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ORIGINAL ARTICLE

Surgical reconstruction of comminuted coronoid fracture in terrible triad injury of the elbow

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Abstract The terrible triad injury of the elbow is the combination of an elbow dislocation, a radial head fracture and a coronoid process fracture. In this study, we explored the outcome of a modified protocol for terrible triad injury of the elbow in a consecutive series of 14 patients, with a focus on reconstruction of comminuted coronoid fractures. Fourteen patients with terrible triad injuries of the elbow were retrospectively reviewed at a mean follow-up of 23 months (range, 15–30 months) and were clinically and radiographically evaluated. For comminuted coronoid fractures, autografting with resected radial head fragment or ilium fragment with cartilage surface and transosseous suture with non-absorbable suture were performed. Internal fixation of the radial head was performed in six cases and arthroplasty in five. The collateral ligaments were repaired. Mean flexion at last follow-up was 125°, ranging from 100° to 135°. Mean extension loss was 13°, ranging from 0° to 38°. Mean pronation was 70° and mean supination was 66°. No patient experienced dislocation of the radial head prosthesis. The mean Mayo Elbow Performance Score (MEPS) was 87 (range, 75–100), with six excellent cases and eight good cases. According to our intraoperative examination, no patient demonstrated unacceptable residual instability in extension following restoration of all of the osseous and ligamentous lesions. In conclusion, our protocol can achieve stable reconstruction of the coronoid process, which promotes the functional outcome of surgical treatment on terrible triad injuries of the elbow.

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Introduction

A complex elbow dislocation with associated radial head and coronoid process fractures was named the terrible triad by Hotchkiss because of historically poor outcomes [1]. Traditional treatment involves fixation or replacement of the radial head and/or repair of the collateral ligaments, but outcomes are usually poor [2, 3] owing to recurrent instability and stiffness from prolonged immobilization [1]. Coronoid process contributes significantly to the stability of the elbow joint [4–8]. Most patients with terrible triad injuries had small comminuted (<50%) coronoid fractures [9], and reducing the small fractures of the coronoid process is important for the treatment of unstable elbow dislocation [10]. Therefore, a standard protocol was introduced, which involved additional fixation of the coronoid and articular capsule using drill holes in the ulna [11, 12]. In the present study, we explored the outcome of a modified protocol for terrible triad injury of the elbow in a consecutive series of 14 patients, with a focus on reconstruction of comminuted coronoid fractures.

Patients and methods

Patients

We identified 14 consecutive skeletally mature patients (14 elbows) who had an elbow dislocation associated with fractures of the radial head and coronoid process between June 2007 and February 2010. The patients were informed

that data from the case would be submitted for publication and they gave their consent. There were 8 male patients and 6 female patients, with a mean age of 42.5 years (range, 16–80 years). The mechanisms of injury included 10 cases of falls (nine falls from a lower height and one high-velocity fall from a great height), two cases of motor vehicle accidents and two cases of sport accidents. The 14 elbows were treated at a mean time of 4.3 days (range, 2–10 days) after the injury. The specific indications for operative intervention included a displaced intra-articular fracture, inability to obtain or maintain a concentric reduction in a closed fashion and residual instability of the elbow in a functional arc of flexion and extension (30°–130°) [13].

All dislocations were closed injuries and no neurovascular deficits could be noted. The initial assessment included A/P and lateral radiographs of the elbow to rule out associated bony pathology. In all cases, it was a posterolateral dislocation of the elbow joint with associated fractures of the radial head and coronoid process of the ulna. Fractures of the radial head were graded according to the Mason classification, as modified by Johnson [14]: type I, non-displaced fractures; type II, non-comminuted displaced fractures; type III, comminuted fractures. Our series included two type I fractures, four type II fractures and eight type III fractures. Fractures of the coronoid process were graded according to the Regan and Morrey classification [2], which distinguishes three different types of fractures: type I, avulsion of the tip of the bone; type II, detached fragment of less than 50% of the coronoid process; type III, detached fragment of more than 50% of the coronoid process. According to this classification, there was two type I fractures and 12 comminuted type II fractures (eight cases of which associated with a Mason type III radial head fracture). No type III coronoid process fractures were identified.

Operative technique

The operative approach is shown in a flow chart scheme in Fig. 1. In details, patients were placed in a supine position under general anaesthesia, with a tourniquet around the proximal arm. In all cases, a lateral surgical approach was carried out through the Kocher interval, between the extensor carpi ulnaris and anconeus muscles. The lateral approach was associated with a medial approach, providing better access to the coronoid process and the ulnar collateral ligament. The damaged structures were repaired sequentially from deep to superficial, as seen from the lateral approach (coronoid to anterior capsule to radial head to lateral collateral ligament complex to common extensor origin).

Regarding the coronoid process, two type I fractures were neglected. In twelve patients with comminuted type II fractures, autografting was performed to reconstruct the

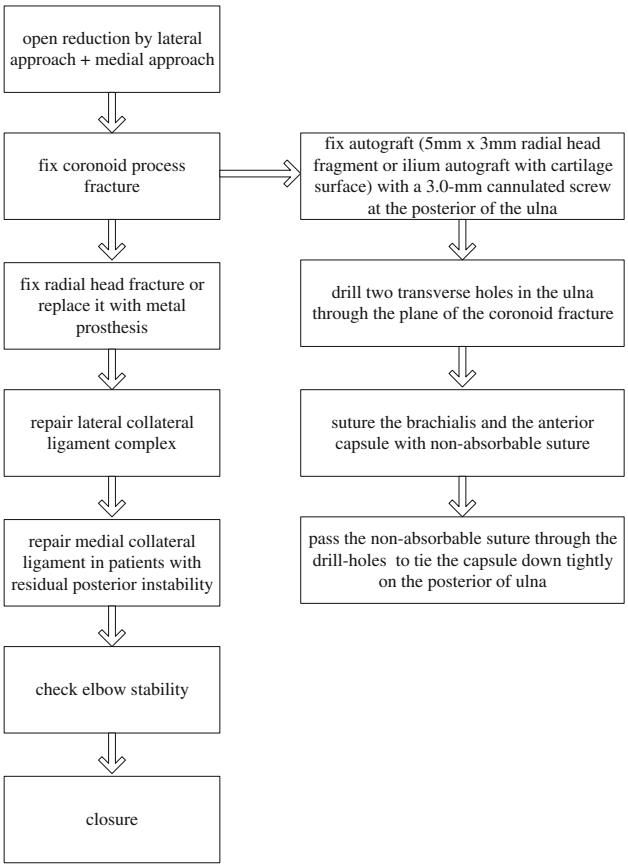

Fig. 1 Flow chart scheme of the operative approach

coronoid process with a 5 mm × 3 mm radial head fragment (eight cases) or ilium autograft with cartilage surface (four cases), which was fixed with a 3.0-mm cannulated screw at the posterior of the ulna. Two transverse holes were drilled in the ulna through the plane of the coronoid fracture. Non-absorbable suture was used to suture the brachialis and the anterior capsule, and then passed through the drill holes to tie the capsule down tightly on the posterior of the unla (Fig. 2).

In the four cases of Mason type II fractures, the radial head fracture fragments were temporarily fixed with small Kirschner wires. Definitive fixation was then performed with one or two 3-mm lag screw, which was buried in the radial head to prevent interlocking of the humeroradial joint. In five cases of non-reconstructible type III fractures, a modular and bipolar radial head prosthesis (GUEPAR—DePuy) was placed. In the other three type III fractures, the radial head was resected. Two resections were partial (<30%) and one was complete. The complete resection resulted in instability of the humeroulnar joint, which required the insertion of a stabilizing humeroulnar pin.

The collateral ligaments were repaired in terrible triad injury of elbow according to the standard protocol by Pugh et al. [11] and Mckee [12] . The lateral collateral ligament

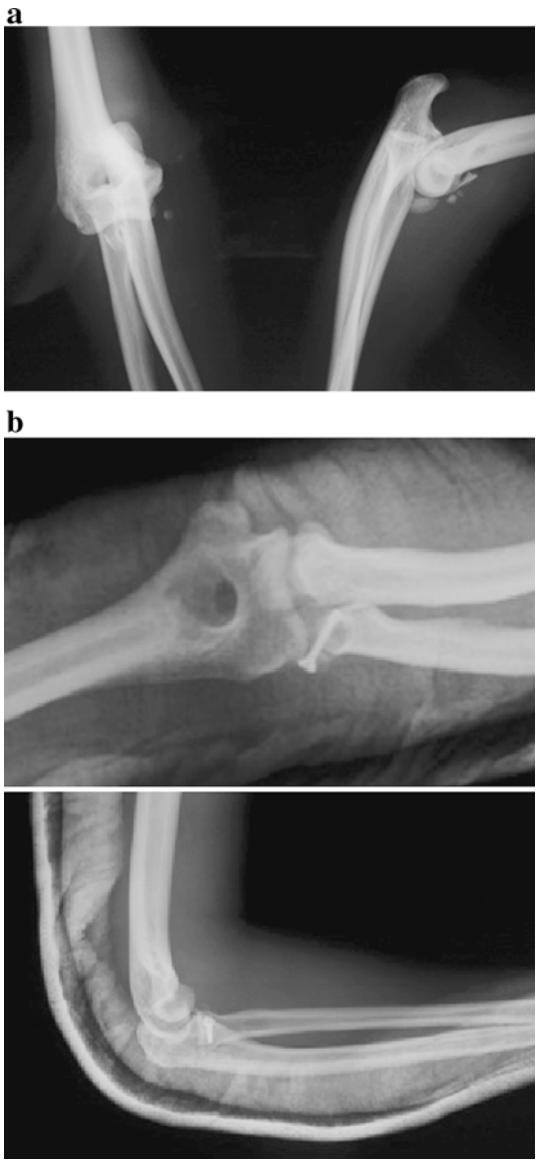

Fig. 2 **a** Pre-operative anteroposterior and lateral radiographs showing a terrible triad injury of the elbow. **b** Anteroposterior and lateral radiographs showing reconstruction of the comminuted type II coronoid process fracture

complex was repaired to restore lateral stability. The medial collateral ligament was repaired in patients with residual posterior instability.

Before closure, the elbow was examined for stability (concentric reduction with no posterior or posterolateral subluxation or dislocation through an arc of flexion–extension from 20° to 130°).

Post-operative management

External fixator was used in two patients. In the remaining 12 patients, if the medial collateral ligament was intact, then the elbow was immobilized in a well-padded fibreglass splint at 90° of flexion, with the forearm in full pronation to avoid posterolateral instability and to protect the lateral collateral ligament repair. If both the medial collateral ligament and lateral collateral ligament had been repaired, then the arm was splinted in a neutral rotation. If the lateral collateral ligament had been securely fixed and the medial collateral ligament had not, immobilization at 90° of flexion and in full supination was applied. The splint was retained for 10 days. Then active and active-assisted exercises were allowed in a brace for 4 weeks. Active pronation and supination movements were allowed with the elbow placed in 90° of flexion. Maximum extension was limited to 30° or 60°, according to the elbow stability assessment performed after reduction. Once complete healing was achieved, active maximum range-of-motion exercises were initiated through physical postures. A muscular rehabilitation protocol was initiated at 3 months post-trauma to strengthen the periarticular stabilizing muscles.

Follow-up and functional evaluation

Fourteen patients (14 elbows) were reviewed at a mean follow-up of 23 months (range, 15–30 months) and were clinically and radiographically evaluated. Patients were clinically assessed according to the Mayo Elbow Performance Score (MEPS), on the basis of pain, mobility, stability and functional evaluation [15]. This score is based on a 100-point scale, with maximum scores of 45 points for pain relief, 25 points for function (5 points each for grooming, feeding, personal hygiene, putting on a shirt and putting on shoes), 20 points for motion and 10 points for stability. The MEPS falls into four grades: $\geq$90, excellent; 75–89, good; 60–74, fair; <60 and poor. Radiographic assessment of the elbow, based on A/P and lateral views, was also performed at last follow-up.

Results

At the final follow-up, eight patients had no pain, while six reported mild pain. None of the patients suffered from severe pain. Mean flexion at last follow-up was 125°, ranging from 100° to 135°. Mean extension loss was 13°, ranging from 0° to 38°. Mean pronation was 70° (range, 30°–85°) and mean supination was 66° (range, 30°–80°). All patients maintained a concentric reduction in both the ulnotrochlear and the radiocapitellar articulation, with isometric fixation of the lateral collateral ligament. No patient experienced dislocation of the radial head prosthesis. The mean MEPS was 87 (range, 75–100), with six excellent cases and eight good cases. According to our intraoperative examination, no patient demonstrated unacceptable residual instability in extension following restoration of all of the

Table 1 Patient characteristics and functional outcomes

Patient no.	Age (years)	Sex	Regan–Morrey type	Mason type	Days between injury and surgery	Autograft for reconstruction of coronoid process	Post-operative complications	Follow-up duration (months)	Range of motion	MEPS
1	41	F	I	I	10	–	–	26	132	100
2	21	M	II	III	2	RH	TUI	30	117	90
3	42	M	II	II	5	Ilium	–	28	108	90
4	16	M	II	III	2	RH	–	27	120	95
5	39	M	II	III	4	RH	TUI	27	102	85
6	17	F	II	III	4	RH	–	25	125	95
7	56	F	II	III	3	RH	HO	24	117	85
8	30	M	II	III	2	RH	TUI	23	111	90
9	67	F	II	II	5	Ilium	HO	22	106	80
10	80	M	I	II	6	–	PA	22	115	85
11	28	F	II	III	2	RH	–	20	118	85
12	45	M	II	III	3	RH	TUI	19	92	75
13	62	F	II	I	7	Ilium	PA	16	101	80
14	51	M	II	II	5	Ilium	HO	15	108	85

RH radial head, *TUI* transient ulnar nerve injury, *HO* heterotopic ossification, *PA* post-traumatic arthritis, *MEPS* Mayo Elbow Performance Score

osseous and ligamentous lesions. The patients' characteristics and functional outcomes are summarized in Table 1.

Among the 14 patients (14 elbows), three (21.4%) developed heterotopic ossification at the level of the anterior capsule. None of them required additional surgery; the mean range of motion (ROM) was 110°. Four patients (28.6%) had transient ulnar nerve injury, which resolved after 1 week. Two patients (14.3%) showed post-traumatic arthritis.

Radiographs of all patients were reviewed. All of the radial head fractures that received open reduction and internal fixation obtained union according to the final follow-up radiographs. The coronoid fracture showed a solid osseous union on the final follow-up radiographs. We used the Broberg and Morrey 18 classification for the radiographic assessment of post-traumatic arthritis. Twelve elbows had no evidence of degenerative changes (grade 0) and two elbows showed grade 1 changes; there were no grade 2 or 3 changes. There were radiolucent lines around one of the three silicon-type radial head prostheses, but no evidence of dislocation, subluxation or progressive bone loss or shortening was observed. Heterotrophic ossification was observed in three cases.

Discussion

The coronoid process of the ulna is a key element for elbow stability and forms an anterior buttress with the radial head to prevent posterior dislocation of the elbow [4–8]. There are several biomechanical and anatomical cadaver studies that have addressed the role of the coronoid process in elbow stability against axial, posterolateral rotatory or varus loads [4–8, 16–18]. Certain structures that have a significant role in elbow stability are inserting on the coronoid process. The anterior bundle of the medial collateral ligament, lateral collateral ligament complex, anterior elbow capsule and brachialis muscle are inserting on the coronoid process and tend to be injured by complex elbow injuries, including coronoid fracture [19]. According to the work of Morrey et al. [20], 50% of the height of the coronoid process is necessary to ensure humeroulnar sagittal stability. Doornberg and Ring [9] found that most patients with terrible triad injuries had small comminuted (<50%) coronoid fractures. Inadequate treatment can lead to instability, rapid progress of post-traumatic arthritis and stiff elbow. In the present study, we performed autografting to reconstruct the coronoid process in all ($n = 12$) comminuted Regan and Morrey type II fractures, using a radial head or ilium autograft with cartilage surface to reconstruct the coronoid process as well as its cartilage surface. Transosseous suture with non-absorbable suture was used to capture the brachialis and the anterior capsule, and then pass through drill holes to tie the capsule down tightly on the posterior of the unla, which resulted in stable fixation. The use of non-absorbable suture decreased the possibility of reoperation for later removal of internal fixators.

Treatment of the radial head fracture was performed for terrible triad injury of elbow according to the standard protocol by Pugh et al. [11] and Mckee [12]. Basically, radial head stability was restored through fixation for reconstructible fractures or replacement with a metal prosthesis for

non-reconstructible fractures. In our series, three radial heads were resected: two partial resections of less than 30% of the articular surface, with no effect on stability, and one complete resections resulting in intraoperative instability requiring additional stabilization with humeroulnar pinning. Therefore, type II radial head fractures should be preserved and treated with osteosynthesis in case of terrible triad injuries of the elbow.

Our treatment for terrible triad injuries of the elbow resulted in similar functional outcomes in range-of-motion variables comparable to published studies [21, 22], but with no unacceptable residual instability after the surgery.

In summary, coronoid fracture is an important part of complex elbow injuries. For comminuted coronoid fractures, autografting with resected radial head fragment or ilium fragment with cartilage surface plus transosseous suture with non-absorbable suture can achieve stable reconstruction of the coronoid process, which promotes the functional outcome of surgical treatment on terrible triad injuries of the elbow.

Conflict of interest No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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