

Operative treatment of terrible triad of the elbow with a modified Pugh standard protocol

Retrospective analysis of a prospective cohort

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Abstract

The aim of the present study was to investigate the efficacy of the surgical treatment of terrible triad injuries of the elbow using a modified standard surgical approach, and treatment determined by the mode and mechanism of injury, and intraoperative findings.

The study was a retrospective analysis of a prospective cohort of patients presenting with terrible triad injuries of the elbow, who underwent surgical treatment between July 2009 and January 2014. All patients were treated surgically according to a modified Pugh standard protocol. Elbow functional status and range of movements were evaluated at 3 months, 6 months, 1 year, and 2 years or more after surgery. Radiographic signs of post-traumatic arthritis were rated according to the Broberg and Morrey system.

Our series included a final cohort of 29 males and 13 females with a mean age of 48.23 ± 10.95 years at the time of injury. The mean follow-up period was 30.47 ± 7.65 months. The mean flexion-extension arc was $107^\circ \pm 22^\circ$, and the average forearm rotation arc was $145^\circ \pm 14^\circ$. The mean Mayo Elbow Performance Score was 88 ± 10 points (range 55 to 100 points), with excellent results in 24 elbows, good results in 16, and poor results in 2. Functional results of the elbow improved significantly from 3 months postoperatively ($P < .05$), but tended to plateau from 1 year after surgery. Thirteen patients had radiographic signs of arthrosis (9 grade 1, 4 grade 2). Postoperative complications were local infection around the incision ($n = 1$), transient postoperative median nerve paralysis ($n = 1$), and postoperative posterior interosseous nerve paralysis ($n = 1$). Four patients required further surgery. Five patients had evidence of heterotopic ossification.

Overall, we show that slight modifications to Pugh standard protocol for the surgical treatment of terrible triad injuries can lead to good to excellent results, although there were a good number of complications. The ideal surgical approach and treatment should be based on the mode and mechanism of injury, and intraoperative findings, and modifying the standard surgical treatment approach for terrible triad elbow injuries may be beneficial.

Abbreviations: CT = computed tomography, EDC = extensor digitorum communis, LCL = lateral collateral ligament, MCL = medial collateral ligament, MEPS = Mayo Elbow Performance Score.

Keywords: elbow fracture-dislocation, fracture, internal fixation, operative treatment, terrible triad of the elbow, traumatic instability

1. Introduction

The term “terrible triad” was coined by Hotchkiss^[1] in 1996 to describe an injury complex that consisted of a dislocated elbow along with radial head and coronoid fractures. This injury is very uncommon, and although most terrible triad injuries are managed surgically, the exact incidence of this injury is unknown.^[2–8] In 2004, Pugh et al^[3] achieved good results in nearly half of their patients with terrible triad injury of the elbow

with a standardized surgical protocol. The surgical protocol included radial head fixation or arthroplasty, repair of the lateral collateral ligament (LCL), and coronoid fixation or repair of the anterior capsule. They also repaired the medial collateral ligament (MCL) if the elbow remained unstable after reconstruction, and employed a hinged external fixator when sufficient stability of the elbow could not be achieved after MCL repair.

Although this procedure has been shown to be effective,^[3,4,7] some of the treatment aspects, such as the surgical approach and whether to treat the MCL and coronoid fracture, remain controversial.^[2–8] The purpose of the present study was to investigate the efficacy of a modified standard protocol for the surgical treatment of terrible triad injuries of the elbow based on the mode and mechanism of injury, and also intraoperative findings.

2. Materials and methods

2.1. Study design

This study was a retrospective analysis of a prospective cohort of patients presenting with terrible triad injuries of the elbow, who underwent surgical treatment at a tertiary care center between July 2009 and January 2014 by 1 of the 2 senior authors (GYL and WHM). All patients were treated surgically according to a modified Pugh standard protocol. Inclusion criteria included

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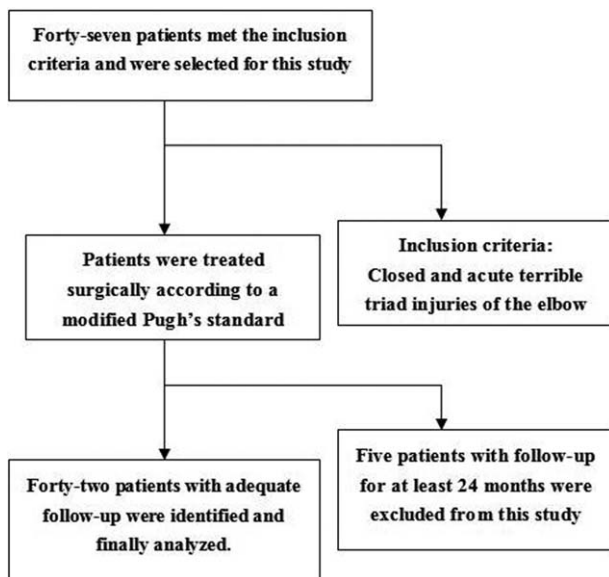


Figure 1. Flow diagram shows how the patients were enrolled in the study.

closed and acute terrible triad injuries of the elbow. Exclusion criteria included open and old injuries, patients younger than 18 years of age, and patients with a follow-up period of less than 24 months. Forty-seven patients met the inclusion criteria and were selected into this study. Forty-two patients with adequate follow-up were identified (Fig. 1). Medical records and radiographs were reviewed from our hospital database records to identify and analyze details of the initial injury and treatment. These patients were then invited to our hospital for clinical and radiographic evaluation. This research was approved by the Institutional Ethics Committee of the Ningbo 6th Hospital (No. 2016001, Date March 17, 2009).

2.2. Study population

Our series included a final cohort of 29 males and 13 females, with a mean age of 48.23 ± 10.95 years at the time of injury. The minimum follow-up was 24 months (mean 30 months; range 24–56 months). Radial head fractures were classified according to Mason.^[9] There were 2 type I, 28 type II, and 12 type III radial head fractures. We categorized coronoid fractures according to both the Regan and Morrey^[10] and O'Driscoll et al^[11] classification systems. Using the Regan and Morrey system, there were 11 type I, 29 type II, and 2 type III coronoid fractures. Using the O'Driscoll system, 29 patients had a tip fracture (4 subtype 1, and 25 subtype 2), 12 had an anteromedial type fracture (1 subtype 1, 10 subtype 2, and 1 subtype 3), and 1 patient had a basal subtype 2 fracture. All patients underwent surgery within a mean of 6.52 ± 2.37 days after injury.

2.3. Surgical stepwise procedure

Figure 2 outlines our modifications to the standard protocol for operative treatment of terrible triad injuries of the elbow. For each patient, we carefully evaluated the radial head and coronoid fractures on preoperative radiographs and computed tomography (CT) scans. First, we identified the type of coronoid fracture according to the O'Driscoll system and made a choice as to how best to fix it. If the coronoid fracture was a tip fracture, the

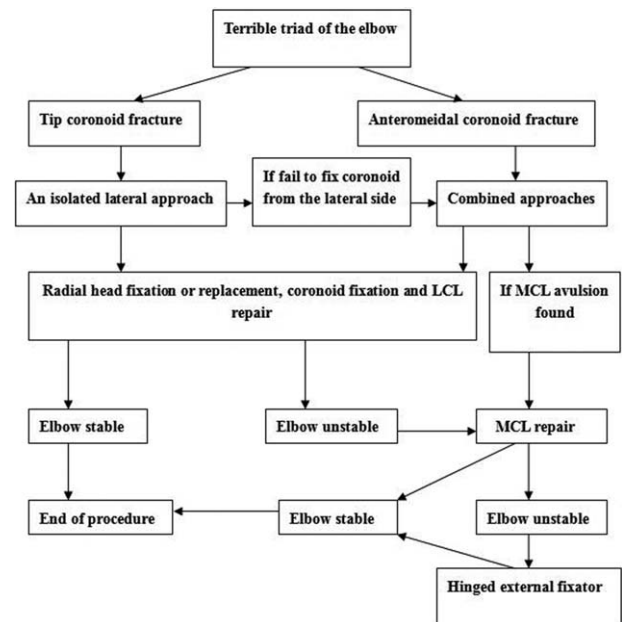


Figure 2. A modification of the standard protocol for operative treatment of terrible triad injuries of the elbow.

method of choice was to fix the coronoid process, and repair the radial head and the LCL through a lateral approach. An extensor digitorum communis (EDC) splitting approach^[12] was used instead of a Kocher approach^[13] to provide improved coronoid exposure from the lateral side of the elbow. The 3 structures damaged during this exposure were repaired sequentially, beginning with the deepest layer. In our study, 18 patients with a tip coronoid fracture were surgically managed through an isolated lateral approach (Fig. 3).

Where we were unable to repair the tip coronoid fracture using a lateral approach, particularly in cases of comminuted coronoid fractures or modest radial head fractures, the second choice was to repair the coronoid process through a separate anteromedial approach and then combine this with a lateral approach to repair the radial head and the LCL 5 (n = 11 elbows; Fig. 4).

In cases where the coronoid fracture was an anteromedial or basal coronoid fracture, we used a combined approach for repair^[5,8,11] (Fig. 5). In the present series, 13 patients with an anteromedial or basal coronoid fracture were treated through a combined approach. Radial head fixation or arthroplasty and LCL repair were performed through a lateral Kocher approach (n = 7 elbows) or an EDC splitting approach (n = 6 elbows). In cases where superior exposure to the anterior aspect of the radial head was needed, we preferred the EDC splitting approach to the lateral Kocher approach.^[13] A separate anteromedial incision was used and a common flexor origin muscle splitting approach was used to expose the coronoid fracture.^[14–17] The MCL was routinely checked, and, when found injured, was repaired by suture anchors using the same anteromedial approach as that created to fix the coronoid fracture (n = 5 elbows).

Countersunk head screws with or without mini plates are commonly used for radial head fracture fixation.^[2–8] Bone autografting from the lateral supracondylar ridge of the humerus was performed when bone defects were found in the radial head fractures (n = 5 elbows). If the radial head fracture was irreparable, arthroplasty was performed (n = 4 elbows).



Figure 3. A 59-year-old female sustained a terrible triad elbow injury and was treated through an isolated lateral approach (case 1). (A, B) Preoperative CT scans showed comminuted and displaced fragments of a Mason type III radial head fracture, and a tip fracture of the coronoid. (C, D) Postoperative radiographs after the patient was treated with radial head replacement, LCL repair, and coronoid fixation through a lateral approach. CT = computed tomography, LCL = lateral collateral ligament.

The surgical management of coronoid fractures should be based on fragment size and fracture location. Small coronoid tip fragments were usually repaired using the suture lasso technique or a suture anchor. For larger fragments, internal fixation was performed using 3.0-mm cannulated screws and/or a T-type locking plate. Anteromedial or basal coronoid fractures were best managed with fixation with a buttress plate and screws through an anteromedial approach.^[16,17] In the current series, the coronoid was fixed with suture anchors (n=8), suture lasso technique (n=2), cannulated screws (n=11), buttress plate fixation (n=9), or combined fixation techniques (n=12).

The LCL complex was always torn in our series, and was repaired using suture anchors (n=34 elbows) or transosseous sutures (n=8 elbows).

Elbow stability was assessed with the hanging arm and elbow valgus stability tests.^[17] If instability persisted after surgical intervention, each element of the repair was re-assessed. If unacceptable instability was diagnosed, the MCL was exposed

and repaired.^[3] Two patients who had residual instability after management of the radial head, coronoid, and LCL underwent exposure of the medial side and MCL repair (Fig. 6). If instability persisted after the MCL repair, we would have used a hinged external fixator for repair, as per Pugh et al.^[3]

2.4. Postoperative management

Patients routinely used a hinged plastic brace for 6 weeks. Early mobilization was encouraged, usually 3 or 4 days postoperatively. However, patients were asked to avoid extending their elbow beyond 30° flexion until 5 weeks postoperatively. In patients who were treated with isolated LCL repairs, the arm was fixed with the hinged plastic brace in a neutral position when they were not performing mobilization. In patients who required additional MCL repairs, the arm was fixed in pronation. Indomethacin or irradiation for heterotopic ossification prophylaxis was not routinely used.



Figure 4. A 37-year-old male sustained a terrible triad elbow injury and was treated through a lateral and anteromedial approach (case 9). (A, B) Preoperative radiographs and CT scans revealed a Mason type II radial head fracture and comminuted and displaced fragments of a tip fracture of the coronoid process. (C) A postoperative radiograph after osteosynthesis of the radial head and LCL repair through a lateral surgical approach, and osteosynthesis of the coronoid process through an anteromedial approach. CT = computed tomography, LCL = lateral collateral ligament.

2.5. Follow-up

Elbow functional status and range of movements were evaluated at 3 months, 6 months, 1 year, and 2 years or greater after surgery. The elbow functional status was assessed using the Mayo Elbow Performance Score (MEPS).^[18] Radiographic

signs of post-traumatic arthritis were rated at the final follow-up according to the system of Broberg and Morrey.^[18] Patient clinical outcomes were reviewed by an independent physiotherapist and x-rays were reviewed by an independent radiologist.

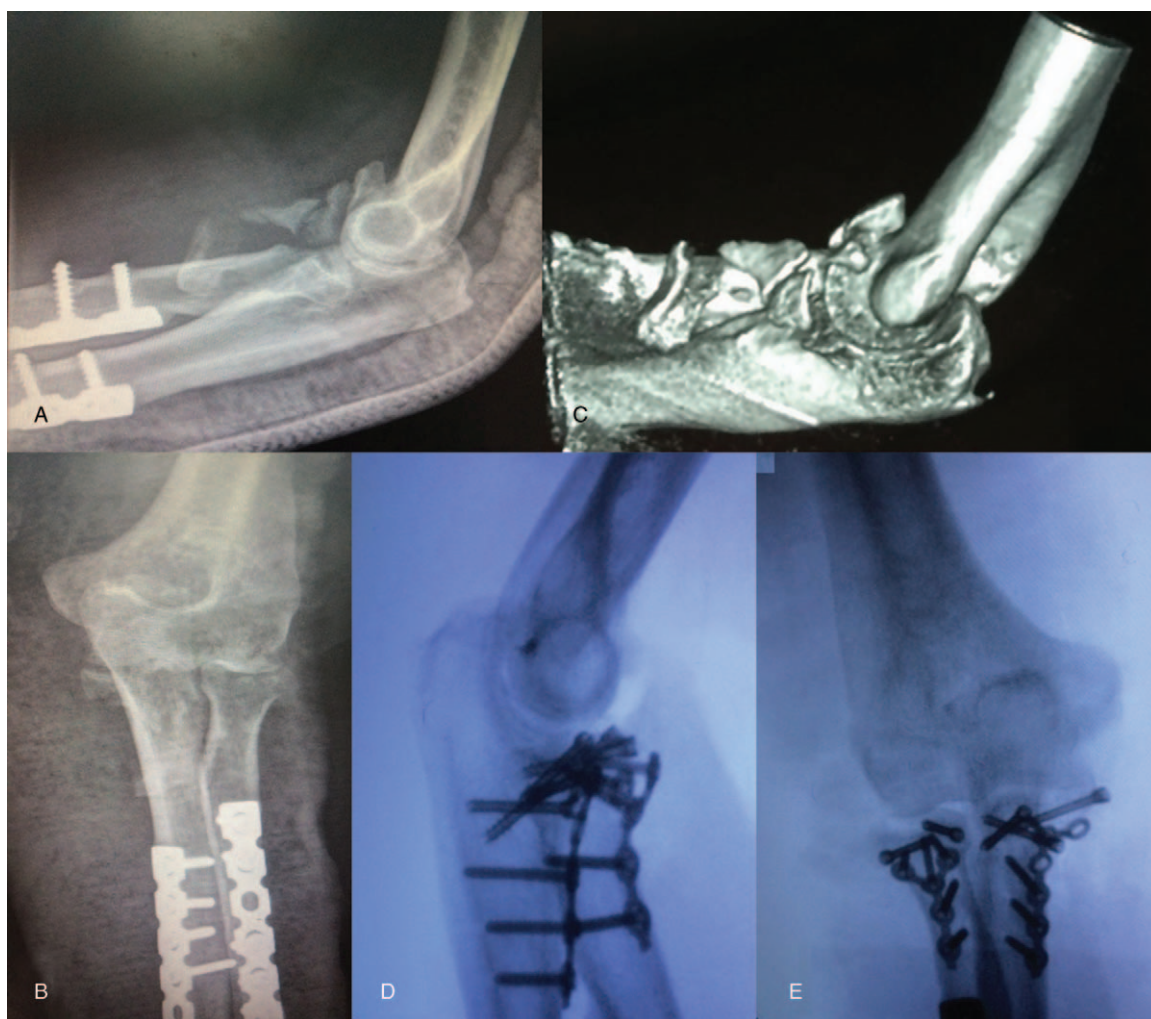


Figure 5. A 42-year-old male sustained a terrible triad elbow injury and was treated through a lateral and anteromedial approach (case 36). (A, B) Preoperative radiographs and CT scans revealed a comminuted fracture of the anteromedial facet of the coronoid process. The comminution involved the tip of the coronoid. This patient had undergone surgery for the forearm fracture ten years earlier. (C, D) Postoperative radiographs after radial head osteosynthesis and LCL repair through a lateral surgical approach, and osteosynthesis of the coronoid process through an anteromedial approach. CT=computed tomography, LCL=lateral collateral ligament.

2.6. Statistical analysis

Data analyses were performed with SPSS 17.0 (SPSS Inc, Chicago, IL). Data are presented as the mean \pm SD for continuous variables. Analysis of variance and Bonferroni correction were performed to compare range of movements and MEPS at different postoperative intervals. All *P* values were 2-sided, and values less than .05 were considered statistically significant.

3. Results

The final clinical results are summarized in Table 1. Forty-seven patients were eligible and included in the study, but only 42 patients had completing follow-up and were finally analyzed. Our series included a final cohort of 29 males and 13 females with a mean age of 48.23 ± 10.95 years at the time of injury. Eighteen patients were managed through an isolated lateral approach and 24 patients through a combined lateral and anteromedial approach, as detailed in the “Materials and methods” section.

The mean follow-up period was 30.47 ± 7.65 months (mean 30 months; range 24–56 months). The mean flexion-extension arc was $107^\circ \pm 22^\circ$, the mean flexion contracture was $20^\circ \pm 10^\circ$, and the mean flexion was $127^\circ \pm 14^\circ$ at the final follow-up. The average forearm rotation arc was $145^\circ \pm 14^\circ$, which included an average pronation of $73^\circ \pm 8^\circ$ and an average supination of $71^\circ \pm 9^\circ$ at the final follow-up. The functional motion arc threshold criteria established by Morrey et al.^[19] was satisfied in 36 (86%) of 42 patients. The mean MEPS was 88 ± 10 points (range 55–100 points), with excellent results in 24 (57%) elbows, good results in 16 (38%) elbows, and poor results in 2 (<5%) elbows at the final follow-up. Thirteen (31%) patients had radiographic signs of arthrosis according to the Broberg and Morrey system (9 elbows were grade 1 and 4 were grade 2). Table 2 shows results of range of movements and MEPS at different intervals. Mean range of movements increased from 90° to 106° for flexion-extension arc ($F=4.182$, $P=.007$), and 131° to 144° for forearm rotation arc ($F=6.979$, $P<.001$), and MEPS increased from 82 to 88 ($F=2.933$, $P=.033$). Functional results of the elbow improved

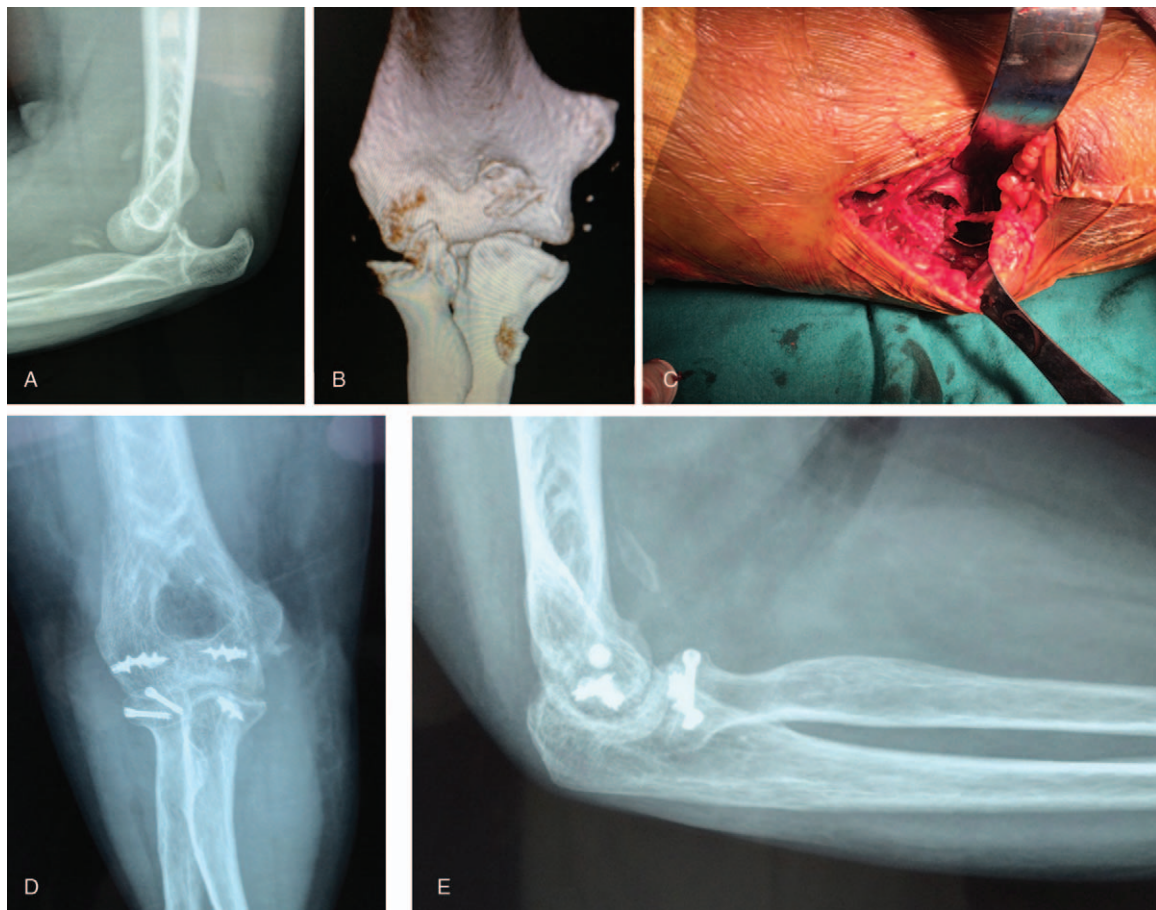


Figure 6. A 50-year-old female sustained a terrible triad elbow injury and was treated through a lateral and anteromedial approach (case 42). (A, B) Preoperative radiographs and CT scans identified a radial head and coronoid tip fracture. (C) The MCL was avulsed from the epicondyle and was repaired with suture anchors. (D, E) Postoperative radiographs. After repair of the anterior capsule with an anchor screw, and radial head fixation and LCL repair through a lateral approach, the elbow remained unstable. The patient required an additional MCL repair to provide stability. CT=computed tomography, LCL=lateral collateral ligament, MCL=medial collateral ligament.

significantly from 3 months postoperatively ($P < .05$), but tended to plateau from 1 year after surgery.

All patients maintained a concentric reduction of both the ulnotrochlear and the radiocapitellar articulations, without evidence of elbow instability. A local infection around the incision developed in 1 patient, and this healed uneventfully after antibiotic therapy. Another patient who underwent a combined surgical approach experienced transient postoperative median nerve paralysis, which recovered completely by 8 weeks after surgery. Another patient who underwent an EDC splitting approach experienced postoperative posterior interosseous nerve paralysis, and recovered completely by 12 weeks after surgery.

Four (9.5%) patients had complications that required further operative procedures. Five (12%) patients had evidence of heterotopic ossification, of which 4 had minimal periarticular ossification and did not require additional surgery. The remaining patient showed significant heterotopic ossification and required an elbow release, which consisted of heterotopic bone removal, and calcification and capsular resection. The resultant improvement in flexion-extension and forearm rotation was 105° and 15°, respectively (flexion-extension: 70° to 90° preoperatively, 5° to 130° postoperatively; rotation: 70° to 60° preoperatively, 80° to 65° postoperatively). One patient

developed ulnar neuropathy and required an anterior ulnar nerve transposition. Two patients, who had shifting hardware, but still achieved union, required a second surgery to remove the implant: 1 patient had a Kirschner wire shift from the radial head, and the other had a loose screw in the coronoid process.

4. Discussion

The results of 42 cases showed that the modified surgical procedure achieved predominantly good to excellent outcomes. The mean flexion-extension arc was 107°, and the average forearm rotation arc was 145°. The mean MEPS was 88 points and the excellent rate was 95%. Only 4 (9.5%) patients required further operative procedures. The mean MEPS for the series by Pugh et al was 88 (range 45–100), with 8 (22%) patients requiring a secondary operation. Two patients suffered postoperative posterolateral rotatory instability, with 1 requiring revision surgery. Comparatively, our functional results were similar to or better than those reported in studies with analogous patient populations.^[3,5,8,14,20] Furthermore, our series had lower rates of reoperation and higher rates of excellence than the series of Pugh et al.^[3] Although 4 patients required further surgery in our series, none of the patients showed evidence of postoperative instability.

Table 1
Presentation of the reviewed patients from this series.

Classification						Treatment				Results				
Patient no.	Age	Sex	Mason	Regan-Morrey	O'Driscoll	Approach	Radial head	Coronoid	MCL	Follow-up	FE	PS	MEPS	Complication
1	59	F	III	I	Tip sub 2	Lateral	PR	SA + RS	—	24	10–150	80–85	100	None
2	26	M	II	II	Tip sub 2	Combined	ORIF	PF	—	27	20–120	70–75	90	None
3	40	M	II	II	Anterome-dial sub 2	Combined	PR	PF	—	26	15–135	70–70	85	None
4	43	M	II	I	Tip sub 2	Lateral	ORIF	ST + KW	—	54	10–145	80–55	100	Infection
5	47	M	II	II	Anterome-dial sub 2	Combined	ORIF	ST	—	50	0–130	85–85	100	HO
6	39	M	II	I	Tip sub 1	Lateral	ORIF	SA	—	32	20–150	75–75	90	None
7	63	M	II	II	Anterome-dial sub 2	Combined	ORIF	KW + SA	—	56	30–130	75–80	100	None
8	60	F	III	II	Tip sub 2	Lateral	ORIF	RS	—	26	15–135	70–70	85	None
9	37	M	III	II	Tip sub 2	Combined	ORIF	PF	Repair	26	15–110	80–80	80	Median nerve paralysis
10	43	M	II	II	Tip sub 2	Lateral	ORIF	RS + AS	—	24	30–110	70–60	80	None
11	50	F	II	II	Tip sub 2	Combined	ORIF	PF	—	37	20–130	65–70	90	None
12	40	F	III	II	Tip sub 2	Lateral	PR	ST	—	40	35–135	60–75	85	None
13	29	M	II	II	Anterome-dial sub 2	Combined	ORIF	PF	Repair	30	5–130	80–65	85	HO
14	32	M	II	II	Tip sub 2	Combined	ORIF	SA	—	26	15–140	60–70	100	No
15	60	M	II	II	Tip sub 2	Combined	ORIF	AS	—	29	15–135	80–65	95	None
16	62	M	II	III	Basal 2	Combined	ORIF	PF + KW	—	25	40–100	75–60	80	KW shift
17	39	M	II	II	Tip sub 2	Combined	ORIF	AS + KW	—	30	10–130	55–60	85	None
18	59	F	II	II	Anterome-dial sub 2	Combined	ORIF	PF + RS + KW	Repair	25	55–100	50–55	55	HO
19	49	M	III	II	Anterome-dial sub 2	Combined	ORIF	AS + SA	—	27	30–90	75–55	80	Screw loosening
20	51	M	III	II	Anterome-dial sub 2	Combined	ORIF	PF	—	26	5–140	75–70	85	None
21	30	M	II	I	Tip sub 1	Lateral	ORIF	SA	—	27	15–125	75–75	90	None
22	65	F	II	II	Anterome-dial sub 2	Combined	ORIF	SA + ST	—	30	25–135	80–85	100	HO
23	36	M	III	I	Tip sub 2	Lateral	ORIF	AS	—	33	15–140	70–60	95	None
24	53	F	III	II	Tip sub 2	Lateral	PR	AS	—	28	20–120	80–50	100	None
25	62	M	II	II	Tip sub 2	Lateral	ORIF	AS	—	24	10–150	80–85	100	None
26	40	M	III	I	Tip sub 2	Lateral	ORIF	AS	—	36	10–120	80–85	95	Radial nerve paralysis
27	49	M	II	I	Tip sub 1	Lateral	ORIF	SA	—	26	20–130	85–85	100	None
28	31	M	II	II	Tip sub 2	Lateral	ORIF	AS	—	30	25–125	70–70	85	None
29	57	F	II	I	Tip sub 2	Lateral	ORIF	AS	—	40	30–140	60–80	90	None
30	53	F	II	I	Tip sub 2	Combined	ORIF	PF	—	28	20–130	80–70	80	None
31	60	F	III	II	Tip sub 2	Lateral	ORIF	PF	—	28	25–120	75–80	90	None
32	58	F	I	II	Anterome-dial sub 2	Combined	NO	PF	—	25	40–90	80–75	80	Ulnar neuropathy
33	64	F	II	I	Tip sub 2	Combined	ORIF	AS	Repair	27	30–120	75–65	80	None
34	46	M	III	I	Tip sub 1	Lateral	ORIF	SA	—	29	10–130	70–60	100	None
35	63	F	I	II	Tip sub 2	Combined	ORIF	PF + KW	Repair	26	15–115	70–65	95	None
36	43	M	III	I	Anterome-dial sub 1	Combined	ORIF	SA	—	25	20–150	85–80	100	None
37	41	M	II	II	Anterome-dial sub 2	Combined	ORIF	AS	Repair	27	20–130	65–60	55	HO
38	58	M	II	II	Tip sub 2	Combined	ORIF	PF + AS	—	28	15–135	70–65	90	None
39	42	M	II	II	Tip sub 2	Lateral	ORIF	AS	—	30	10–135	75–65	90	None
40	51	M	II	II	Tip sub 2	Lateral	ORIF	SA	—	24	25–130	65–80	95	None
41	46	M	II	III	Anterome-dial sub 3	Combined	ORIF	PF + AS	—	33	30–130	75–70	85	None
42	50	F	II	II	Tip sub 2	Combined	ORIF	SA	Repair	36	25–125	60–65	80	None

AS=anteroposterior screw, FE=flexion-extension (mean arc), HO=heterotopic ossification, KW=Kirschner wire, MEPS=Mayo Elbow Performance Score, ORIF=open reduction and internal fixation, PF=plate fixation, PR=prosthesis replacement, PS=pronation-supination (mean arc), RS=retrograde screwing, SA=suture anchor, ST=suture technique.

Table 2
Functional results at different intervals (mean ± SD).

Time, mos	3	6	12	≥24
Flexion-extension arc, °	90 ± 22 ^{*†}	100 ± 24	105 ± 21 [*]	106 ± 22 [†]
Forearm rotation arc, °	131 ± 13 ^{‡§}	137 ± 13	140 ± 14 [‡]	144 ± 14 ^{‡§}
MEPS	82 ± 9	86 ± 11	88 ± 11	88 ± 10

MEPS=Mayo Elbow Performance Score, SD=standard deviation.

^{*} P=.029.

[†] P=.009.

[‡] P=.013.

[§] P=.001.

^{||} P=.045.

Our major deviations from Pugh standard protocol included: a lateral or combined approach; a lateral Kocher approach or an EDC splitting approach when required; the identification of the anteromedial coronoid fracture preoperatively, and its anatomical reduction with rigid fixation through a separate anteromedial approach; the routine repair of the MCL when injured through the same anteromedial approach taken to treat the coronoid fracture.

Firstly, we modified the selection for surgical approaches. In the case series by Pugh et al,^[3] a lateral approach was used for 26 elbows, a posterior exposure in 8 elbows, and a combined lateral and medial approach in 2 elbows through a posterior incision. Comparatively, Egol et al^[4] advocated for the use of an isolated

lateral approach for their 29 patients with terrible triad injuries. However, others reported the use of a combined lateral and medial approaches.^[5,7,8] The ideal surgical approach should be based on the mode and details of injury. We preferred a direct lateral or combined approach, which avoided the need for a large posterior flap while still having adequate exposure; albeit, a posterior approach allows both sides of the elbow to be treated with 1 incision. We routinely used a Kocher approach for the lateral side exposure, and we used an EDC splitting approach instead, when better exposure was required to fix the anterior aspect of radial head and a coronoid fracture from the lateral side. Desloges et al^[12] found that the EDC splitting approach provides a more reliable visualization of the anterior half of the radial head and the coronoid process. On the contrary, the Kocher approach limits access to the anterior portion of the radial head and coronoid process, and proximal extension of the modified Kocher approach, by dissecting through the common extensor origin, may add an iatrogenic injury to the stability of the elbow. The limitation of the EDC approach is the potential to cause injury to the posterior interosseous nerve. The safe zone of the EDC splitting approach to avoid injuring the posterior interosseous nerve is limited to 52 mm from the radiocapitellar joint.^[12] One patient in the present series treated though this approach experienced transient postoperative posterior interosseous nerve paralysis, but recovered completely.

Secondly, we directly exposed and fixed anteromedial coronoid fracture from an anteromedial approach. Although it is unusual for anteromedial or base fractures to be associated with terrible triad injuries, preoperative CT scans of the elbow should be carefully studied and 3D reconstruction of CT images can help to identify the presence of a fracture in the anteromedial facet of the coronoid. In this series, 13 patients with anteromedial or basal coronoid fractures were managed with a combined approach. Most (9 elbows, ~70%) of these fractures extended laterally in the coronal plane to involve the tip (O'Driscoll anteromedial subtype 2 coronoid fractures). O'Driscoll et al^[11] recommended that these types of injuries should be distinguished from what could be mistakenly thought of as a comminuted fracture of the coronoid tip. The latter can be treated with near-anatomic reduction and nonrigid fixation through a lateral approach. However, the former should be reduced anatomically with rigid fixation, and this requires a separate approach.^[11,16,17] There are several ways to address anteromedial coronoid fractures, and an optimal approach remains to be identified.^[5,17,21–24] We preferred to use an anteromedial approach.^[15] Accurate and stable internal fixation was easily achieved with anteroposterior screws and a buttress plate. The MCL could also be repaired through this incision if necessary.^[5]

Thirdly, we modified the procedure for MCL repair. MCL avulsion is likely to be present in many terrible triad injuries, and there is no consensus as to the need for a medial exposure in a terrible triad injury.^[3–8,25] Pugh et al^[3] repaired the MCL in 6 (17%) of 36 patients with terrible triad elbow injuries, and only in cases where the patients showed residual posterior instability after repair. Zhang et al^[5] used preoperative MRI to evaluate MCL injuries, and repairs were needed in 5 (24%) of 21 cases. On the contrary, Forthman et al^[6] reported good results in 22 patients with terrible triad injuries without MCL repair. Toros et al^[25] repaired the MCL in 8 patients, and reported better functional results as compared with the other 8 patients who did not undergo MCL repair. In our series, 7 (17%) patients underwent MCL repair based on an intraoperative diagnosis of MCL injury. We repaired the MCL in 5 patients when the MCL

was observed to be torn under direct visualization and in 2 patients when the elbow remained unstable after radial head and coronoid fracture fixation and LCL repair. The torn MCL was reattached to either the medial epicondyle or the sublime tubercle with suture anchors.

In the study by Pugh et al^[3] patients wore a hinged external fixator to compensate for any residual instability. We did not employ this technique because the patients in our series obtained immediate elbow stability following routine surgical repair. However, a hinged external fixator can help to restore stability of the elbow in some complex cases.

Finally, there were some limitations to our study. We were limited to 42 cases, and our sample size may therefore preclude us from developing a comprehensive and valid protocol; albeit, terrible triad elbow injuries are rare. To improve the validity of our findings, future randomized and controlled studies should be reported.

5. Conclusions

Overall, we show that slight modifications to Pugh standard protocol for the surgical treatment of terrible triad injuries can lead to good to excellent results, although there were a good number of complications. The ideal surgical approach and treatment should be based on the mode and mechanism of injury, and intraoperative findings and modifying the standard surgical treatment approach for terrible triad elbow injuries may be beneficial.

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