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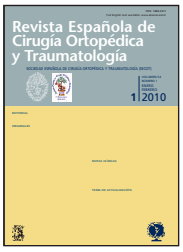

TOPICAL ISSUE

Acute complex instability of the elbow: aetiopathogenesis, diagnosis and reasoned surgical strategy

Inestabilidad compleja aguda de codo: etiopatogenia, diagnóstico y estrategia quirúrgica razonada

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Introduction

Elbow instability is the result of injuries to the bone and ligament structures that stabilise the elbow. This condition presents as a dislocation, subluxation, or as an articular incongruity and misalignment. Up until the last decade, publications leading to an establishment of the treatment of choice for elbow instability were scarce.[1-4] The few articles published regarding this combination of lesions consisted of short studies with poor results due to persistent instability, pseudoarthrosis, malunion, rigidity, proximal radioulnar synostosis, post-traumatic osteoarthritis, and pain.[5] The orthopaedic treatment frequently resulted in failure due to the complex nature of the combined injuries that dislocated inside the cast. In other cases of long periods of immobilisation, longer than 6 weeks, which followed the principle that elbow rigidity is easier to treat than instability, contractures developed severely limiting the functionality of the elbow.

The concept of complex instability of the elbow is a recent one. Great advances have been made in the study of primary and secondary stabilisers, understanding of the mechanisms of elbow injury, and patterns of instability.[1,2,6,7] These advances, along with improved surgical fixation methods, have allowed the design of reasoned surgical strategies for treatment.[3-5,8,9]

The principal objective of this study is to understand acute complex elbow instability, that in which articular incongruity is accompanied by skeletal lesions. An adequate treatment of this condition requires a proper assessment of the instability and identification of the variable underlying injuries. We propose the "terrible triad" as a model of acute complex instability: the majority of concepts for the treatment of complex elbow instabilities can be deduced from an understanding of the aetiopathogenesis and treatment of the terrible triad.[1] The authors wish to put special emphasis on the recent progress made from the study of fractures of the ulnar coronoid apophysis and the therapeutic implications of the findings.

Elbow stabilisers

The primary varus-valgus elbow stabilisers are the humeroulnar joint, the humeroulnar medial ligament (anterior portion), and the humeroulnar lateral ligament. The radial head, insertions for flexor and extensor muscles, and the joint capsule make up the secondary stabilisers. Other structures function as dynamic stabilisers: the anconeus muscle, the triceps brachii and anterior brachialis muscles. The muscles that cross the elbow joint transmit compressive forces over the articulation.

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It is useful to note that the coronoid and the radial head fundamentally limit posterior subluxations; the humeroulnar medial collateral ligament limits internal rotation, and the humeroulnar lateral collateral ligament and the radial head limit external rotation. Jensen et al demonstrated *in vitro* that the radial head also plays an important role in limiting internal rotation.[10]

Without a doubt, the most important stabiliser is the humeroulnar joint. Injury involving 50% of the coronoid apophysis can produce instability and over 70%can produce constant instability. A 30%injury of the coronoid produces instability when combined with injury to the radial head, while in the presence of intact ligaments.[11]

When one of the primary stabilisers is compromised, the radial head becomes a critical stabiliser: in cases of displaced coronoid fractures, the radial head prevents posterior dislocation, and in the case of injury to the medial collateral ligament, the radial head provides sufficient valgus stability in order to prevent a joint subluxation. In all of these cases, an excision is contraindicated. In the case of injury to the lateral ligament complex, a posterolateral rotatory instability is produced; patients without a radial head receive poorer prognoses due to the loss of its capsuloligamentous tensor function.[12]

Aetiopathogenesis

The majority of elbow dislocations result from falls landing on the hand with the elbow extended and the shoulder abducted. The mechanism of dislocation injures the bony structures and soft tissues sequentially. O'Driscoll describes 3 phases of instability before arriving at elbow dislocation, and points out the ligamentous lesions associated with each one.[1,2,6] Ninety percent of these dislocations are posterior or posterolateral. The most frequently encountered mechanism of destabilisation is the posterolateral rotatory mechanism.[1,2,13] This starts with the disruption of lateral structures, especially the humeroulnar lateral ligament: the first level of injury is a posterolateral subluxation. The most frequently seen ligamentous lesion is detachment from the epicondyle (fig. 1); intra-articular ligamentous lesions have also been described. Recently published studies show consistent findings in lateral ligament complex and posterolateral capsule injuries.[9] A lack of healing in the lateral complex has been clinically proven by surgical approaches of chronic cases: following the injury, the complex is distally displaced over the capitellum, and thus cannot cicatrise; this appears to be the cause of chronic posterolateral rotatory instability.

First, the force is transmitted anteriorly and posteriorly and more or less medially. Minor or major injury is sustained by the radial head, the coronoid apophysis, the posterolateral joint capsule, and the extensor-supinator musculature (with frequency, if the coronoid apophysis is damaged, the anterior capsule is preserved). On the medial side the humeroulnar medial ligament is also injured (50%), with the final injury sustained by the anterior portion of this ligament around which the elbow pivots.

Injuries produced in the flexor-pronator muscles are also common, and osteochondral lesions of the humeral trochlea and capitellum are frequently encountered.

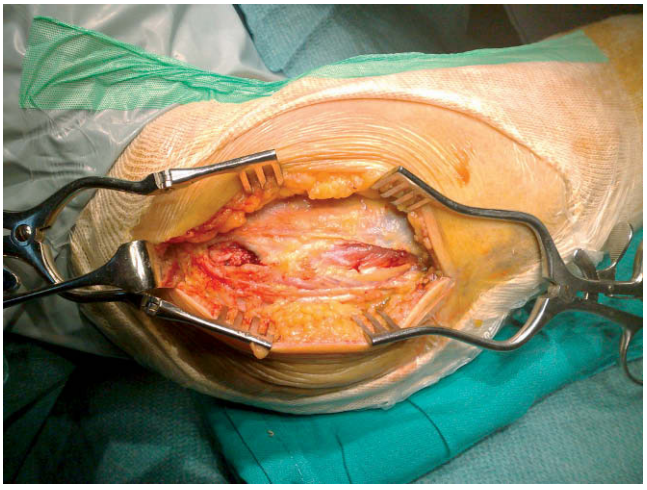

Figure 1 Common injury to the extensor-supinator musculature. Lateral approach of the elbow. The musculature is found to be detached from the distal section of the humerus following an incision of the superficial aponeurosis.

The most unstable elbows are associated with a detachment of flexor-pronator and extensor-supinator muscular masses. Complete instability is produced when the distal humerus loses all soft tissue insertions and requires a flexion greater than 90° for stabilisation; it dislocates inside the cast.

The mechanism we have described provokes the terrible triad of the elbow that Hotchkiss[14] described as an elbow dislocation with fractures of the head of the radius and coronoid apophysis.

Diagnosis

Medical histories provide information about the mechanism of action of the trauma, as well as the associated injuries to the wrist and shoulder.

Imaging includes a basic radiographic study with anteroposterior and lateral views in order to evaluate the elbow in various positions of pronosupination. Three-dimensional CT reconstructions permit high accuracy real-time assessment of the fracture morphology.

Following reduction, functional clinical instability can be evaluated by gentle flexion/tension and pronosupination movements. The best evaluation is achieved while under general anaesthesia. The varus and valgus stability should be evaluated in extension with a 30° flexion; this flexion unlocks the olecranon from the bony fossa.[1] The evaluation of valgus stability is performed with the forearm in pronation: the medial structures act as a fulcrum and avoid posterolateral displacement of the ulna and radius over the humerus, which can occur following injury to the humeroulnar lateral ligament. If evaluated in supination, the posterolateral instability can give a false positive for valgus instability.[15] Furthermore, valgus instability is always greater in pronation due to the reduced stability arising from the joint geometry.[16]

The lateral pivot-shift[15] is a test to provoke symptoms: the examiner is situated at the head of the patient who is lying in supine position with the arm over the head, and takes the extremity, as if working with a knee, and, placing the elbow in supination, flexes it to 40° with valgus stress. If a posterolateral subluxation of the head is provoked, triggering apprehension or pain, then the test is positive and posterolateral rotatory instability is diagnosed.

Classification

Various classification criteria can be considered: if we focus on the direction of the displacement, the majority would be posterolateral; if we focus on the injured structures, several lesion patterns correlated with known mechanisms of injury are defined; if we focus on chronological criteria, they can be acute or chronic, and if we focus on the degree of displacement, we will consider subluxation and dislocation.

The complete description of the injury requires a separate classification for each of the associated fractures.

Radial head fracture

The most widespread classification system is described by Mason and modified by Johnston;[17,18] it distinguishes 4 types: type 1 is a fracture without displacement, type 2 is a displaced marginal fracture, type 3 is a comminuted fracture, and type 4 is associated with a dislocation of the elbow. Hotchkiss[19] proposed a 3-type practical classification system distinguished by: type I with little or no displacement (<2mm); type II includes displaced fractures with the possibility of reconstruction and type III are those fractures where reconstruction is impossible.

Coronoid fractures

Regarding the apophysis, recent advances in the description of patterns of fracture stand out, putting special emphasis on fractures of small size.

Regan and Morrey[20] distinguished the following three types of fracture: type i are fractures of less than 10% of the coronoid, and it is important to note that these are not produced by avulsion mechanisms, since the joint capsule is

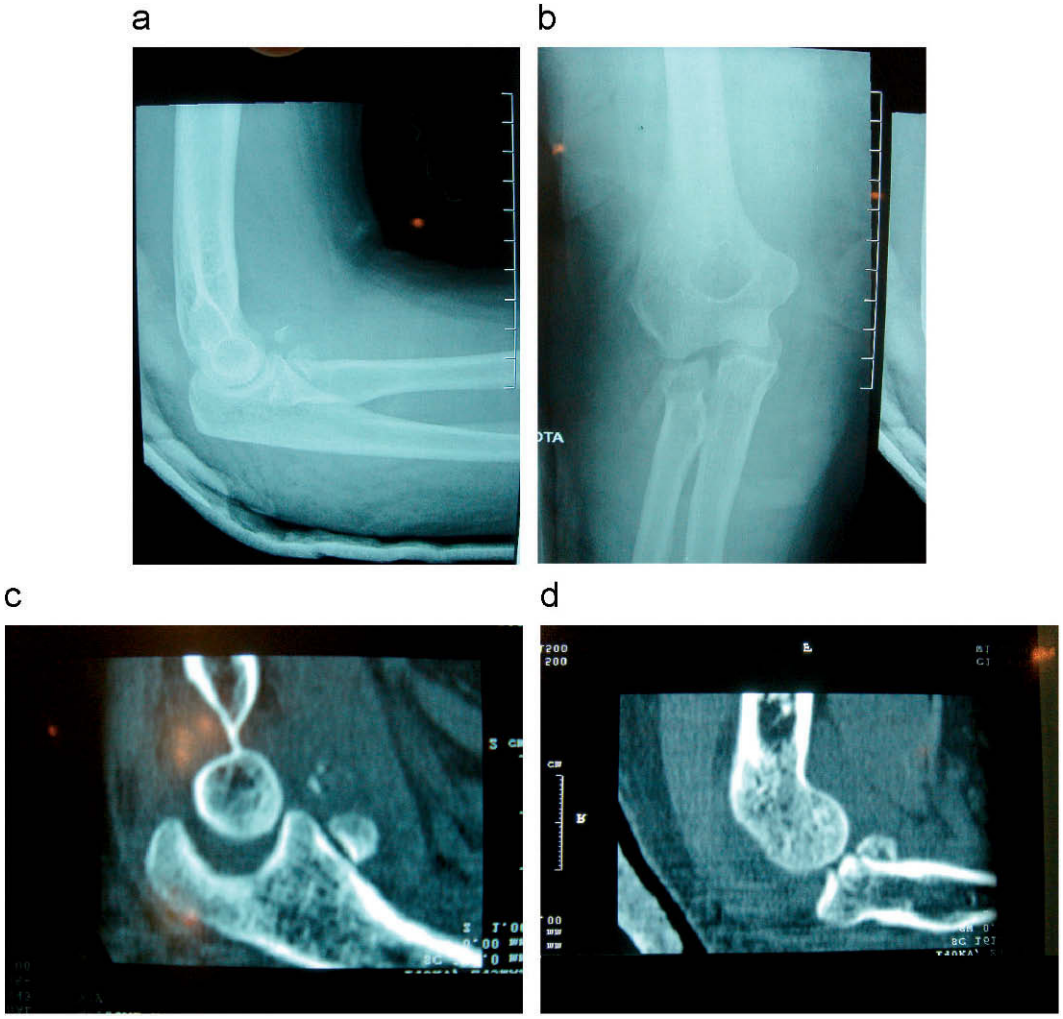

Figure 2 Terrible triad of the elbow. The radial head fracture is accompanied by a small coronoid fracture. This CT exam shows the loss of humeroulnar joint congruity and a posterolateral subluxation of the radial head.

more distally inserted around 5-6mm from the tip;[21] they are produced by shearing mechanisms, which makes them a pathognomic sign of an episode of instability (subluxation or dislocation).[5] Type ii fractures affect between 10 and 50% of the coronoid, and type iii fractures affect more than 50%. Ring and Jupiter[22] also highlighted the importance of small fractures due to their association with posterolateral injuries; they are considered to be the most problematic. In their terrible triad study, these authors observed small-scale (< 50%) coronoid fractures with appearance of small triangular fragments in lateral radiographs of the elbow, which are difficult to distinguish from fractures in the head of the radius (fig. 2). Their appearance is different from larger fractures that are associated with dislocation fractures of the olecranon.

Figure 3 Type ii coronoid fractures according to the O'Driscoll et al classification system (O'Driscoll, 2003), which in this case affect the anteromedial facet and the coronoid tip.

Recently, O'Driscoll et al[23] have proposed a new classification system based on recognising anteromedial facet fractures of the coronoid. The location and morphology of the fracture are related to certain global patterns of elbow injuries. Type i fractures are at the coronoid tip; they include sub-type i, with a size less than 2mm, and subtype ii, with sizes greater than 2mm. Type ii fractures are those that affect the anteromedial facet of the coronoid (fig. 3); 3 subtypes are distinguished here: subtype i are fractures of the anteromedial ridge, subtype ii are fractures affecting the anteromedial ridge and the tip, and type iii fractures are those affecting the anteromedial ridge, the tip, and the sublime tubercle. It is important to highlight the fractures that affect the anteromedial facet of the coronoid, as these are due to lesions distinct from posterolateral mechanisms of injury. The injuries themselves and the treatment will therefore be different as well. These are caused by a posteromedial mechanism of varus rotation with axial loading and varus subluxation. They are rarely associated with radial head fractures or medial ligamentous lesions; however, they are associated with injuries to the humeroulnar lateral ligament. Both ligaments are injured in elbow dislocations. Conventional radiology is usually insufficient for the assessment of this type of injury, making CT scans integral to a proper evaluation. Isolated anteromedial coronoid fractures are atypical of triads. However, we can encounter combined anteromedial facet and coronoid base fractures in cases of posterolateral injuries (triads).

Treatment

The main objective of surgical treatment of complex elbow instabilities is to reconstruct the bony stabilisers and convert a dislocation-fracture into a simple dislocation, which has been shown to produce generally positive long-term results.[1,23,24] A practical surgical objective is to stabilise the elbow in neutral pronosupination between 20 and 130° of flexion; this is the functional arc of elbow mobility.[25] However, maintaining the joint reduction between 0 and 60° of flexion appears to be "sufficient" as a criteria for stability: this has been shown to be the position of maximum *in vitro* instability for triad cases.[11]

The surgical approach can be made through a single middle posterior incision with elevation of two large skin flaps for access to the lateral and medial lesions. We prefer to use independent lateral and medial approaches.[5,8]

A Kocher approach between the anconeus and posterior ulnar muscles provides access for repairing the humeroulnar lateral ligament and common muscular insertions, the radial head, and the coronoid apophysis. The annular ligament must also be opened. A Z-incision has been proposed in the annular ligament of the lateral capsuloligament complex for improved vision.[3] The anterior capsule can be freed

from the epicondyle while preserving the collateral ligament. Furthermore, in cases of chronic lesions with flexion rigidity, this provides anterior arthrolysis. Posterior enlargement detaches the collateral ligament and destabilises the elbow, and is performed when the fracture requires it or for the placement of a radial head prosthesis. The medial approach is reserved for fractures of the coronoid apophysis when access through a lateral approach is impossible or in order to revise the medial collateral ligament. In order to access the coronoid, the incision can be deepened through the fibres of the anterior ulnar muscle or by opening a section of the flexopronator muscle anterior or posteriorly. It is important to take advantage of lesions to the soft tissue by working through the injury itself, extending them distally and proximally, so as to leave the healthy tissue undamaged. When working with a dislocation-fracture of the elbow with an olecranon fracture, this can serve as a point of access for the coronoid apophysis and head of the radius.

Terrible triad of the elbow

Surgical planning should be based on a sequential repair of injured structures until achieving sufficient stability. The principles of the surgical technique are a) recover stability of the coronoid through osteosynthesis or reinsertion of the anterior capsule in type i fractures; b) recover stability of the radial head through osteosynthesis or prosthesis, and c) recover lateral stability by repairing the lateral ligament complex. If the patient presents residual instability following completion of the standard treatment protocol, the humeroulnar medial ligament must be repaired or an external fixator put into place.

Various methods for fixation are available; the choice depends on the size, location, and morphology of the injury.

Coronoid apophysis

Being the deepest structure in a lateral approach, this presents the first step of surgical repair. If the head of the radius or the external capsuloligament complex is treated first, we will be obligated to perform an independent medial approach in order to access this lesion.

Large coronoid fractures, or fractures of the base, are considered to be more severe. The level of instability increases with the size of the fractured fragment, since the base of the coronoid acts as a posterior support and is the insertion site for the anterior band of the humeroulnar medial ligament. Surgical stabilisation of these injuries is made easier using cannulated screws placed on the subcutaneous face of the ulna or by using specially designed plates placed along the medial approach.

Small coronoid fractures implicate an episode of instability, as has been discussed. Ring and Jupiter,[22] as well as highlighting the importance of these fractures, have successfully promoted their surgical repair. Small fragments can be more easily repaired by suture or cerclage placed through the joint capsule, tunnelised through the ulna and knotted to the bone (fig. 4).

With respect to anteromedial fractures of the coronoid, evidence shows that insufficient treatment of the anteromedial aspect leads to poorer functional results and can produce secondary osteoarthritis; this has justified the medial approach for access to the fracture, and the development and use of specialised implants for internal fixation.[7,23,26]

Figure 4 Coronoid fracture treated by cerclage placed through the joint capsule, tunnelised through the ulna and knotted at the posterior section.

Fractures of the head of the radius

Simple marginal fractures can be fixated satisfactorily using compression screws, preferably cannulated. In cases of comminution of the fragment, partial excision can proceed, as long as the fragment is smaller than one-third the size of the head and does not compromise the proximal radioulnar articulation. If it exceeds one-third the size of the radial head, a prosthetic replacement is recommended.

Osteosynthesis with screws or specialised plates is indicated in complete fractures of up to 3 fragments of the radial head and neck. Comminuted fractures are candidates for prosthetic replacement. The presence of comminution in the head of the radius is highly indicative of a high-energy trauma and an unstable injury. This increases the risk of synthesis failure and the probability of finding impacted fragments or small fragments with little subchondral bone and little chance of synthesis.

For placement of a radial head prosthesis, there are several types of implants available on the market. Silicone prostheses have been proven to be mechanically insufficient.[25,27,28] Metallic prostheses provide sufficient stability to take the place of the fractured head. Some studies show a stability similar to the original,[10,27] while others conclude that the stability afforded is sufficient, but not at the same level as the native head.[16] Some controversy surrounds the selection of the implant: bipolar prostheses could be inferior in their capacity for *in vitro* stabilisation,[11,16] but have the theoretical advantage of diminishing stress at the height of the joint between the radius and capitellum. Short modular uncemented prostheses have some advantages when placed as a spacer. The modularity facilitates insertion of the implant, permits adjustments to the diameter and height of the head, diminishes possible

residual instability, and avoids placement with excessive tension (overstuffing). The lateral edge of the coronoid apophysis is useful as a reference point to determine the height of the prosthesis; the head of the radius stays an average of 1mm higher than this lateral border.[9] Short prostheses avoid the 15° angle zone of the proximal radius, and eliminate the increase of angular compensation with the rotation of the forearm;[7] additionally, this method facilitates an eventual revision since it does not affect the bicipital insertion zone.

Lateral ligament complex

The repair of this structure is not a habitual procedure, but arises in cases where the stability of bony elements is diminished. The condyle is often found denuded; here the ligament, the posterolateral capsule and common origin of the extensor-supinator musculature are reinserted. We used transosseous sutures or anchor type fixations (preloaded screws with sutures) (fig. 5).

In those patients who present with residual instability following completion of the standard treatment protocol, the need for repairing the humeroulnar medial ligament or placement of external fixation is evaluated.

No general consensus exists regarding reparation of the medial ligament. Many authors still consider repair of the humeroulnar medial ligament to be an important procedure. This concept was extended by *in vitro* biomechanical studies: they showed the role that the ligament plays in valgus stability, while no relevant role was found for the humeroulnar lateral ligament until rotational forces were applied in the studies.[24] Some experimental works have shown that repair to the anterior fascicle of the humeroulnar medial ligament can be sufficient for a functional stability of the elbow;[10] others have proposed its repair in comminuted radial head fractures with medial instability in order to promote early mobility and obtain improved results.[3] Various studies have shown positive results without a systematic repair of this ligament.[5,9,23,24] In our experience we have found scarce indications for repair of this ligament. If we take into account the prospective studies that have shown similar results in isolated elbow dislocations with and without repair of the medial collateral ligament, we can infer that the concentric reduction of the elbow allows healing of this ligament with similar results to surgical repair.[29] Such a procedure requires an additional complementary medial approach and mobilisation of the ulnar nerve. Furthermore, the ligamentous fascicles requiring repair are frequently difficult to identify following a trauma. We restrict surgical treatment of the ligament to those cases in which a concentric reduction of the elbow was not obtained due to interpositioning of soft tissues in the medial face, analogous to what occurs in bimalleolar injuries of the ankle.

If instability persists at this point, a temporal fixation with a Steinmann pin that transfixes the joint can be performed as a salvage technique, which is sufficient in the majority of cases. In the hands of a surgeon familiar with external fixators of the elbow, this is a good choice: it permits quick healing of the ligaments and early mobilisation, which is a secondary objective in the treatment protocol.

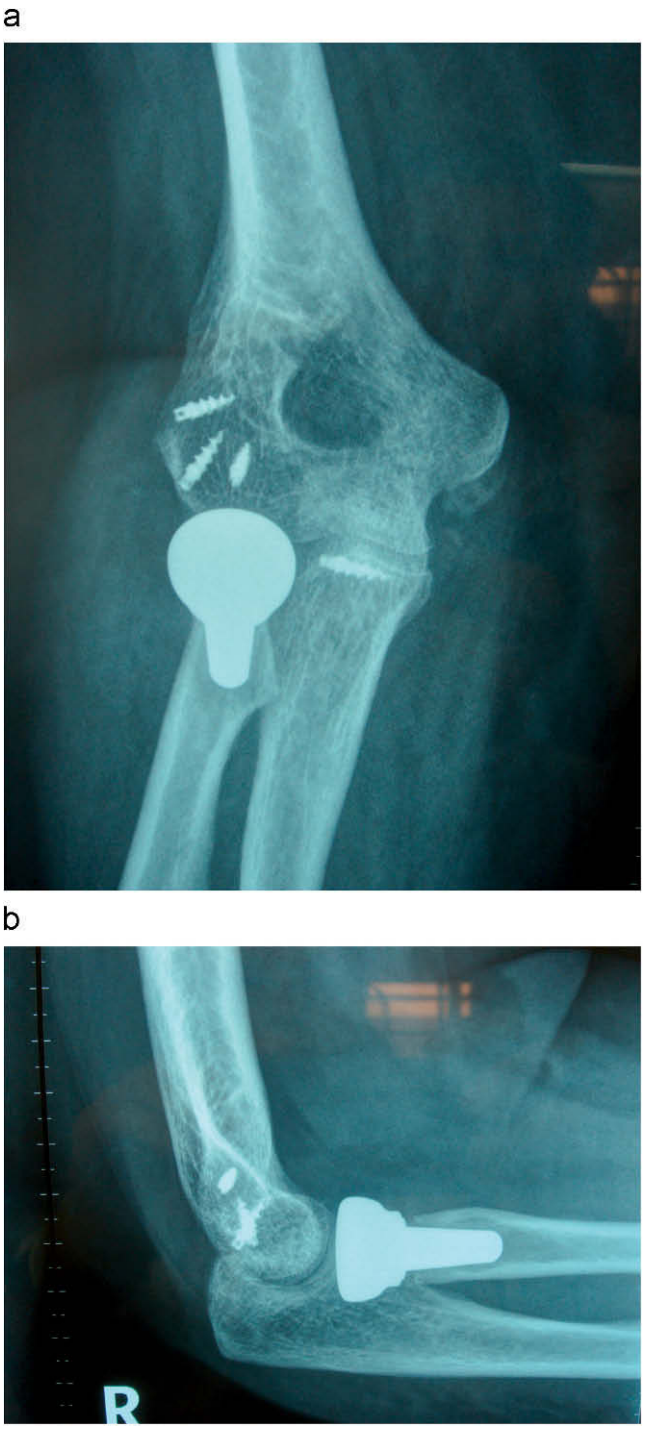

Figure 5 Radiological follow-up after the surgical treatment of a terrible triad injury. The anterior capsular lesion has been repaired by a preloaded screw with sutures, and a small-sized coronoid fragment has been dismissed; the radial head has been replaced by a modular uncemented prosthesis, and the lateral ligament complex and extensor-supinator musculature has been repaired using a reinsertion over preloaded screws with sutures.

The placement of this apparatus is technically complex: it requires a careful identification of the axis of rotation of

Figure 6 Placement of the external fixator. This requires a preoperative strict lateral view in order to correctly determine the centre of rotation of the joint. The capitellum and trochlea are superimposed.

the joint in order to situate the reference needle. It is not always simple to get a strict lateral view with superpositioning of the joint surface of the capitellum and trochlea; the centre of rotation is in the centre of the circle that remains visible (fig. 6). There is also a risk of nerve damage when placing the reference needle or nails.

The postoperative treatment schedule starts with immobilisation in a position of 90° flexion and neutral pronosupination. Early active movement is recommended: exercising flexion/extension, avoiding the final 30° of extension for at least 4 weeks, and working pronosupination at 90° flexion. The stabilising capacity of the musculature is utilised when ligamentous injuries are involved. Therefore, exercises are performed in pronation in lateral injuries, and in supination in medial injuries. It is recommended to start mobility between the first and third weeks, since prolonged immobilisation creates rigidity. Stretches and strengthening should be postponed at least 6 weeks. In either case, the protocol is mandated by the preoperative evaluation of stability, and the surgeon will evaluate the authorised range of motion, known as the safe zone. An orthosis can provide some additional stability. The efficacy of prophylaxis of heterotopic ossification with 25mg of indometacin has yet to be demonstrated.[5]

Results

We cannot supply definitive data for the treatment of terrible triads of the elbow; the studies are short. Evidence does exist that patients with untreated injuries to the coronoid and excision of the radial head present the worst results.[1]

In general terms, the prognosis depends on the associated injuries. If all are treated correctly, good results seem to be obtained in > 75% of cases. Moro et al[30] published one of the first studies on radial head metallic prostheses in 25 patients with Mason type iii and iv fractures, and with criteria for instability in at least half of them; they found regular or poor results in 32% of patients. Pugh et al published their results on the recovery of the functional arc of the elbow in 29 of 36 patients,[5] with good or excellent results in 78% of cases at 3 years. Ashwood et al[3] achieved satisfactory results in 81% of 16 cases, and only 6 of them were complex instabilities; other 6 were associated with valgus instability. Forthman et al[24] published similar results (77%) from their study of 34 patients in which 22 were terrible triads. Doornberg et al[9] obtained even better results: good or excellent in 91% of their study, composed of 36 cases with 16 terrible triads, 10 Monteggia lesions, and valgus instability.

These injuries are difficult to treat, and in spite of an adequate surgical approach there is still an elevated rate of complications; these include heterotopic ossifications at the level of the collateral ligaments that tend not to have clinical relevance, with a published incidence between 12 and 36% of patients,[9,24,30] reinterventions for removal of material and arthrolysis (20%), proximal radioulnar synostosis, rigidity, and recurrent instability, which can reach 6% of cases, according to studies.[24]

Osteoarthritis has been observed even in cases where concentric reduction of the elbow was achieved. This affects between 20 and 36% of patients evaluated at 3 years.[9,30] This osteoarthritis can be secondary to the initial trauma, but can also be secondary to instability; as such, although obtaining sufficient stability is the principal treatment objective, it is considered worthwhile to restore as many stabilising factors as soon as possible.[22,23,29,31]

Long-term outcome of the use of metallic prostheses is still uncertain. Radiological signs of osteopaenia of the capitellum have been published with highly variable incidences (up to 78%[8,30]). Additionally, long-term effects of contact between the prosthesis and the bony surface of the capitellum are unknown.[22,29,31] Radiolucent images around the stem are also visible (68%),[9,30] which apparently are not progressive and whose long-term repercussions are also unknown.

Discussion and conclusions

Dislocation of the elbow is a frequent injury with a good prognosis. The most frequent complication is a loss of extension. Redislocations are infrequent. The results from the treatment of recurrent dislocations have been uneven; some authors have published positive results without needing to perform salvage procedures, such as muscular lengthening or repair/reconstruction of the collateral ligaments, at least in cases treated within 2 months of the accident. Concentric reduction of the elbow and mobility with an external fixator seem to be sufficient for providing balanced healing to the surrounding soft tissues.[29]

Complex instability, in which associated fractures exist, is a much less frequent injury in clinical practice, and its study has been the subject of important progress during the last decade. Mostly, these are secondary to a posterolateral rotatory mechanism, and the initial injury is to the lateral ligament complex. The ligamentous centre of attention has shifted from the medial ligament complex to the lateral ligament complex. An un-repaired injury to the lateral ligament complex can cause a chronic posterolateral instability.

The repair of the medial collateral ligament is still the centre of some controversy: some authors habitually repair it, and with success in the case of valgus instability.[3] However, the need to repair the collateral medial ligament may have been overstated: the injury tends to heal correctly using conservative treatment, and only produces medial instability in some instances. Our experience supports the idea that isolated valgus laxity of the elbow is not an indication for ligament repair.[5] When a medial ligamentous lesion is presented, the radial head becomes a primary stabiliser; treatment centres around reconstruction through osteosynthesis or a prosthetic replacement. Chronic medial instability is frequently secondary to repetitive overload of the medial ligament complex with repetitive valgus movements, as in throwing athletes.[2] Expert surgeons have proposed a treatment protocol in which the medial collateral ligament is the final structure to be repaired in complex instabilities, and believe that a repair procedure of this structure is completely necessary.[5,8,23,24]

The radial head has definitely ceased to be considered a dispensable part of the skeleton. The excision of this structure is absolutely contraindicated in the context of an unstable injury to the elbow, whether secondary to humeroulnar medial ligament insufficiency or due to lesion of the interosseous membrane (Essex-Lopresti lesion); this must be repaired at all costs, since excision provokes osteoarthritis of the elbow and persistent instability, and cases of axial instability of the forearm can also provoke osteoarthritis of the wrist.[9,16,30,31]

Small-sized coronoid fractures can be the most problematic, and are accompanied by severe instability.

Advances in the understanding of mechanisms of injury and observations on studies of complex instabilities have lead to the development of reasoned treatment protocols that are applicable in the majority of cases. Repair of bony elements combined with ligamentous and lateral dynamic components can reach sufficient stability for early mobility.

Conflict of interest

The authors affirm that they have no conflicts of interest.

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