

# Outcomes of coronoid-first repair in terrible triad injuries of the elbow

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## Abstract

**Background** Clinical outcomes of terrible triad injuries (TTIs) of the elbow are historically poor. To date, it is still debatable whether the coronoid needs to be fixed and if so, how and in which sequence.

**Methodology** Between 2010 and 2013, 13 patients were treated surgically for acute TTIs of the elbow at a Tertiary Level 1 Trauma Centre by a single surgeon, using a standardized protocol, which included coronoid-brachialis complex fixation via pull-through trans-osseous sutures, radial head fixation or prosthetic replacement and a repair of the lateral ulnar collateral ligament. Repair of the medial collateral ligament (MCL) was done if valgus-stress test demonstrated persistent instability. Patients were then followed-up with clinical and radiological evaluation by the senior author until fracture union and elbow range of motion reached a plateau. Outcomes measured were range of motion, DASH scores and MEPS, as well as surgical complications.

**Results** Intraoperative stability was achieved in all 13 cases, MCL repair was required in 3 cases and application of external fixation was not required in any case. Patients were followed-up for an average length of 27.7 months and the minimum follow-up period was 12 months. The average age of patients was 46.4 years (range 35–79 years old)

at the time of trauma. This included eight Regan–Morrey Type I and five Regan–Morrey Type II coronoid fractures, with ten Mason Type I/II and three Mason Type III radial head fractures. The average arc of ulno-humeral motion was 105.0° (range 80°–135°). The average flexion contracture was 15.0° (range 0°–40°). The average supination-pronation arc was 114.9° (range 0°–180°). The average MEPS was 85 of 100 (range 45–100) and the average DASH score was 21.2 of 100 (range 1.7–61.2). A single case of radio-ulnar synostosis, heterotopic ossification and two cases of recurrent elbow instability were noted.

**Conclusions** The coronoid-first surgical approach, using a suture-lasso fixation method, has technical benefits for us and showed good clinical success in our series. This is important with postero-medial rotatory instability being common in our series of TTIs. We emphasize not to miss a TTI in an apparently isolated low Mason class radial head fracture.

**Keywords** Terrible triad injuries · Elbow trauma · Coronoid fractures · Radial head fractures · Elbow dislocations · Suture-lasso technique

## Introduction

Terrible triad injuries (TTIs) of the elbow describe a constellation of elbow dislocation with disruption of the lateral ulnar collateral ligament (LUCL), and fractures of both the radial head and the ulnar coronoid process. It is a complex injury with variable outcomes [1, 2]. The combination of both osseous and ligamentous components make this injury difficult to treat, with persistent pain, stiffness and post-traumatic arthritis commonly seen. Clinical outcomes have

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been historically poor, as the surgeon seeks to balance the maintenance of stability of fracture fixation and the maximization of functional range of motion [3].

Surgical reconstruction aims to restore sufficient stability to permit early mobilization of the joint. Most published treatment protocols advocate fixation of all radial head and coronoid process fractures and repair of the LUCL to achieve a stable anatomic reduction of the elbow [2, 4–7]. In cases with residual elbow instability, repair of the medial collateral ligament (MCL) and/or application of hinged or static external fixation may be required [7–9]. With regard to coronoid fractures, there is currently no consensus amongst surgeons. From the experience of the senior author, for TTIs of the elbow, all the coronoid fractures still attached to the anterior brachialis-capsule complex should be repaired to maximize the elbow stability for early range of motion. We hypothesize that fixing the coronoid first is a good approach for TTIs compared to the published protocols in the current literature, which mostly advocate fixation of coronoid after radial head fixation and LUCL repairs, if required.

## Study methodology

13 patients with terrible triad injuries of the elbow were treated surgically between 2010 and 2013 at a Tertiary Level 1 Trauma Centre by a single fellowship-trained surgeon. All patients were clinically assessed for soft-tissue condition and neurovascular status, with basic anteroposterior and lateral radiographs done to delineate fracture patterns. 9 out of the 13 patients had computer tomographic scans (CT with 3D reconstruction), for delineation of the fracture patterns, as shown in Fig. 1, facilitating pre-operative planning. This was not required in the remaining four patients as the fracture patterns were not obscured on initial radiographs. Magnetic resonance imaging was not routine, as physical assessment guided our surgical management. Examination under anaesthesia (EUA) was performed preoperatively for all patients. The posterolateral approach (Kocher's interval) was used if there were no instability on valgus-stress tests; otherwise a posterior global approach was used.

The coronoid fractures were addressed first. All Regan–Morrey Type II and III fractures were fixed via a suture-lasso technique with pull-through trans-osseous sutures tied over the olecranon. Type I fractures were repaired via the same technique if the fragment was bound to anterior soft-tissue complex. Otherwise, it was treated conservatively. Following which, fractures of the radial head was addressed, with either surgical fixation (via 2.0 mm headless screws or 2.0 mm T modular plates if there were concurrent extension of fracture lines into the radial neck), or

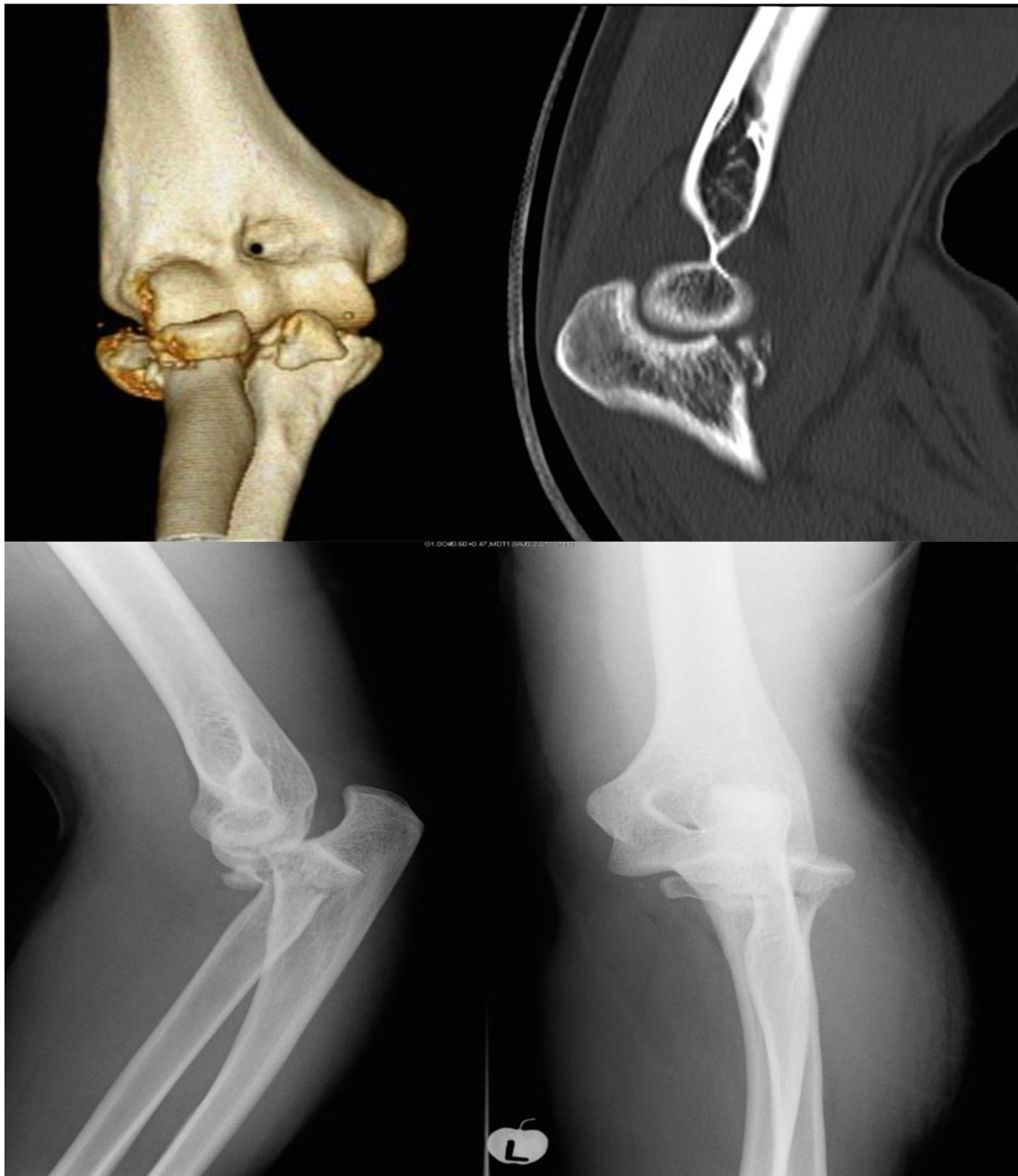
replacement (if comminution precluded anatomical restoration). The LUCL was then explored regardless and repaired (via bioabsorbable suture anchors) if disrupted. Thereafter, valgus-stress test was repeated with laxity assessed, and under fluoroscopic guidance, the maintenance of ulno-humeral congruence from 20° to 120° flexion–extension arcs in neutral forearm rotation was checked. The medial collateral ligaments were explored and repaired using bioabsorbable suture anchors for any instability/incongruence detected.

Postoperatively, all patients were protected in a hinged elbow brace at neutral pronation-supination for the first two postoperative weeks. From week 3–6, interval splinting was performed. During the first 6 weeks, patients performed active range of motion from 30° to maximal tolerated flexion. At week 7, the splint was removed, with active and passive elbow and forearm rotation initiated. Full strengthening and work simulation was started week 10, targeting to return to work at week 12. Patients were followed-up at regular intervals with radiographs and they attended consultations until fracture union and functional range of motion had reached a plateau.

We measured the (1) range of motion (ROM); (2) clinical scores using the disabilities of the arm, shoulder and hand (DASH) and the Mayo Elbow Performance Score (MEPS); and assessed radiographically the development of (3) arthritic changes, heterotopic ossification and/or late elbow instability in all these patients whose TTIs of the elbow were treated surgically (DASH score being a measure of the disabilities of the upper limb experienced, with 30 items scored on a scale of 1–5, with higher scores reflecting poorer results; MEPS being a specific measure of elbow functions, scored on the pain, stability, motion and daily activities performed—total score is 100 and higher scores reflects better results, greater than 90 being excellent, 75–89 good, 60–74 fair and less than 60 poor).

## Results

There were a total of 4 females and 9 males, with the average age being 46.4 years (range 35–79 years old) at the time of trauma. All the injuries were unilateral injuries. 12 injuries were sustained after falls, 8 were from the ground level and the remaining 4 were from a height beyond 2 m. One single case occurred as a result of a road traffic accident. All dislocations and fractures were closed injuries without neurovascular deficits. All the dislocations were in the posterolateral direction. Fractures of the radial head included 4 Mason Type I, 6 Type II and 3 Type III fractures. Fractures of the coronoid process comprised eight Regan–Morrey Type I fractures and five Type II fractures. One patient had a concurrent ipsilateral humeral



**Fig. 1** Pre-operative CT (with 3D reconstruction) demonstrating coronoid fracture pattern, otherwise obscured on plain radiographs

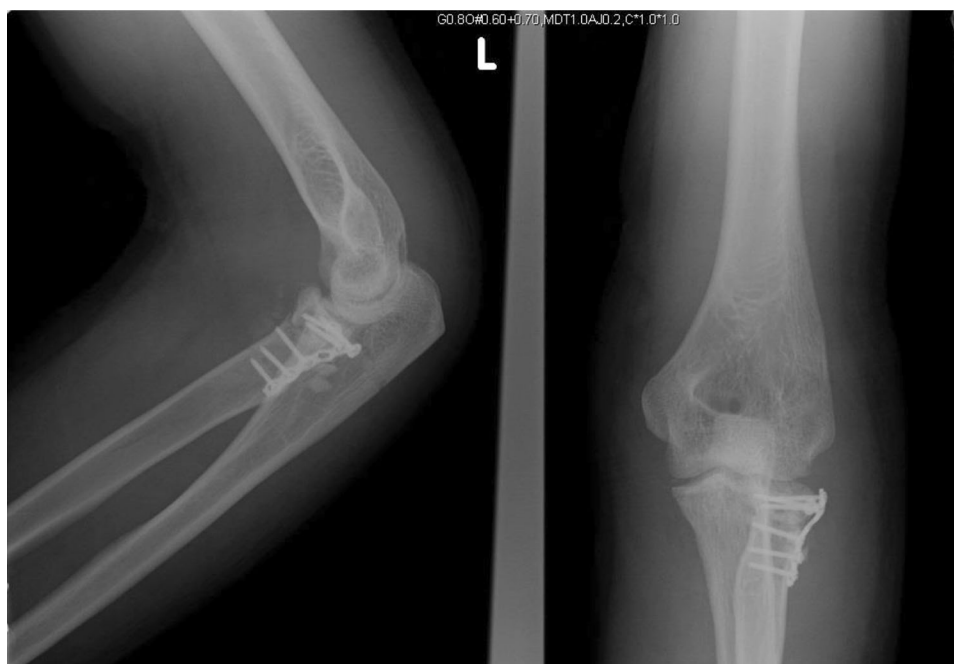
medial epicondyle avulsion fracture and another patient had a concurrent ipsilateral segmental radial shaft fracture. The demographics and mechanism of injury and fracture patterns are summarized in Table 1.

There was an average of 12.6 days from the date of injury (range 3–20 days) to definitive surgical reconstruction in our series. 12 out of 13 surgeries were performed via the posterior global incision and 1 case was performed via the posterolateral Kocher's approach. 12 out of 13 patients had their coronoid-brachialis complexes repaired with pull-

through suture lassos tied over the olecranon, demonstrated in Fig. 2 which shows the post-operative radiograph of the same patient in Fig. 1. None of them required re-insertion with bioabsorbable suture anchors or coronoid resection. Ten radial head fractures were fixed and three radial head fractures were managed conservatively. None of the patients required radial head replacement. All patients had their damaged LUCL reconstructed with the use of bioabsorbable suture anchors. Three patients required medial collateral ligamentous complex reconstruction, and this

**Table 1** Patient demographics, mechanism of injury and fracture patterns

S/N	Age	Gender	Mechanism	Regan–Morrey	Mason	Concurrent fractures
1	60	Female	Fall (ground level)	I	II	Humeral medial epicondyle avulsion
2	44	Male	Fall (>2 m)	II	II	–
3	34	Male	Fall (ground level)	I	I	Proximal radial segmental
4	53	Female	Fall (ground level)	II	II	–
5	59	Male	Fall (>2 m)	I	I	–
6	35	Male	Fall (ground level)	I	III	–
7	34	Male	RTA	II	II	–
8	36	Female	Fall (ground level)	II	I	–
9	38	Male	Fall (>2 m)	I	III	–
10	79	Female	Fall (ground level)	I	III	–
11	30	Male	Fall (>2 m)	II	I	–
12	66	Male	Fall (ground level)	I	I	–
13	35	Male	Fall (>2 m)	II	II	–

**Fig. 2** Post-operative radiographs demonstrating the reduction of the coronoid fragment achieved using the suture-lasso technique

was performed with bio-absorbable suture anchors as well. None of the patients required further stabilization with an external fixator. Patients were followed-up for an average length of 27.7 months. The minimum follow-up period was 12 months.

The average arc of elbow motion was  $105.0^\circ$  (range  $80^\circ$ – $135^\circ$ ). The average flexion contracture was  $15.0^\circ$  (range  $0^\circ$ – $40^\circ$ ). The average pronation arc was  $58.8^\circ$  (range  $0^\circ$ – $90^\circ$ ) and the average supination arc was  $56.1^\circ$  (range  $0^\circ$ – $90^\circ$ ). Fracture union of the radial head and neck was achieved in all patients on follow-up radiographs while coronoid union was achieved in 9 out of 12 patients. On the

final follow-up visit, seven patients reported no pain, four reported occasional mild pain and two reported occasional moderate pain. None had severe pain. 10 of the 13 patients were available for functional outcome assessments. The average DASH score was 21.2 (range 1.7–61.2, higher scores reflecting poorer results). The average MEPS were 85.0 (range 45–100, higher scores reflecting better results). Five patients reported excellent outcomes, three with good results, one with fair score and only one patient had a poor outcome. There was a single case of radio-ulnar synostosis and a single case of heterotopic ossification. There were two cases of recurrent elbow instability, of which both

were non-compliant with hinge brace regime, removing the brace within the first 2 weeks post-operatively. These two cases had radiographic evidence of ulno-humeral subluxation at final follow-up.

## Discussion

Terrible triad injuries (TTIs) of the elbow are challenging to manage. With the increased knowledge of injury characteristics and stabilizers of the elbow, surgical reconstructions have evolved and improved outcomes reported. Surgical reconstruction aims to restore sufficient elbow stability to allow early mobilization within a stable arc of motion [1, 2, 5, 8, 10, 11]. Most of the current literature supports the consensus that the radial head should be fixed or replaced, and the LUCL repaired to restore elbow stability [5, 6, 12–15]. However, there is no consensus on coronoid fixations to date.

In our series of coronoid first, all the patients had their elbow ROM restored to good functional arcs. The average arcs of motion are comparable with the results of similar clinical series of TTIs treated with surgical protocols that also involved coronoid and/or anterior capsular fixation [5, 8, 16–18]. The average DASH score in our series is 21.2, which is comparable to the scores of 15 and 16 reported by Lindenhovius et al. [19] and Garrigues et al. [16], respectively [minimally clinically important difference (MCID) for DASH is 10]. This was despite the fact that on the average, the TTIs in our study may have been of a higher energy, with a greater proportion requiring MCL reconstruction. 80% of our patients reported good to excellent elbow specific function score, comparable to Lindenhovius et al. and Garrigues et al. (77% and 83% on Broberg–Morrey score, respectively). Notably, an average of 85 on the MEPS was achieved in our series, which was slightly better than the average MEPS in Rafael et al. [20], which was 78. The favorable outcome scores could be attributed partially to the surgical decision matrix, the fixation techniques, and/or the early rehabilitation protocols used.

In a protocol that addresses the coronoid first, a single posterior incision technique provides the advantages of intra-operative flexibility and good exposure. For posteromedial rotatory instability (PMRI), coronoid, radial head fixations and LUCL repairs are likely required and if there is residual instability, the MCL needs to be addressed. These could be done through a single posterior approach or a 2-incision technique (posterolateral and anteromedial—addressing the coronoid, radial head and LUCL with the posterolateral approach and exploring the MCL with the anteromedial incision, which would have been required in 3 out of 13 of our patients). In our opinion, a lateral

approach alone cannot completely expose the coronoid and operating space is limited. The advantages of the single posterior approach would be a lower potential for cutaneous nerve injuries and that it could be used for elbow arthroplasty in the future. Based on our experience in this coronoid-first series, this approach provided technical benefits such as good coronoid exposure and ease of fixation for the coronoid. Good clinical outcomes were also achieved. When compared with the results reported in Rafael et al. [20], where a dual lateral-medial approach was used, our series had a slightly better average maximum flexion (120° compared to 114°). Although there is a possibility of increased hematoma formation and flap necrosis, these were not encountered in our series. In the event of pure varus instability, which is rare, the posterolateral approach would be sufficient for LUCL exploration and repairs, utilized for one case in our series. Often, combined injuries are present in TTIs and the posterior approach provides versatility in addressing both with a single “global” incision.

Pugh et al. [8], reported an average flexion contracture of 19° while Garrigues et al. [16] reported an average flexion contracture of 21°. Both studies exercised protocols that attempted coronoid or anterior capsular fixation regardless of coronoid fracture configurations, using a mixture of screws, suture anchors and suture-lasso. Our series recorded a lower average flexion contracture of 15°. This could have been due to less anterior soft-tissue contractures, possibly influenced by the reduced soft-tissue dissection (all our coronoid fixations were done using the suture-lasso technique). However, the clinical significance of such an improvement cannot be concluded using this study alone.

The best fixation for coronoid fractures is still debatable, especially for small and/or comminuted fragments. Some surgeons advocate that Type I fractures may be excised or left alone [6, 13, 18, 21], whilst others would fix any associated coronoid fracture, regardless [4, 5, 14]. We are of the view that via the suture-lasso technique, the anterior capsule is directly captured and reduced together with the fracture fragment [7, 16], and thereby the anterior elbow complex is repaired altogether. By reducing the coronoid first, the initial point of bony failure in a TTI, it facilitates reconstructions of the soft tissues to be tensioned optimally, be it a LUCL repair and/or a MCL repair. Additionally, out of the three patients that had non-union of the coronoid after fixation in our series, only one developed recurrent instability. This supports the notion that reconstruction using the suture-lasso technique provides an advantage towards conferring additional stability to the elbow.

Fractures of the radial head result in the loss of a secondary stabilizer against valgus loading and posterior translation of the elbow. In our experience, we prefer



reconstruction instead of replacement whenever possible. In our series, none of the radial head fractures were non-reconstructable via fixation methods. There were no cases of posterior interosseous nerve injury, non-union or implant failure present. Compared to Rafael et al. [2, 6], which treated most of their radial head fractures with prosthetic replacements, our current study reported higher average arcs of motion and MEPS scores. Although this could possibly be because of the higher energy injuries sustained in their series, which required 11 out of 15 of their elbows to have the MCLs repaired, the avoidance of capitellar erosion and overstuffing of radiocapitellar joint may have also contributed to the better scores. This further supports the notion that in TTIs, whenever possible, the native radial head should be preserved and osteosynthesis performed [17]. Interestingly, there was a notable high incidence of low Mason classes of radial head fractures. Out of the 13 patients with TTIs, 10 had Mason type I/II radial head fractures. These TTIs could have been missed should the clinician focus on the radial head fracture and not conducted a complete evaluation of the elbow for possible coronoid fractures and ligamentous injuries, especially if the elbow could have been dislocated and relocated prior to orthopaedic assessments.

In TTIs, elbow external fixators are placed if residual instability persists following surgical reconstructions. Although good results can be achieved using a hinged external fixator [22, 23], we prefer not to since immediate elbow stability is achievable in most patients, as observed in our series, and hinged external fixators are technically demanding to apply, with a relatively high complication rate. Even with the center of rotation of the elbow being restored by the hinged external fixator, it was reported in Pugh et al. that instability may persist after implantation removal, raising concerns that soft-tissue healing may not be adequate. Elbow arthrosis was not observed in any cases within our series. It varies widely from cohort to cohort, with Pugh et al. and Garrigues et al. reporting 39% and 28%, respectively. This could be due to our small cohort numbers or the short follow-up period (mean follow-up period of 21.2 months compared to 34 and 24 months, respectively). One could also speculate that the early rehabilitation protocol used may have delayed the onset of arthrosis. Recurrent instability was observed in two patients that were non-compliant to bracing protocols. Consequently, they had high DASH scores and worse MEPS. No patients had subsequent reoperations as of the drafting of this manuscript.

## Conclusion

The coronoid-first surgical approach, using a suture-lasso fixation method, has technical benefits for us and showed good clinical success in our series. This is important with

postero-medial rotatory instability (PMRI) being common in our series of TTIs. We emphasize not to miss a TTI in an apparently isolated low Mason class radial head fracture.

**Author contributions** JZ: first author and correspondence. MT: collection of clinical data. EBKK: senior author and mentorship, contribution of cases.

## Compliance with ethical standards

**Ethical statement** This study was conducted in compliance with ethical standards.

**Conflict of interest** Zhang JR, Tan M, and EBKK declare that there are no conflicts of interests and we are agreeable for the transfer of the copyright of the original article to the journal upon acceptance for publications.

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**Human and animal rights statement** This article does not contain any experimental studies with human participants or animals performed by any of the authors.

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

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