7 Terrible Triad Injuries

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Epidemiology

The estimated incidence of elbow dislocations is 5.21 per 100.000 persons per year. Thereby, the elbow represents the second most commonly dislocated joint following the shoulder joint [17, 26, 44]. Terrible triad injuries comprise only 8% of all elbow dislocations and, hence, can be considered rather rare injuries [35].

The mean age of patients at the time of injury is 45 years with the dominant arm being involved more frequently (60.8%) [4, 6, 11, 14–16, 27, 28, 34–36, 40, 47, 48, 51]. Terrible triad injuries occur more commonly in men than in women with a male-to-female ratio of approximately 1.7: 1 [4, 6, 11, 14–16, 27, 28, 34–36, 40, 47, 48, 51]. They are associated with sports activities in nearly half of all cases [44].

Especially in case of a high-energy trauma, concomitant injuries to the ipsilateral shoulder, forearm or wrist can occur [11, 14, 28, 48].

Classification

The terrible triad injury has first been described by Hotchkiss [1] in 1996 and is defined as a

- posterior elbow dislocation with concomitant
- radial head fracture and
- coronoid fracture

Radial Head Fracture

Radial head fractures are classified according to the modified Mason classification [3] (cross reference to chapter 5). Since the terrible triad injury represents a fracture-dislocation, all radial head fractures in this injury pattern are considered type IV fractures. The majority of radial head fractures in terrible triad injuries are displaced fractures. 51.1% are displaced two-part fractures (corresponding to Mason type II); 40.7% represent multi-fragmentary fractures (corresponding to Mason type III). Only 8.2% of radial head fractures in terrible triad injuries are non-displaced two-part fractures (corresponding to Mason type I) [4, 6, 11, 14, 15, 27, 28, 35, 39, 47, 48, 51].

Coronoid Fracture

In 1989, Regan and Morrey proposed a classification system for coronoid fractures depending on the amount of the coronoid involved [37]. Type I fractures are considered as avulsion fractures of the coronoid tip. Fractures classified as type II involve less than 50% of the coronoid; type III

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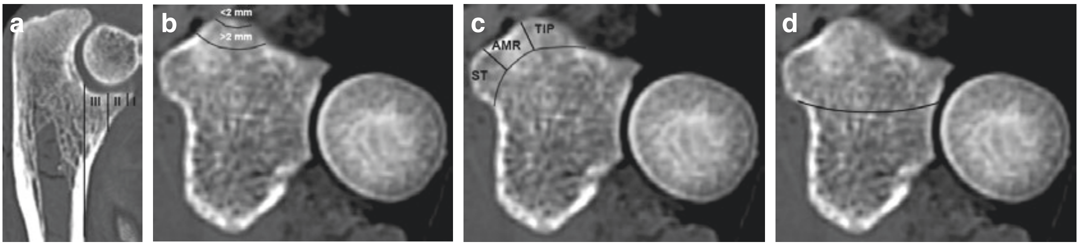

Fig. 7.1 Coronoid fracture classifications. (**a**) *Regan and Morrey classification*. *I*: avulsion of the *coronoid tip*; *II*: *<50%* of the coronoid height; *III*: *>50%* of the coronoid height [37]. (**b–d**) *O'Driscoll classification* [33]. (**b**) *I*: transverse shear fractures. *I.1*: <2 mm, *I.2*: >2 mm. (**c**) *II: anteromedial facet fractures*. *II.1*: anteromedial rim (AMR), *II.2*: AMR + coronoid tip (TIP), *II.3*: AMR + sublime tubercle (ST) ± tip. (**d**) *III*: basal fractures. *III.1*: coronoid body/base fractures, *III.2*: trans-olecranon basal coronoid fractures

fractures involve more than 50% of the coronoid process (Fig. 7.1a). Most coronoid fractures in terrible triad injuries are either type I (28.5%) or type II (68.9%). Type III fractures are rarely seen in terrible triad injuries and comprise only 2.6% of all cases [4, 6, 11, 14, 15, 27, 28, 35, 39, 47, 48, 51].

O'Driscoll formed a new classification system in 2003 which takes different fracture mechanisms into consideration: Type I fractures are transverse shear fractures (Fig. 7.1b). Type II fractures represent fractures of the anteromedial facet (Fig. 7.1c). Particularly type II.3 fractures, which involve the sublime tubercle, result in pronounced valgus and posteromedial instability. Type III fractures are fractures of the base or the body of the coronoid (Fig. 7.1d) [33]. Coronoid fractures in terrible triad injuries are usually transverse shear fractures according to O'Driscoll type I. Type II or III fractures are seldomly seen [8, 9, 14, 28, 51].

Symptoms and Diagnostics

Initial Evaluation

Patients with terrible triad injuries usually present immediately after trauma with painful swelling and tenderness of the elbow. The injury mechanism might not be remembered in detail, yet, most patients describe a fall on the outstretched hand. The injury commonly occurs due to high-energy trauma and/or during sports; particularly in elderly patients, a low-energy trauma can also result in terrible triad injuries. Deformity of the elbow may or may not be present as the elbow joint reduces spontaneously prior to presentation in some cases. A thorough physical examination is mandatory in order to evaluate any possible *concomitant injuries* – especially but not limited to the ipsilateral shoulder, forearm and wrist. Injuries to the skin must be inspected as they could be suggestive of an open fracture. The *neurovascular status* has to be obtained and documented.

Diagnostic Workup

First, conventional radiographs of the elbow in antero-posterior and lateral view have to be obtained. An additional oblique view can be useful to further evaluate the radial head. Fractures of the coronoid are easy to miss as the fragments might be overlapped by the distal humerus or by radial head fragments. Small, triangular-shaped fragments proximal to the coronoid or the absence of the distinctive shape of the coronoid tip can hint at a coronoid fracture on lateral radiographs (Fig. 7.2).

If a posterior dislocation of the elbow joint is confirmed with conventional radiographs, *closed reduction* under anesthesia should subsequently be performed. The forearm is supinated and distraction forces are applied while moving the

Fig. 7.2 Non-operative treatment of a terrible triad injury. (**a**, **b**) Plain radiographs upon presentation revealing a posterior elbow dislocation with radial neck fracture (Mason type II) and a coronoid tip fracture (O'Driscoll type I.1). The black arrow points to missing coronoid tip. (**c–e**) CT scans following closed reduction showing a concentric radiohumeral joint in a sagittal view (**c**), a concentric ulnohumeral joint in a sagittal view with displacement of the coronoid tip fragment (**d**) and a congruent joint in a coronal view (**e**)

elbow from extension to flexion in order to reduce the joint. Under fluoroscopy, varus and valgus stress tests should then be applied to evaluate the lateral and medial collateral ligament. The degree of valgus and varus instability should be documented. Moreover, the *joint stability* during passive flexion and extension has to be evaluated and documented. *Redislocation* during varus/valgus testing or upon flexion of the elbow joint of 30° or more is highly suspicious of gross instability. Immediately after joint reduction and evaluation of stability, a splint is applied in 90° of flexion and neutral rotation. The neurovascular status has to be obtained and documented again to rule out neurovascular complications.

Successful reduction has to be confirmed with standard radiographs. While standard radiographs may suffice in some cases, a subsequent computed tomography (CT) scan with three-dimensional reconstructions should be performed as it facilitates the fracture classification, the evaluation of joint congruity and the localization of displaced fragments (Figs. 7.2, 7.3, and 7.4). Additional magnetic resonance imag-

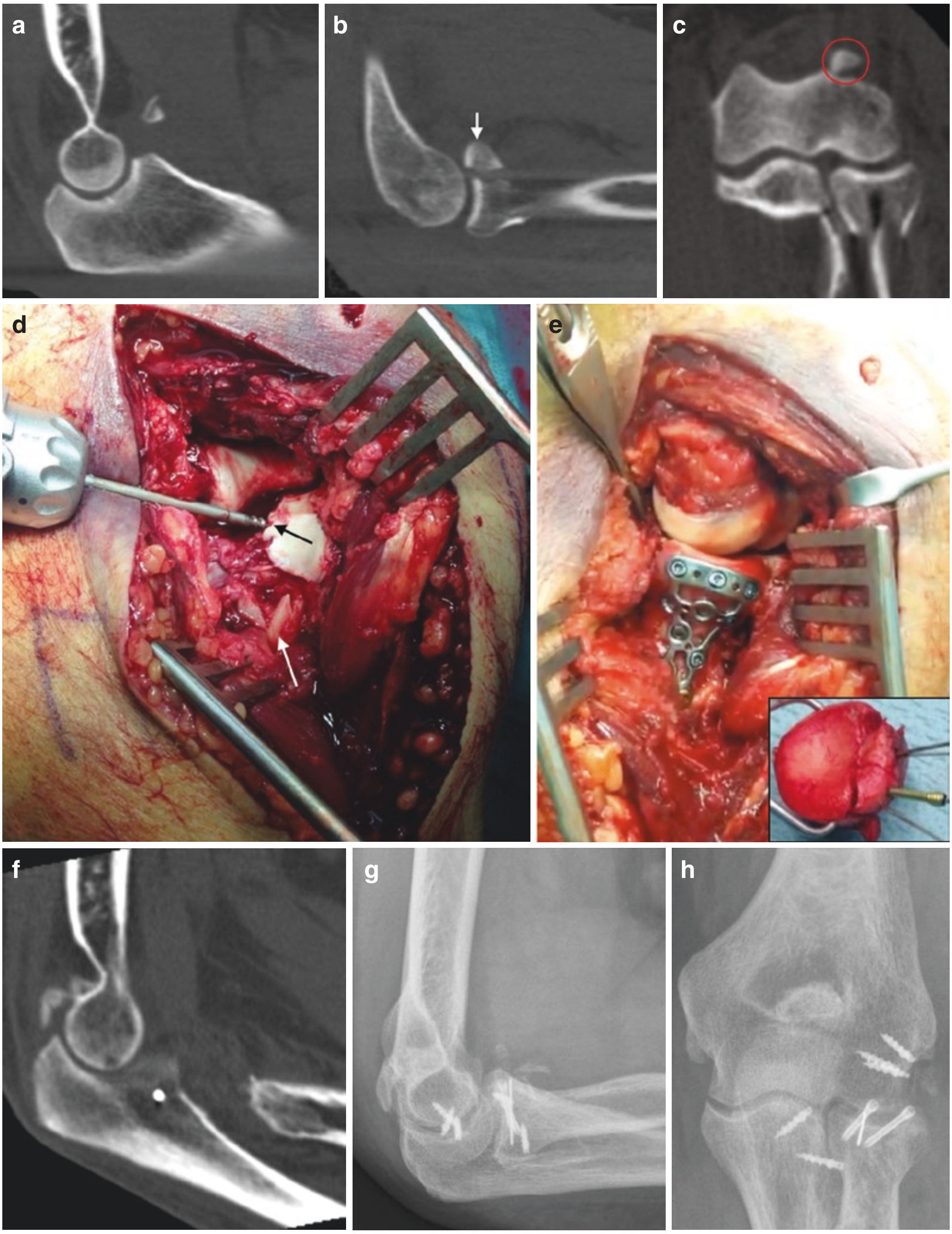

Fig. 7.3 Operative treatment of a terrible triad injury with ORIF of the radial head and suture anchor refixation of the coronoid tip. (**a**–**c**) Preoperative CT scans revealing a displaced coronoid fracture (O'Driscoll type I.2) (**a**) and a multi-fragmentary radial head fracture (**b**, **c**). The red circle (**c**) depicts a radial head fragment which lies at the posterior aspect of the capitulum as a result of the dislocation. (**d**, **e**) Intraoperative photographs. Lateral view through a Kocher approach. (**d**) After resection of the radial head fragments, suture anchor refixation of the coronoid tip (black arrow) is performed. The white arrow indicates the radial shaft. (**e**) After on-table reconstruction of the radial head (lower right corner), osteosynthesis of the radial head/neck fracture with an anatomically preshaped locking plate is performed. (**f**–**h**) CT scan and plain radiographs 1 year postoperatively showing a consolidated radial head fracture. In the meanwhile, removal of the plate has been performed. The CT scans and plain radiographs reveal heterotopic ossification (HO) in the olecranon fossa limiting extension. The patient was satisfied with the outcome and did not want to undergo revision for removal of the HO

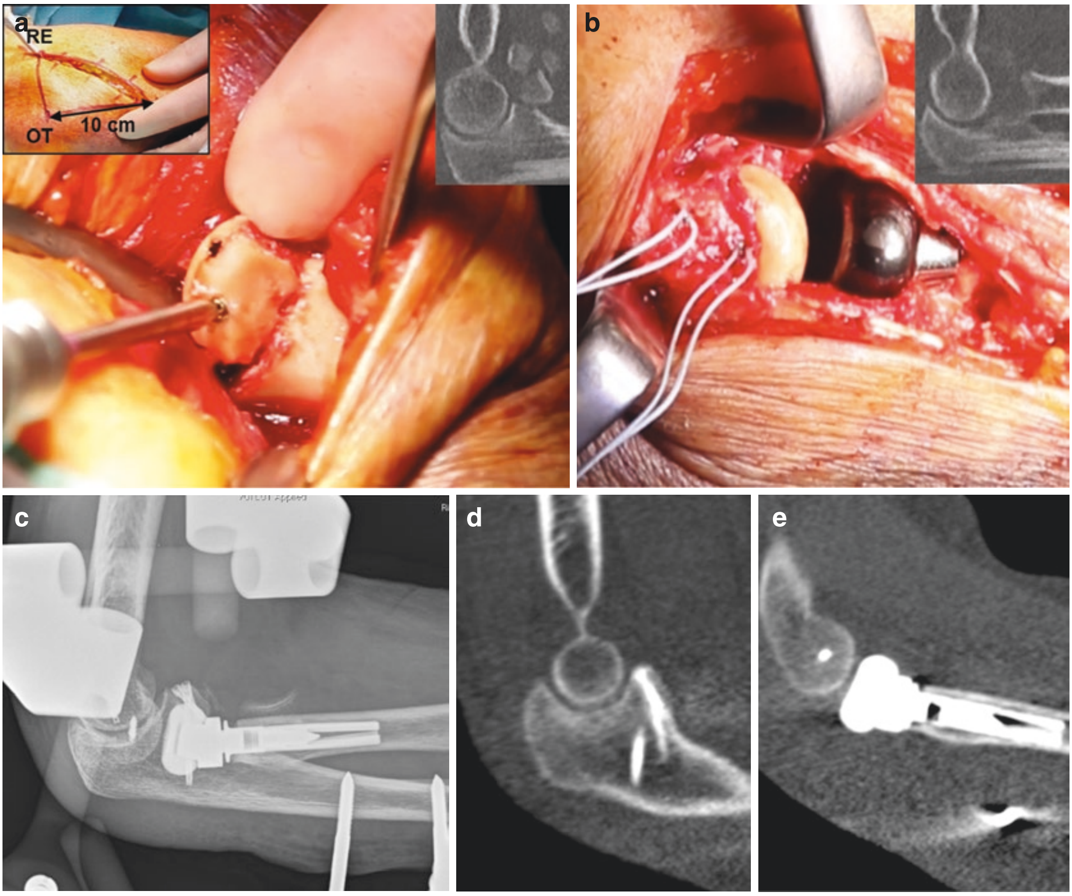

Fig. 7.4 Operative treatment of a terrible triad injury with radial head replacement and coronoid reconstruction. (**a**) Reconstruction of the coronoid with a radial head fragment. Left upper corner: Illustration of the skin incision – a rectangular triangle is drawn from the olecranon tip (OT) to the radial epicondyle (RE) and to a point 10 cm distal to the olecranon tip. The skin incision is performed over the hypotenuse of this triangle which serves as a projection of the Kocher interval. (**b**) Replacement of the radial head with a modular, monopolar radial head prosthesis. (**c**) Postoperative radiograph in the lateral view. Due to persistent instability after radial head replacement and coronoid reconstruction, a hinged external fixator was applied. (**d, e**) Joint congruity with consolidated coronoid reconstruction and intact radial head replacement at the latest follow-up

ing (MRI) of the elbow joint is usually not necessary.

Injury Pattern and Surgery Related Anatomy

Injury Mechanism

Terrible triad injuries typically occur due to a *fall on the outstretched hand* with the elbow extended or slightly bent. Fitzpatrick et al. [13] were able to show by means of an in-vitro biomechanical study that terrible triad injuries occur more frequently as a result of a fall on the *pronated forearm* while supination of the forearm typically leads to simple elbow dislocation. Pronation enforces joint congruity because of pre-tensioning of the lateral stabilizers [10, 24]. It might thus increase the osseous impact and increase the probability for radial head and/or coronoid fractures in posterior elbow dislocation.

As a result of the impact of the fall, the forearm rotates externally or internally and translates posteriorly which ultimately leads to posterior dislocation. The coronoid process and the “anterior rim” of the radial head act as primary constraints against posterior translation of the forearm. Hence, the coronoid process gets perched underneath the trochlea which leads to *transverse shearing fractures* of the coronoid (O'Driscoll type I [33]). Similarly, the "*anterior rim*" of the radial head hits against the capitulum causing a radial head fracture. Initial varus or valgus load causes radiocapitellar or ulnohumeral abutment which might result in more complex fractures of the radial head and/or the coronoid process. Especially in high-energy trauma, the axial compression forces may lead to multi-fragmentary radial head fractures and larger coronoid fractures.

Radial head fractures – and terrible triad injuries even more so – represent osteoligamentous injuries [23]. According to a study by McKee et al. [30], terrible triad injuries go along with *disruption of the lateral collateral ligament* (LCL) in 100% of cases while the *medial collateral ligament* (MCL) is disrupted in 56% of patients. The most common site of disruption for both the MCL and the LCL is their humeral origin [30].

Surgery Related Anatomy and Biomechanics

Along with the MCL, the radial head serves as the main *valgus stabilizer* of the elbow [45]. Moreover, approximately 60% of axial forces along the elbow joint are transmitted through the radial column – making the radial head a crucial *axial stabilizer* [32]. Consequently, radial head resection has a devastating effect on the stability of the elbow joint [2]. Particularly in case of concomitant osseous and ligamentous injuries – as present in terrible triad injuries – *radial head resection* is *obsolete* and the radial column has to be preserved. If reconstruction of the radial head is not feasible, radial head replacement should therefore be performed instead. Even though available radial head prostheses cannot completely reproduce the biomechanical profile of the native radial head, they restore valgus and axial stability [21, 41, 45]. In the acute setting, *monopolar prostheses* may be preferred over bipolar implants as they may provide superior radiocapitellar stability [5, 31].

Coronoid fractures increase rotatory instability of the elbow as the fractured coronoid can no longer act as a constraint against the trochlea when posterior translation forces are applied. Moreover, the coronoid can be considered as an important stabilizer against varus forces [22]. Open reduction and internal fixation (ORIF) of the coronoid is mandatory in type III fractures of the coronoid as well as in any fracture involving the *sublime tubercle* – which represents the attachment site of the MCL and therefore contributes to valgus stability of the elbow – and should at least be considered in type II fractures in order to sufficiently restore joint stability [42]. If ORIF of the coronoid is not possible due to severe comminution, the olecranon tip, a bone graft (harvested from the iliac crest) or a fragment of the fractured radial head should be used to reconstruct the coronoid (Fig. 7.4) [25].

Therapeutic Options

Non-operative Treatment

While the vast majority of terrible triad injuries require surgical treatment [29], some cases can be treated non-operatively [4, 15] if the following *criteria* are fulfilled (Fig. 7.2):

- joint congruity following closed reduction
- stable flexion arc without tendency to redislocate (extension lag <30°)
- minimally displaced radial head fracture (<2 mm corresponding to Mason type I [3])
- small transverse shear fracture of the coronoid (<30% of the coronoid process) without involvement of the anteromedial facet
- no block of motion upon flexion-extension and pronosupination (e.g. due to intra-articular osteochondral lesions)

A *close follow-up* of patients undergoing conservative treatment is mandatory. If one or more of the above-mentioned criteria are not being met any longer, surgical revision has to be considered.

In our clinical practice, the patient's elbow is immobilized in a *splint* at 90° of elbow flexion and neutral rotation for *7–10 days* before an early *functional treatment* regimen is initiated. A hinged elbow orthosis is then applied which allows flexion and extension in neutral rotation. Within the orthosis, extension is limited to 20° for 4 weeks to avoid full extension which could predispose to recurrent instability. Physical therapy should at least be performed two to three times a week. During physical therapy, the orthosis can be removed to carefully mobilize the joint over the full range of motion. Pronosupination should only be performed in 90° of flexion. Four weeks after trauma, static progressive splinting in extension maybe performed overnight to counteract flexion contracture. Load bearing is introduced at week 7 or after radiologic evidence of fracture consolidation.

Surgical Treatment

If any of the criteria for conservative therapy are not fulfilled and no absolute contraindications for surgery are present, operative treatment is recommended for terrible triad injuries to restore joint congruity and stability.

Diagnostic arthroscopy may be performed at the beginning of the surgery to evaluate the injuries or to retrieve displaced fragments especially from the posterior aspect of the elbow joint (Fig. 7.3c). In case of simple two-part fractures of the radial head (Mason type II) and the coronoid process (O'Driscoll type I, Regan and Morrey type I/II) without comminution, arthroscopically assisted, percutaneous reduction and internal fixation of the radial head and the coronoid can be attempted with cannulated headless compression screws. If this treatment strategy does not succeed or in case of a more severe fracture pattern – as common in terrible triad injuries –an open, lateral approach is indicated.

Lateral Approach

The patient is placed in *supine* position with the arm resting on an arm board in 90° of abduction. A tourniquet may or may not be used depending on the surgeon's preference. A rectangular triangle is now drawn from the olecranon tip to the radial epicondyle and to a point 10 cm distal of the olecranon tip at the posterior edge of the ulna (Fig. 7.4a) as a projection of the anconeus muscle. The skin incision is performed at the hypotenuse of this triangle reflecting the *Kocher* interval between the anconeus and the extensor carpi ulnaris. After careful dissection of the skin and the subcutaneous tissue, the forearm fascia is incised to identify the "fatty streak" of the aforementioned Kocher's interval. Through blunt dissection, the anconeus and the extensor carpi ulnaris can be separated to expose the lateral collateral ligament and the joint capsule. The annular ligament and the joint capsule are incised longitudinally to reveal the underlying radial head. The lateral collateral ligament complex and the common extensors can be sharply released from the lateral epicondyle and reflected ventrally to allow better exposure of the radiocapitellar joint as well as the coronoid. Particularly in high-energy trauma, the lateral approach to the joint may already be established once dissecting through the skin and subcutaneous tissue due to the severely disrupted soft tissue structures (Fig. 7.3d).

In case of simple, non-comminuted shearing fractures of the coronoid (O'Driscoll type I) and the "anterior rim" of the radial head (corresponding to Mason type II), a common extensor split may suffice to achieve fracture reduction.

Treatment of the Radial Head Fracture

Once the approach has been established, the radial head fracture is evaluated. In case of a two- or three-part fracture with solid fragments, ORIF with cannulated headless compression screws is usually sufficient. If severe comminution of the entire radial head is present, an *on-table reconstruction* of the fragments should be attempted. If the radial head can be reasonably reconstructed, subsequent internal fixation with an anatomically pre-shaped locking plate can be performed (Fig. 7.3e). Care has to be taken to place the plate at the "*safe zone*" of the radial head – if possible – to avoid radioulnar impingement with limitation of pronosupination [38]. In full supination, the plate should be fixed close to the posterior edge of the proximal radioulnar joint in order to respect the "safe zone".

Whenever reconstruction of the radial head is not feasible or more than 30% of the radial head are missing [43], *radial head replacement* is recommended in order to restore radiocapitellar stability (Fig. 7.4b). Radial head resection should not be performed in a fracture-dislocation as it potentially leads to gross joint instability. We advocate the use of monopolar radial head prostheses in acute fracture-dislocations as biomechanical evidence suggests that they might lead to superior joint stability when compared to bipolar prostheses [5, 31]. Especially in terrible triad injuries, correct placement of the radial head replacement is crucial [18]. Slight *over- or under-stuffing* can severely alter joint biomechanics and can lead to radiocapitellar and ulnohumeral impingement or to persisting joint instability [45]. Van Riet et al. were able to validate the posterolateral edge of the lesser sigmoid notch of the ulna as a point of reference [46]. Hence, in order to adequately restore the radial length, the radial head prosthesis should be in line with this anatomic landmark.

When reviewing the current literature, surgical treatment of radial head fractures in terrible triad injuries consists of radial head replacement in nearly two thirds of the cases while ORIF is performed in approximately one third of treated patients [4, 7, 11, 12, 14–16, 27, 28, 34–36, 39, 48, 50, 51].

Treatment of the Coronoid Fracture

In general, we recommend coronoid fixation whenever possible to *optimize joint stability*. Before performing fixation of the radial head, the coronoid can be visualized through external rotation of the forearm – particularly in case of complete disintegration of the radial head (Fig. 7.3d).

In *O'Driscoll type I.1 fractures*, the fragment is usually too small for screw fixation. Fixation of these fractures can be achieved with suture anchors. One or two *suture anchors* are placed in the fracture bed with their respective sutures grasping the anterior capsule attached to the fragment. Thereby, tying of the sutures leads to reduction of the coronoid fragment. Alternatively, a *lasso loop* technique can be used where a suture is looped around the ulna through two anteroposterior drill holes and passed through the anterior capsule to, once again, achieve fracture reduction by tying the suture [36].

Screw or plate osteosynthesis is commonly used for *O'Driscoll type I.2 fractures*. If sufficient exposure of the coronoid is achieved through an extended Kocher approach, two K-wires can be placed through the proximal ulna from anterior to posterior for temporary fixation of the coronoid fragment. Two *cannulated headless compressions screws* can then be placed over the K-wires to reach stable internal fixation. Alternatively, plate osteosynthesis can be performed. In case of limited exposure of the coronoid, percutaneous placement of two K-wires from posterior to anterior can be used to achieve temporary fixation of the coronoid fracture with subsequent retrograde osteosynthesis with cannulated headless compression screws. In high-energy trauma, refixation of the coronoid fracture might not be feasible due to severe comminution. In that case, *reconstruction of the coronoid* can be performed with a radial head fragment – if the radial head has to be replaced at the same time – (Fig. 7.4a), with the tip of the olecranon or with a bone graft from the iliac crest.

In *O'Driscoll type II and type III fractures* – which are rarely seen in terrible triad injuries – plate osteosynthesis through an *additional medial approach* should be considered to achieve stable fracture fixation. As the coronoid can usually be exposed adequately through a lateral or medial approach, an anterior approach performing a brachialis split is obsolete used due to its close proximity to the neurovascular bundle.

LCL Repair

Following stable fixation of the radial head and the coronoid process, the lateral collateral ligament – along with the common extensors – has to be reattached to its humeral original. We prefer placing one *suture anchor* into the motion axis of the capitulum for refixation of the lateral collateral ligament and another suture anchor in the lateral epicondyle for refixation of the common extensors (Fig. 7.4b). The *forearm fascia* has to be closed carefully as it contributes to lateral elbow stability and serves as an important barrier for deep infection.

Additional Procedures

Following ORIF of the radial head and the coronoid as well as reconstruction of the lateral soft tissue structures, joint stability should be evaluated once more. If valgus stability persists, an *additional medial approach* with refixation of the medial collateral ligament and the flexor-pronator mass has to be considered. Through a flexor carpi ulnaris split, the decompression of the ulnar nerve can be performed and the medial collateral ligament as well as the flexor-pronator mass arising from the medial epicondyle can be exposed. Analogical to the lateral approch, refixation of the medial soft tissue structures can be performed by *suture anchoring*.

Instead of or in addition to medial repair, a *hinged external fixator* can be applied if persisting instability is present. Great care has to be taken to place the hinge of the external fixator in line with the motion axis of elbow joint to achieve concentric flexion and extension. The guide wire can be placed in the lateral epicondyle before wound closure. This facilitates the correct positioning of the guide wire due to better exposure. Placement of the humeral pins has to be performed cautiously in order to avoid radial nerve injuries [19, 20, 49]. We recommend a mini-open approach through a small incision to minimize the risk of neurological complications.

Alternatively to the described protocol, some surgeons prefer a *posterior longitudinal skin incision* establishing full-thickness flaps around the elbow to be able to approach the joint laterally and medially through a single incision.

Figure 7.5 summarizes the aforementioned *treatment algorithm* for terrible triad injuries.

Postoperative Care

Following surgical treatment, elastic compression bandages are applied until swelling subsides. The patient's arm is placed in a hinged elbow orthosis which limits extension to 20° for 4 weeks and flexion to 90° for the first week. Afterwards, flexion is increased by 10° each week. Within the orthosis, the patient can actively flex and extend the elbow in neutral rotation within the described range of motion. Physical therapy can be introduced immediately after surgery. During physical therapy, the orthosis can be removed to perform active-assistive flexion and extension over the full range of motion. Pronosupination should be performed at 90° of flexion only. At week 5, static progressive splinting in extension can be introduced overnight to avoid flexion contracture. The orthosis is usually removed after 6 weeks. Load bearing is introduced at week 7 or after radiologic evidence of fracture consolidation.

If a hinged external fixator had to be applied, the hinge initially remains blocked. After 7 days, the hinge is released and active flexion and extension can be performed. The external fixator is removed after 6 weeks but can be applied for up to twelve weeks if there is pronounced instability.

Outcomes and Complications

Non-operative Treatment

Only few patients meet the presented criteria for non-operative treatment of terrible triad injuries. According to McKee et al. [29], *less than 5%* of patients with terrible triad injuries can undergo non-operative treatment. Thus, only few reports of conservative therapy are available in the literature. Guitton et al. [15] reported a case series of four patients who underwent non-operative treatment following posterior elbow dislocation with associated radial head and coronoid fractures. While three of their patients had good to excellent clinical results at the latest follow-up, one 32-year old male patient developed ulnar neuropathy and had to undergo revision surgery 8 months after trauma. This patient had a Mason type II fracture with more than 5 mm of displacement involving about 30% of the articular surface and thus did not meet the presented criteria for non-operative treatment (check algorithm – Fig. 7.5).

In 2014, Chan et al. [4] reported so far the largest case series of 12 patients who underwent non-operative therapy following a terrible triad

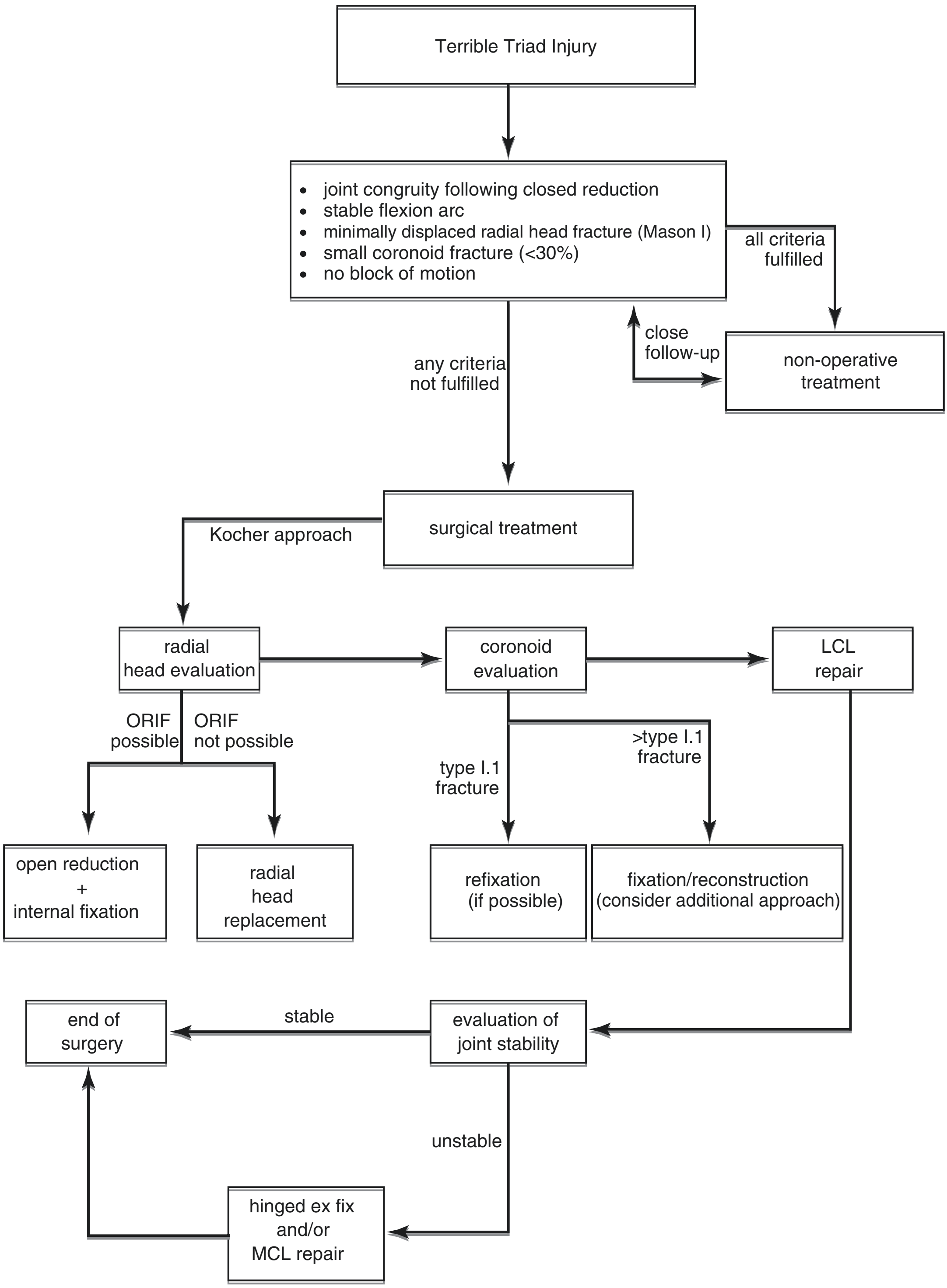

Fig. 7.5 Treatment algorithm for terrible triad injuries

injury. At a mean follow-up of 36 months, their patients had a mean flexion arc of 128° with a mean flexion contracture of 6°. The Mayo Elbow Performance Score averaged 94 out of 100 points and the mean Disabilities of the Arm, Shoulder and Hand (DASH) Score was 8 points. Two of their patients experienced complications: One patient had to undergo revision for early recurrent instability. Another had arthroscopic debridement for heterotopic ossification in the olecranon fossa. The study of Chan et al. [4] shows that non-operative treatment can lead to excellent clinical outcome when correctly indicated.

Surgical Treatment (Table 7.1)

The Early Stages

Early reports of surgical treatment for terrible triad injuries did not contain a standardized treatment protocol. Subsequently, Ring et al. reported poor results in seven of their eleven cases back in 2002 [40]. In none of the cases did they perform coronoid fixation and in four cases the radial head was resected which might explain their unsatisfactory results [40].

Establishing Standardized Protocols

Consequently, Pugh et al. [36] described a *standardized protocol* that is still considered valid today containing of a lateral Kocher approach, radial head reconstruction or replacement, coronoid fixation and lateral collateral ligament repair. If instability persisted following these procedures, the authors suggested medial collateral ligament repair and/or the use of a hinged external fixator. After a mean of 34 months, they reported a mean Mayo Elbow Performance Score of 88 points in their 36 patients. The flexion arc averaged 112° ± 11°. Eight of their patients (22%) had to undergo revision surgery for elbow stiffness (4), synostosis (2), infection (1) and recurrent instability (1) [36]. While their treatment protocol improved the overall clinical outcome significantly, complications following this severe injury remain fairly common.

Doing It Right the First Time

Initial correct treatment of terrible triad injuries is crucial in order to minimize the risk of lasting disability. Lindenhovius et al. [28] were able to show that patients who initially underwent inadequate treatment went on to have worse clinical

Table 7.1 Clinical outcome following surgical treatment of terrible triad injuries

Author	Year	n	FU	RH	Coronoid fixation	Other	Rom	Score	Compl.
Ring et al. [40]	2002	11	84	5 ORIF, 4 resection, 2 none	0/11	none	n/a	BMS: 76	7/11
Pugh et al. [36]	2004	36	34	20 ORIF, 13 RHR, 3 none	36/36	2 hinged ex fix	112°	MEPS: 88	8/36
Egol et al. [11]	2007	29	27	8 ORIF, 15 RHR, 3 resection	0/29	13 hinged ex fix	109°	MEPS: 81, DASH: 28	13/29
Forthman et al. [14]	2007	22	28	1 ORIF, 20 RHR, 1 allograft	22/22	4 ulnar nerve release	112°	MEPS: 86, DASH: 13	8/22
Lindenhovius et al. [28]	2008	18	29	1 ORIF, 17 RHR	18/18	4 ulnar nerve release	119°	MEPS: 88, DASH: 15	5/18
Leigh et al. [27]	2012	24	41	13 ORIF, 11 RHR	23/23	none	135°	ASES: 85, DASH: 10	7/24
Watters et al. [48]	2013	39	24	9 ORIF, 30 RHR	39/39	none	115°	BMS: 90, DASH: 16	14/39
Zhang et al. [51]	2014	21	32	19 ORIF, 2 RHR	21/21	none	126°	MEPS: 95	5/21

A review of literature
n number of cases, *FU* follow-up time, *RH* radial head, *Rom* range of motion, *Compl.* complications, *ORIF* open reduction and internal fixation, *RHR* radial head replacement, *ex fix* external fixator, *BMS* broberg-morrey score, *MEPS* mayo elbow performance score, *DASH* disabilities of the arm, shoulder and hand score

outcomes despite revision (subacute cohort) than patients who were treated acutely (acute cohort). The acute cohort had a mean flexion arc of 119° with an average flexion contracture of 17° while the subacute cohort had a mean range of motion of only 100° with an average extension lag of 30° ($p < .05$).

ORIF vs Radial Head Arthroplasty

Two studies have focused on the influence of ORIF versus replacement of the radial head regarding the clinical results following terrible triad injuries. Watters et al. [48] did not observe any significant differences between groups in terms of range of motion as well as DASH and Broberg/Morrey scores at a minimum of 18 months follow-up. However, *radiographic signs of osteoarthritis* were seen more frequently in patients who underwent radial head arthroplasty. On the other hand, patients who underwent *ORIF were revised more frequently* (4/9) than patients who had radial head replacement (7/30). Due to a limited amount of cases, no significant differences could be obtained. Similarly, Leigh et al. [27] found that revision surgery was more common in the ORIF group (5/13) than in the radial head replacement group (2/11) after a mean follow-up of 41 months.

Systematic Review

A systematic review of available data regarding the outcome of terrible triad injuries reveals a *mean flexion arc of 113°* with an average flexion contracture of 18° and a mean pronosupination of 138°. The mean DASH score was 17 points, the Mayo Elbow Performance and Broberg/Morrey score averaged 87 points at the latest follow-up [4, 7, 11, 12, 14–16, 27, 28, 34–36, 39, 48, 50, 51]. *Elbow stiffness* represents the most common complication following terrible triad injuries and can be observed in 10.3% of all cases. *Failure of osteosynthesis* was found to be the second most common complication with 6.7%, followed by *ulnar neuropathy* (6.2%). *Recurrent instability* was seen in 2.6% while complications related to the radial head replacement – mostly due to o*verstuffing* – were found in 1.9%. Treatment of terrible triad injuries was complicated by *infection* in 1.2% of cases [4, 7, 11, 12, 14–16, 27, 28, 34–36, 39, 48, 50, 51]. Heterotopic ossification and radiographic signs of osteoarthritis are common following terrible triad injuries but only rarely influence the clinical results [7].

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