

Arthrolysis combined with reconstruction for treatment of terrible triad injury with a poor outcome after surgical as well as conservative intervention

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Abstract

Introduction The treatment of terrible triad injury with a poor outcome after intervention has not been successful thus far. The purpose of this study was to evaluate the efficacy of arthrolysis and reconstruction in the treatment of terrible triad injury with a poor outcome after surgical as well as conservative intervention.

Materials and methods Twelve patients (12 elbows) with the diagnosis of terrible triad injury were respectively reviewed. All the 12 patients had elbow dysfunction after conservative and surgical treatment of the terrible triad injury. Preoperatively, the flexion arc and forearm rotation

were $36.7^\circ \pm 28.5^\circ$ and $51.3^\circ \pm 43.4^\circ$, respectively, and the Mayo Elbow Performance Score was 56.3 points. The mean interval between the primary injury and our surgical treatment was 6.6 months. Our surgical intervention included elbow arthrolysis, ulnar nerve transposition, radial head replacement, coronoid process and ligament repair, and hinged external fixation. Patients were encouraged to participate in rehabilitation training 24 h after surgery.

Results The mean follow-up duration was 20.1 months; the flexion arc and forearm rotation were $122^\circ \pm 18^\circ$ and $140^\circ \pm 20^\circ$, respectively, and the mean Mayo Elbow Performance Score was 94.6 points (9 excellent, 3 good). Concentric stability was restored in all elbows. Complications included superficial pin tract infection (1), heterotopic ossification (3), and ulnar nerve palsy (1); the ulnar nerve symptoms had improved at the last follow-up.

Conclusions The combination of open arthrolysis and reconstruction performed at a mean interval of 6-month posttrauma can restore functional mobility in cases of terrible triad injury with a poor outcome after surgical as well as conservative intervention. Thus, it may be an effective alternative for the treatment of the poor outcome terrible triad injury. We recommend early functional rehabilitation with adherence to the guidelines for hinged external fixation.

Keywords Terrible triad injury · Poor outcome · Elbow stiffness · Arthrolysis · Reconstruction · Hinged external fixator

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Introduction

The term “terrible triad of the elbow” was coined by Hotchkiss [1], to describe a specific pattern of injury, including

complete dislocation of the elbow joint-associated ligament damage, radial head, coronoid process, olecranon and epicondyle fractures. The principles of treatment for this injury were detailed by Pugh et al. [2] as well as Ring et al. [3]; several investigations [2, 4–10] have addressed the surgical results using these protocols, and relatively satisfactory outcomes have been reported. However, there are several reasons for a terrible triad injury (TTI) of the elbow to have a poor outcome; they include missed diagnosis, failure to address the primary lesion and complications such as heterotopic ossification (HO) and elbow contracture, which finally lead to an abnormal bony structure and elbow stiffness [11, 12]. These pathologies and the complex nature of the TTI injury make its treatment a daunting challenge for surgeons.

Recently, only a few published reports deal specifically with the management and prognosis of the poor outcome TTI [8, 9]. We, therefore, need to find an alternative method to treat these injuries and evaluate the outcome. Open arthrolysis is a classical and effective method for treatment of elbow stiffness [11, 12]. Additionally, in order to regain functional mobility of the elbow, further reconstruction should be conducted to restore the bony structures and soft tissues damaged by the old TTI injury. The purpose of our study was to evaluate the effectiveness of open arthrolysis and reconstruction as secondary treatment in patients with a TTI who had a poor outcome after conservative as well as surgical treatment.

Materials and methods

Patients

Twelve patients (9 men, 3 women; mean age 34.7 years [range 22–56 years]) with a TTI who had conservative treatment or poor outcome after primary surgery as seen on radiography or a computerized tomography (CT), and had elbow stiffness, were treated by open arthrolysis and reconstruction in our hospital between February 2010 and April 2012. The surgeries were performed by the same surgeon (CYF). The outcome was evaluated by an assessment of the flexion arc (flexion and extension), forearm rotation, elbow stability and pain, and Mayo Elbow Performance Score (MEPS). Meanwhile, a radiography was taken to evaluate the joint congruity, posttraumatic HO and arthritic changes. The physical examination (degree of flexion–extension and forearm rotation, stability, and complications) was performed by the same investigator, and the radiograph was evaluated by two investigators. All of them were blinded to the study at the last follow-up.

Of the 12 cases, 7 were low-energy (falling while walking), and 5 were high-energy (falling from over 3 m or

traffic accidents) injuries. The coronoid fractures were classified according to Regan and Morrey [13] as follows: type III (1 patient), type II (6 patients), and type I (5 patients). The radial head fractures were classified according to the modified Mason's classification [14] as type III (3 patients), type II (6 patients), and type I (3 patients). The associated injuries included 1 ipsilateral lateral epicondyle fracture of humerus, and 1 ipsilateral distal radioulnar joint dislocation combined with an ulnar fracture. Four patients were initially treated conservatively (elbow reduction and immobilization in a plaster). The remaining eight patients had previous surgical procedures, including percutaneous pinning, internal fixation for the radial head and coronoid process, resection or replacement of the radial head, and external fixation. The mean immobilization duration of the 12 patients following conservative or surgical treatment was 4.1 ± 1.6 weeks (Table 1).

Standard radiographs and a three-dimensional reconstruction CT scan of the elbow were used to evaluate joint congruity, posttraumatic HO, and arthritic changes (Fig. 1a, b showed the typical imaging of case 9). All 12 patients had HO and were classified according to the Hastings–Graham classification [15] as type IIA (1), type IIC (7), type IIIB (3), and type IIIC (1). The patients were classified according to the arthrosis grade [16] as grade 0 (1), grade I (3), grade II (4), and grade III (4). Redislocation of the elbow occurred in five patients, both in the conservative and surgical treatment. Three patients presented with ulnar nerve symptoms before the surgery.

Pre-operatively, the flexion arc, extension, flexion, and forearm rotation were $36.7^\circ \pm 28.5^\circ$, $40.4^\circ \pm 18.6^\circ$, $77.1^\circ \pm 27.4^\circ$, and $51^\circ \pm 43^\circ$ (pronation $10^\circ \pm 18^\circ$, supination $41^\circ \pm 32^\circ$), respectively. The valgus stress test and lateral pivot shift test were performed for medial and posterolateral rotary instability of the elbow [17]. Mean Mayo Elbow Performance Score [18] was 56.3/100 points before surgery (Table 2).

Operative technique

The patient was placed in a standard supine position with abduction of the affected upper limb after a brachial plexus block. A sterile tourniquet was applied. Medial and lateral approaches were adopted in all cases according to the location of the pathology. The extended Kocher approach was used for the lateral incision. The anterior capsule, coronoid fossa, hypertrophic capsule, scar tissue, and heterotopic bone (Fig. 1c) were then exposed. After arthrolysis of the anterior capsule and pathologic tissue, the coronoid was restored in seven patients, in whom the osseous structure had not been addressed before, using an anchor in two patients (nonunion of larger fragments) and repairing anterior capsule with non-absorbable sutures in five patients

Table 1 Details of 12 patients (12 elbows) of poor outcome TTI

Case	Sex/age (years)	Affected side	Injury mechanism	RH/CP fracture classification (Mason/Regan–Morrey)	Primary treatment	Immobilization (weeks)	Complication before	Time from injury (months)
1	M/56	Right	Fall	2/1	Conservative	4	Redis, HO	4
2	M/33	Left	Traffic accident	3/2	ORIF, RH _r	1	HO	8.5
3	M/26	Left	Fall	1/2 ^a	Conservative	4	HO	14
4	M/30	Right	Fall	2/1	ORIF	4	HO	7.2
5	M/39	Right	Traffic accident	1/1	Conservative	4	Redis, HO	1.3
6	F/25	Left	Traffic accident	1/3 ^b	ORIF	2	Redis, HO	3.5
7	M/22	Right	Fall from 6 m	3/2 ^c	ORIF, RH _x	6	UNP	6.5
8	M/33	Left	Fall	2/2	Open reduction, RH _x	3	Redis, HO	7.5
9	M/46	Right	Fall	2/2	ORIF	8	HO	7.4
10	F/44	Left	Fall	2/1	Conservative	3	UNP, HO	3.8
11	F/44	Right	Fall	3/2	Open reduction, RH _x	3	UNP, HO	7.8
12	M/40	Left	Fall from 3 m	2/1	ORIF, LCL/MCL Recons _a , external fixator	4	Redis, HO	7.5

ORIF open reduction and internal fixation, RH_x radial head excision, RH_r radial head replacement, LCL lateral collateral ligament, MCL medial collateral ligament, Recons_a reconstruction with anchor, Redis redislocation, HO heterotopic ossification, UNP ulnar nerve palsy

^a Associated with ipsilateral humerus lateral epicondyle fracture

^b Associated with ipsilateral olecranon fracture

^c Associated with ipsilateral distal radioulnar joint dislocation and ulnar fracture

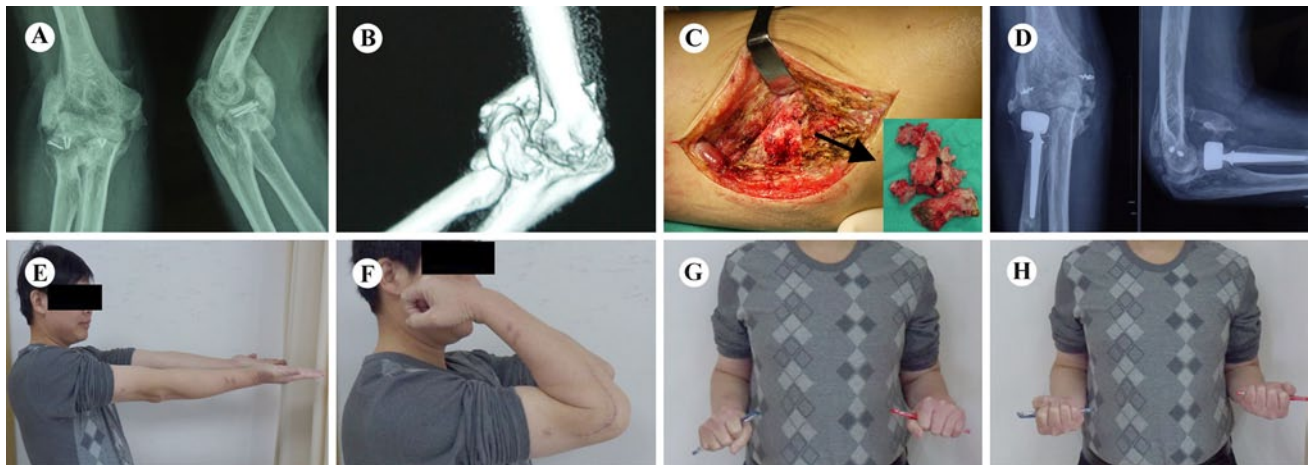


Fig. 1 **a** The anteroposterior and lateral radiographs of a 46-year-old man showing elbow stiffness after the primary surgery. **b** A three-dimensional CT scan showing heterotopic ossification over the anterolateral aspects of the elbow. **c** Removal of obstructive het-

erotropic ossification and malformed radial head during the surgery. **d** Postoperative standard radiographs showing HO on the left side at 12 months after surgery; elbow function was satisfactory. **e** Extension, **f** flexion, **g** pronation, and **h** supination

(smaller fragments) [3]. Eight radial heads were observed as nonunion, malunion or osteomalacia in the surgeries, and then prosthetic replacement (Edina, MN, USA) was performed to restore the lateral stability in six patients. Two other patients underwent radial head resection. The annular ligament was reconstructed using non-absorbable sutures. All patients presented with lateral collateral ligament

complex (LCLC) injury and the main lateral stabilizing ligament, the lateral ulnar collateral ligament (LUCL), as part of the LCLC, needed to be addressed. Thus, LUCL was reconstructed by nonabsorbable sutures in five cases. However, direct suture failed in seven cases, and thus osseous suture anchors were used as described in the study of Giannicola et al. and Olsen [19, 20]. The medial incision

Table 2 Treatment and results for individual patients

Case	Surgical approach	Surgical treatment	Preoperative			Postoperative			Complication	Follow-up (months)
			E°/F°	P°/S°	MEPS	E°/F°	P°/S°	MEPS		
1	M/L	Arthrol, RH _x , UNR, HEF	50/60	0/0	55	10/110	25/60	85	–	24.6
2	M/L	IFR, Arthrol, UNR, HEF	50/75	10/50	55	10/110	50/90	95	–	24
3	M/L	Arthrol, UNR, CP/LCL Recons _a , HEF	35/130	30/45	90	0/130	70/90	100	–	18
4	M/L	IFR, Arthrol, RH _r , UNR, HEF	45/90	10/80	50	0/135	70/90	100	Pin tract infection	36
5	M/L	Arthrol, LCL Recons _a , MCL repair, UNR, HEF	80/105	10/20	20	0/140	65/90	100	Temporary UNP, HO	18
6	M/L	Arthrol, RH _r , CP/LCL Recons _a , UNR, HEF	0/70	0/70	50	10/130	70/80	85	HO	24
7	M/L	Arthrol, RH _r , HEF, ulna shortening	45/95	30/40	65	20/110	70/60	90	HO (limit the motion)	17.7
8	M/L	Arthrol, RH _r , LCL Recons _a , UNR, HEF	45/80	30/80	50	0/130	70/90	95	–	18
9	M/L	IFR, Arl, RH _r , UNR, MCL/LCL Recons _a , HEF	30/30	0/0	55	15/120	50/80	100	Temporary UNP	17
10	M/L	Arthrol, LCL Recons _a , UNR, Ost, HEF	30/50	–30/30	60	2/140	55/90	100	–	16
11	M/L	Arl, RH _r , UNR, MCL/LCL Recons _a , HEF	45/50	30/80	60	0/135	40/90	85	UNP	13
12	M/L	Arl, RH _x , UNR, Ost, HEF	30/90	0/0	65	0/140	55/85	100	–	15

M/L medial and lateral approach, *CP* coronoid process, *LCL* lateral collateral ligament, *MCL* medial collateral ligament, *Arthrol* arthrolysis, *RH_x* radial head excision, *RH_r* radial head replacement, *UNR* ulnar nerve relaxation, *HEF* hinged external fixator, *IFR* internal fixator removal, *Recons_a* reconstruction with anchor, *Ost* humeral media epicondyle osteotomy, *P/S* pronation/supination, *E/F* extension/flexion, *MEPS* Mayo Elbow Performance Score, *UNP* ulnar nerve palsy, *HO* heterotopic ossification

was subsequently performed for posterior release, reconstruction of the medial collateral ligament (MCL), and anterior transposition of the ulnar nerve [12]. After releasing and protecting the ulnar nerve, the bilateral margins of the triceps tendon were separated from the distal humerus to release the posterior elbow, and the olecranon fossa was cleared. Two patients underwent MCL repair with an anchor due to valgus instability.

After reattachment of the muscles, the wound was closed in layers. Drainage was routinely used. The range of motion (ROM) and rotation were checked throughout the surgery, and a hinged external fixator was applied to help maintain a concentric reduction of the elbow while allowing elbow motion exercises for a consolidated effect of arthrolysis and for provision of an ideal state for ligament recovery [21].

Postoperative management

Indometacin (25 mg) was prescribed 3 times a day for approximately 4–6 weeks to prevent HO. To prevent thrombogenesis, passive muscle contraction was conducted as soon as the limb recovered from anesthesia. Early mobilization began on the first or second postoperative day and the postoperative exercises included flexion, extension, and

rotation as well as active, passive and active-assisted range-of-motion exercises of the elbow. Under the supervision of our staff, the rehabilitation protocol was customized for each patient based on the stability achieved (>90 % mobility during the surgery) and pain during the exercises. The length of rehabilitation session was gradually increased to 1 h in subsequent weeks. The hinged external fixator was removed approximately 6–8 weeks after the surgery. The follow-up status was obtained at 6–8 weeks (fixator and pin removal), at 3 months, and then at every 6 months after the surgery. Radiograph was taken routinely (Fig. 1d)

Statistical analysis

All data (mean ± SD) were processed by SPSS Statistics 13.0.

Results

The mean follow-up duration was 20.1 months (range 13–36 months). Postoperatively, the flexion arc improved to 121.9° ± 18.2° (range 90°–140°), the extension to 5.6° ± 7.1° (range 0°–20°), and the flexion to 127.5° ± 12.0° (range 110°–140°). Forearm rotation

improved to $141^\circ \pm 21^\circ$ (range 87° – 160°), pronation to $58^\circ \pm 15^\circ$ (range 24° – 70°), and supination to $83^\circ \pm 11^\circ$ (range 60° – 90°). The mean MEPS was 94.6/100 (range 85–100 points) after surgery, with an excellent result in 9 elbows and a good result in 3 elbows. Figure 1e–h shows the functional result of a typical patient (case 9). Postoperative information is detailed in Table 2.

At the last follow-up, radiographs demonstrated good congruity of the humeroulnar joint in all patients. No drop sign was observed in the radiographs [22]. The arthritis grade after the operation was I in 4 patients, II in 6 patients, and III in 2 patients. In addition, no prosthetic loosening was detected in all 6 patients with radial head replacement (Fig. 1d). An additional radiograph was taken in the five patients with radial head resection and no subluxation of distal radioulnar joint had occurred. All the anchors used to repair LCL and MCL were in position.

Complications included pain (mild [$n = 3$], moderate [$n = 1$]), instability ($n = 1$), heterotopic ossification ($n = 3$), superficial pin tract infection ($n = 1$), and persistent ulnar nerve palsy ($n = 1$). All elbows were stable in the flexion arc according to valgus stress test and lateral pivot shift test, except one patient who had temporary instability; the instability was eliminated subsequently with enhancement of the muscle power in the follow-up.

Discussion

In our study, the average value of the flexion arc was 121.9° , which was similar to that reported in previously conducted studies as the treatment outcome of acute TTI [7, 8]. It is, therefore, possible to approach a functional elbow with an old TTI and a poor surgical outcome with a proper treatment plan, and achieve stability.

With the application of the detailed principles of the standard treatment for TTI, the outcome of this injury has improved dramatically [2, 3]. However, there are several reasons for a TTI to have a poor outcome. In our series, the reasons included delayed treatment (4 patients), improper immobilization (median 4 weeks), and complications such as HO and joint stiffness. It is difficult to treat these stiff elbows that lack anatomical integrity, which was untreated in the primary surgery.

Furthermore, the most investigations were interested in the outcome of acute TTI, only a few of them were focused on the result of subacute or delayed TTI [8, 9]. Lindenhovius et al. [8] compared the surgical outcome of the acute (average 6 days after injury) and subacute (average 7 weeks after injury) groups of TTI. After treatment with their protocol, an average flexion arc of 119° in the acute cohort and 100° in the subacute cohort was obtained. The Broberg and Morrey scores were comparable between cohorts (90 vs 87 points). It

was concluded that stability and strength were restored with both acute and subacute treatments, but earlier treatment is more straightforward and is associated with a better flexion arc. In another investigation, Sørensen et al. [9] treated elbow with persistent instability after posterior fracture-dislocation with internal fixation and hinged external fixation to restore stability and mobility. Most of the cases were treated within 6 weeks after the primary injury. The conclusion of the study was similar to those of the above-mentioned studies in that the results in the early treatment group are better than those in patients undergoing late reconstruction.

Complications after surgical intervention for TTI include ulnar nerve palsy, radial nerve palsy, deep infection, elbow instability, elbow stiffness, and HO [9, 23]. The ulnar nerve is vulnerable to palsy due to traumatic and/or surgical irritation [6, 8, 9, 24], and efforts have been made to reduce this complication. Toros et al. [25] treated 16 TTI patients, in which 8 of them underwent ulnar nerve release during the surgery. At the follow-up, they found swollen around the cubital tunnel displaced nerves in the non-nerve releasing patients by MRI or ultrasonography. Furthermore, the ulnar nerve symptom is much more distinct in patients who developed extension contracture preoperatively, because of the challenge of the space availability for the nerve to the degree that they will obtain postoperatively [26]. Thus, we present a similar but more aggressive approach: perform a routinely prophylactic ulnar nerve release. In our study, the ulnar nerve was protected by either subcutaneous anterior transposition or medial epicondylectomy. As a result, no patient experienced a new onset of persistent ulnar nerve palsy. However, further study is warranted to obtain consensus on this treatment.

Instability is a major complication after surgery of TTI, and in most cases, it needs surgical intervention [2, 5, 6, 9, 27]. There is no doubt that stability is the key to early rehabilitation, which contributes to the functional outcome significantly, and is also the reason why we make efforts to restore all the structures as far as possible. There is no need to routinely repair the MCL as long as the joint is stable after restoring the osseous structure and the LCL [2, 25]. Furthermore, application of hinged external fixator in all the TTI patients is controversial [2–10, 19, 21, 23]. We believe that the hinged external fixator can provide extra stability as well as ideal conditions for ligament healing and early rehabilitation after reconstruction and arthrolysis [12, 21]. In this study, no persistent instability was detected in the mean 20.1-month follow-up, and temporary instability occurred in one patient when his external fixator was removed; however, the stability resolved subsequently with strengthening exercises. This is supported by the study of biomechanics, which states that muscles are dynamic stabilizers [28]. We have, therefore, highlighted the importance of physical strengthening exercises in the improvement of outcomes.

Heterotopic ossification could be a potential problem after elbow surgery; however, it is insignificant in terms of its influence on the outcome [2, 6, 27]. Three patients developed HO in this study, and all of them were mature according to the radiographs taken at the latest follow-up. Only one of them, a 22-year-old man with flexion arc $<100^\circ$, asked for a secondary arthrolysis. It is important to keep in mind that surgical removal of heterotopic bone should be delayed for at least 1 year because early intervention would predispose patients to recurrence [29].

Two patients underwent radial head resection instead of replacement because of financial problems; the MCL must be intact for this procedure. We strongly recommend prosthetic replacement for restoration of lateral stability and a functional humero-radial joint when the radial head is incompetent, especially in the young patients.

One of the limitations of this study is the small sample size. Therefore, we did not perform a power analysis. However, TTI is a relatively rare injury of the elbow. Therefore, we consider a series of 12 patients to be representative and its outcome credible. Furthermore, a comparative study is warranted to reveal the surgical outcome of acute, delayed, and surgically treated TTI. A functional elbow could be restored with our methods in the case of TTI with a poor outcome after surgical and conservative interventions.

Conclusion

Based on our results, we conclude that open arthrolysis and reconstruction of the surgically and conservatively treated TTI with a poor outcome could restore the functional mobility of the elbow. Consequently, we recommend participation in early rehabilitation and application of a hinged external fixator in all patients who underwent ligament repair to improve the outcome of TTI.

Conflict of interest The authors declare that they have no conflict of interest. The study was performed with the approval of the ethics committee (Shanghai Tenth People's Hospital, Shanghai, P. R. China, No. 2013-Res-007).

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