = 0.023) were independent risk factors of elbow stiffness, following elbow surgery for the terrible triad. The use of anti-heterotopic ossification drugs and other factors are not independent risk factors of elbow stiffness after this surgery (Table 5).

TABLE 4 Single factor analysis of elbow joint stiffness

Variable	Stiffness group (n = 30)	Non-stiffness group (n = 70)	Statistical value	*P*-value
Age (Mean ± SD, years)	42.75 ± 8.47	42.16 ± 9.76	1.335	0.182
Gender				
Male	13	33	0.123	0.726
Female	17	37		
BMI (kg/m^2) (mean ± SD)	22.25 ± 2.79	22.24 ± 3.43	0.116	0.907
Diabetes				
Yes	3	6	0.000	1.000
No	27	64		
Tobacco use				
Yes	9	28	0.901	0.343
No	21	42		
Energy level				
High-energy	20	23	9.794	0.002
Low-energy	10	47		
Dominant side				
Yes	15	30	0.433	0.511
No	15	40		
Regan–Morrey types				
I	13	30	0.002	0.965
II	17	40		
Mason types				
I	10	20	0.778	0.678
II	13	37		
III	7	13		
Material of radial head				
Countersunk nail	13	23	1.095	0.578
Mini steel plate	14	37		
Artificial radial head	3	10		
Time from injury to operation				
Within a week	12	50	8.804	0.003
More than a week	18	20		
Postoperative immobilization time				
Within 2 weeks	14	55	9.994	0.002
More than 2 weeks	16	15		
Anti-heterotopic ossification drugs use				
Yes	20	60	4.762	0.029
No	10	10		

TABLE 5 Results of multivariate analysis of independent predictors of elbow stiffness using multivariate GEE regression model

Variable	B	SE	Wald	OR	95% CI	*P* value
Energy level	1.121	0.508	4.878	3.068	1.134 ~ 8.295	0.027
Time from injury to surgery	0.998	0.495	4.070	2.714	1.029 ~ 7.159	0.044
Postoperative immobilization time	1.175	0.517	5.171	3.237	1.176 ~ 8.908	0.023
Whether use anti-heterotopic ossification drugs	0.298	0.590	0.255	1.347	0.423 ~ 4.284	0.614

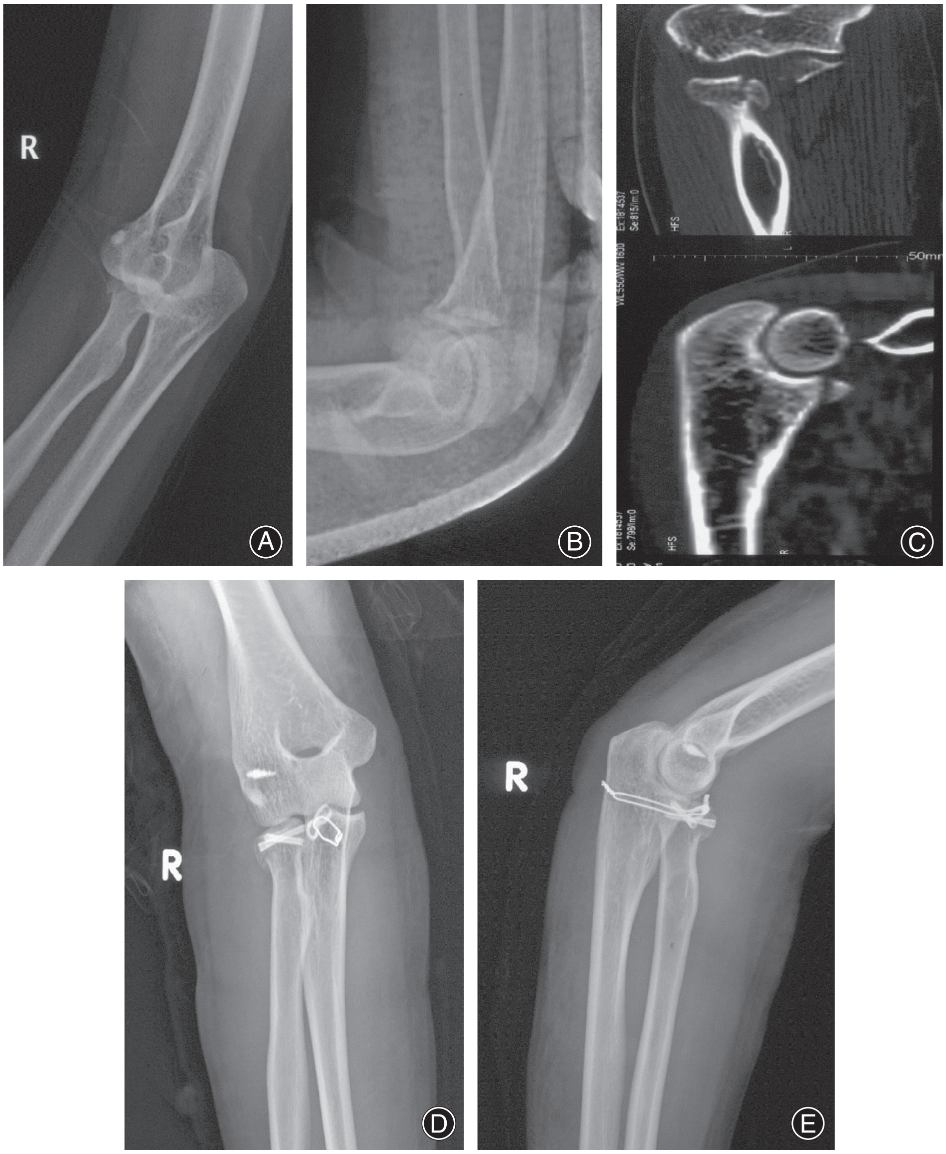

Fig. 1 The terrible triad of the right elbow, the ulnar coronal process was fixed with loop steel plate, the radial head was fixed with countersunk head nail, and the lateral ligament complex was repaired with thread rivet. Preoperative X-ray examination of elbow joint (A, B) CT examination of (C). X-ray examination of elbow joint on the second day after operation (D, E).

Discussion

Studies have shown that the terrible triad of the elbow accounts for 18% of elbow injuries[6], and it is one of the most serious injuries of the elbow. The complex anatomical structure and higher functional requirements of the elbow make treatment of the terrible triad of the elbow more difficult, and there are multiple postoperative complications. At present, most scholars at home and abroad advocate early surgical treatment in order to achieve a better treatment result[7–9]. The common postoperative complications of the terrible triad of the elbow are stiffness of the elbow joint, heterotopic ossification around the elbow joint, and pain in the elbow joint. It has been reported that from 5% to 15% of patients with elbow fractures will experience elbow stiffness after surgery[10, 11]. According to the etiology and location, Morrey categorizes the sources of elbow stiffness into intra-articular factors (posttraumatic arthritis, intra-articular adhesion, etc.) and extra-articular factors (ectopic ossification, joint capsule contracture, etc.)[12]. Although some studies have analyzed the causes of elbow stiffness following surgery for elbow fracture, there are few reports examining the risk factors of elbow stiffness in patients with the terrible elbow triad after operation. Therefore, this study analyzes the risk factors of elbow stiffness after terrible triad elbow surgery, in order to better guide clinical treatment and rehabilitation evaluation.

According to the research[13, 14], on the mechanism of the terrible triad of the elbow injury in the literature, it is reported that the terrible triad of the elbow injury is a variety of high-energy injury, including traffic accidents and falls. These traumas often lead to serious soft tissue injuries and comminuted fractures, etc., which may adversely affect surgical treatment and the recovery of elbow joint function. Studies have found that high-energy injury is an important factor leading to joint instability of the elbow joint, which seriously affects the prognosis[15]. Zhang *et al.*[16] studied 169 cases of posttraumatic elbow stiffness and found that high-energy injury is an independent risk factor (OR = 4.450, $P = 0.003$) for severe elbow stiffness (flexion and extension range of motion >30° and ≤60°). In our study, it was also found that high-energy damage in the terrible triad of the elbow was an independent risk factor for postoperative elbow stiffness (OR = 3.068, 95% CI 1.134–8.295, $P = 0.027$). Although much progress has been made in the understanding, treatment, and rehabilitation measures of the terrible triad of the elbow, the prognosis is not ideal. Therefore, when dealing with the high-energy injury of the terrible triad of the elbow in clinic, we must make a full evaluation of the condition in order to improve the treatment and rehabilitation measures, so as to reduce the occurrence of postoperative elbow stiffness and improve the satisfaction of treatment outcomes.

Although all of the cases selected in this study are closed injuries, the terrible triad of the elbow caused by high-energy is often accompanied by severe soft tissue injury, which is bound to prolong the time from injury to operation, in order to meet the soft tissue condition requirements for surgery. A large number of studies[17–19] have shown that the longer the delay time from injury to surgery, the higher the risk of postoperative elbow stiffness. Zhou *et al.*[17] found that the prognosis of patients with surgical treatment from 24 h after injury to 14 days after injury was significantly better than that of patients with delayed operation of greater than 14 days. Lindenhovius *et al.*[18] reported that a better range of motion can be obtained by undergoing surgery within 2 weeks after injury. Wiigger *et al.*[19] found that every 24 h delay in surgery after injury more than doubled the risk of postoperative elbow stiffness. It can be seen that the longer the time from injury to operation, the more disadvantageous it is for the post-surgical recovery of elbow joint function. In our study, it was discovered that the time from injury to operation of more than 1 week was also an independent risk factor for postoperative elbow stiffness (OR = 2.714, 95% CI 1.029–7.159, $P = 0.044$). The analysis shows that local soft tissue congestion and edema in the early stage of fracture, cell degeneration, and necrosis release a large number of inflammatory mediators to aggravate tissue exudation and necrosis, leading to tissue adhesion and joint capsule contracture; early surgical treatment can halt this chain of deterioration. Therefore, we believe that surgical treatment should be performed within 24 h if the patient's systemic condition permits. When the soft tissue injury is severe, or the patient's physical condition is poor, active detumescence treatment and combined multi-department treatment should be provided in order to shorten the time from injury to operation, so as to reduce the risk of postoperative elbow stiffness.

In the terrible triad of the elbow, the tissue injury is serious, although the operation can restore the original bony anatomical structure and repair the surrounding soft tissue. However, when such a large trauma has been sustained, many patients cannot fully follow the doctor's advice, due to pain and other reasons, so initiating the necessary rehabilitation exercises as soon as possible becomes difficult, resulting in a lengthier elbow joint immobilization time, affecting recovery of elbow joint function after surgery. However, Okazaki *et al.*[20] found that the articular cartilage began to degenerate after immobilization of the knee joint of rabbits for 7–14 days, and moderate to severe degeneration occurred after immobilization for more than 4 weeks. Some scholars[21] suggest that the active or passive extension and flexion of the elbow should begin on the first day post-surgery. Modabber *et al.*[22] reported that when an intra-articular fracture occurs, articular cartilage begins to be repaired by fibrous tissue when the immobilization time is more than 3 days; if the immobilization time is more than 6–12 weeks, even if there is no injury, the joint function will be significantly affected. McKee *et al.*[23] also found that if immobilization time exceeds 4 weeks, it will seriously affect the recovery of joint function. In our study, it was also found that when the postoperative immobilization time was longer than 2 weeks, the probability of experiencing elbow stiffness was 3.237 times (OR = 3.237, 95% CI 1.176–8.908, $P = 0.023$). This indicates that postoperative immobilization time greater than 2 weeks is also an independent risk factor for elbow stiffness. A shorter postoperative joint immobilization time and earlier initiation of necessary functional exercises are both beneficial to the recovery of elbow joint function and reduce the risk of joint stiffness. This requires us to minimize postoperative pain and discomfort, and guide patients to carry out correct rehabilitation exercises.

This study also has some limitations. First, this study is a retrospective analysis of cases. For the collection of data, there is a large difference in grouping according to factors which may affect the accuracy of statistical methods to a certain extent. Second, this study is a multi-factorial study of elbow stiffness after the operation for the terrible triad of the elbow, and the sample size may be relatively small. Third, the case in this study is not the same medical group, so there may be different observation results due to different treatment methods, which may affect the scientific nature of the research results.

According to the objective results, we can still draw some conclusions. High-energy injury, the time from injury to operation > 1 week, and the immobilization time of the elbow joint greater than 2 weeks after surgery are all related to the recovery of joint function after operation on the terrible triad elbow and are independent risk factors of resultant elbow stiffness. This requires that when we deal with patients with terrible triad of the elbow in clinics, we should develop the optimal operation plan and appropriate treatment measures in a timely manner and decrease both the waiting time for surgery and the time of joint immobilization afterwards. Patients should begin functional exercise as soon as possible to reduce the risk of joint stiffness.

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