TECHNIQUE

The "Terrible Triad" of the Elbow

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HISTORICAL PERSPECTIVE

The results of elbow dislocations with associated radial head and coronoid fractures (the so-called "terrible triad" of the elbow) are often poor as a result of arthrosis, recurrent instability, and/or stiffness from prolonged immobilization.[1–6] Difficulty in treating patients with this injury is compounded by the lack of information available regarding techniques, results, and complications. Unfortunately, there is no single study in the literature that has specifically evaluated this condition, and what is available must be extrapolated from the subgroups of patients with this injury that are included in other larger series (such as elbow dislocations).[3–5]

In 1989, Josefsson et al. published the long-term outcomes of 23 patients who sustained an elbow dislocation with a displaced radial head fracture.[5] They noted that redislocations occurred in four patients, all of whom had had an untreated associated coronoid process fracture. Three of these patients had undergone primary radial head excision. Of the 19 patients who had primary radial head excision, 12 developed arthrosis of the elbow. They noted that osteoarthritis tended to occur in patients who had displaced fractures of the coronoid or radial head (or both) that had not been reconstructed. Their final recommendations were to reconstruct the radial head and the coronoid process with repair of the lateral ligaments if possible. In 1987, Broberg and Morrey published similar findings to the findings of Josefsson et al.[1] They found that arthrosis occurred in 22 of 24 patients who had experienced a fracture-dislocation of the elbow managed without repair or replacement of the radial head at an average 10-year follow-up examination.

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In 1989, Regan and Morrey published the Mayo Clinic experience with coronoid process fractures.[7] Regan and Morrey classified coronoid process fractures into three groups: type I, fracture of the tip of the olecranon; type II, < 50% of the coronoid process; and type III, > 50% of the coronoid process. Among type II fractures, the worst results were obtained in patients with associated radial head fractures and elbow instability (the terrible triad of the elbow). Of the five type III fractures in this study, four had poor results secondary to stiffness, pain, and recurrent elbow instability. Two of their conclusions were that prolonged immobilization of the elbow in this situation leads to stiffness and should be avoided if possible, and that all type III fractures and type II fractures associated with elbow instability should be repaired.

These observations essentially demonstrate the dilemma of dealing with this injury in a nonsurgical fashion. Even though it may be possible to obtain a reasonable reduction in a closed fashion, prolonged immobilization (typically in a position of excessive flexion) results in severe stiffness and a nonfunctional elbow range of motion. Earlier mobilization, in an attempt to restore a functional arc, often results in prompt posterior subluxation or redislocation.

There remains some controversy over the mechanism of coronoid fracture seen in these cases. In the past, these fractures have been termed "avulsion" fractures and have been postulated to be from avulsion by the anterior elbow capsule and brachialis muscle. However, the tip of the coronoid is an intraarticular structure, can be clearly visualized during elbow arthroscopy, and is devoid of soft-tissue attachments. We believe that the coronoid fracture typically occurs from a "shearing" mechanism and results as it is driven against the unyielding distal humerus as the radius and ulna dislocate or subluxate posteriorly.[8–10] Thus, in our opinion, a coronoid fracture is a pathognomonic sign of an episode of elbow instability. Questioned carefully, patients with what appears to be an isolated coronoid fracture on radiographs may volunteer that they felt or saw their elbow "clunk" back into joint as part of an episode of subluxation or dislocation with spontaneous reduction.

In 1998, Heim published a review of the AO experience with combined radius and ulna fractures at the elbow.[3] Of 120 total cases, 25 cases involved fractures of the coronoid process and radial head. Of these 25 cases, 11 patients were treated with primary radial head resection. Eight of these patients developed premature arthrosis, and another eight demonstrated valgus instability. An additional 41 cases involved a fracture of the olecranon in addition to radial head and coronoid fractures. Thirty-six of these patients developed arthrosis, especially after radial head resection. Heim recommended restoration of the radial head by open reduction, internal fixation with consideration for prosthetic replacement if severe radial comminution or ulnar instability is present.

The salvage of these injuries is difficult, and conventional treatment is often inadequate to restore sufficient stability to allow early motion, especially if previous surgical intervention has complicated matters (i.e. through injudicious radial head excision). In these situations, hinged external fixation of the elbow can be very rewarding. McKee et al. and Cobb and Morrey described series of unstable elbow dislocations, many associated with radial head and coronoid fractures, that had failed initial management.[2,11] Application of a hinge fixator to the elbow restored concentric stability and allowed early motion while ligamentous healing occurred. However, the authors point out that this is a specialized technique with a high complication rate, and that successful primary management is preferable.

It is apparent from these reports that elbow dislocations with associated fractures of the radial head and coronoid process often result in poor results with conservative management. Similarly, surgical intervention has a high failure rate if certain principles are not followed. In an attempt to improve the outcome of the treatment of patients with these injuries, we have developed a management protocol that concentrates on restoration of the damaged structures (radial head, coronoid process, elbow ligaments) and initiates early elbow motion. Advanced techniques, such as articulated elbow fixation, are reserved for cases that fail primary management or conventional management. In our practice, adherence to these principles has significantly improved the functional outcome of these patients with this potentially devastating injury.[11]

INDICATIONS/CONTRAINDICATIONS

As a general rule, the majority of unstable fracture dislocations of the elbow will require open repair, as opposed to the majority of simple elbow dislocations, which can be treated closed.[12] The main goal of operative intervention is to re-establish sufficient elbow stability so that early movement can be instituted to restore a functional arc of motion (100° of flexion–extension, 100° of pronation–supination). An extensive operative procedure followed by prolonged immobilization (greater than 3 weeks) usually results in significant stiffness and is to be avoided if possible.

Initial management of the "terrible triad" should consist of a gentle closed reduction under intravenous sedation or general anesthesia. This is useful from a number of standpoints: it improves the patient's pain, reduces tension on soft-tissue structures, decreases swelling, and allows for postreduction radiographs that are usually easier to interpret and base treatment decisions on. If the reduction has been done under general anesthesia, then the elbow can be put through a range of motion and have its stability tested.

The decision to operate is based on good-quality postreduction anteroposterior and lateral radiographs. A number of criteria must be met if the elbow is to be treated conservatively: 1) there must be concentric reduction of the ulnohumeral and radiocapitellar joints 2) the radial head fracture must be relatively small (< 25% of the head) or nondisplaced and not block forearm rotation and 3) there must be sufficient stability that motion can be initiated within 2–3 weeks. It is rare that these criteria are met in this injury, and the radiographs must be examined critically. One potential pitfall is subtle posterolateral rotatory subluxation of the joint, most easily identified as a loss of the colinearity of the radial head/neck and the capitellum on the lateral view.[13] Vigilance must be maintained if the patient is nonoperatively treated; a loss of reduction on radiographs should initiate a change in the patient's treatment plan.

Even though we do not routinely use computed tomography scanning or tomography for these injuries, it can be useful when uncertainty persists regarding the nature of the injury despite adequate plain radiographs. The size and shape of the coronoid fragment is typically well-visualized on the computed tomography scan (Figs. 1 and 2).

In conclusion, although the occasional patient may have an absolute (medical) contraindication to surgery, or meet the criteria for conservative management, the majority will require operative treatment of the "terrible triad."

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General Considerations

Once the decision has been made to proceed with operative repair, there are essentially two choices with regards

FIG. 1. Lateral tomogram of an elbow with posterior dislocation, coronoid fracture, and radial head fracture, the so-called "terrible triad" of the elbow. Tomograms can often be very useful in defining bony fragments of the radial head (seen on this section) or coronoid. They are also useful in that there is not as much "scatter" or artifact (when compared with computed tomography scanning) in revision cases with previously implanted hardware.

FIG. 2. A three-dimensional computerized tomographic (CT) reconstruction of a patient with a "terrible triad" injury of the elbow. The fragments of coronoid and radial head can be clearly seen anteriorly as the elbow dislocates posteriorly. This illustration clearly shows how the normal bony restraints of the coronoid and radial head are lost, contributing to posterior elbow instability.

to operative approach. The choice of approach will depend on the individual case and the structures that the operating surgeon has decided to repair. However, regardless of the injuries that are diagnosed, the surgeon must be prepared to visualize the medial and lateral sides of the elbow joint if necessary. This can be done either through a posterior approach, by dissecting around the medial and lateral sides, or through combined medial and lateral approaches. A posterior approach is our first choice in these situations for a number of reasons. The main advantage is the panoramic view of the elbow and the access to the medial and lateral structures that it provides. Also, a hinged external fixator can be applied, or other reconstructive procedures performed, from this approach.[11] Thus, if as a result of failed previous surgery or injury severity, it is anticipated that it will be difficult to restore elbow stability with conventional techniques, a posterior approach facilitating possible hinge application is used. Another advantage of the posterior approach is the position of the limb. Because the approach is performed with the patient in the lateral decubitus position, the forearm hangs down, and, thus, gravity helps counteract the tendency for the elbow to subluxate in a posterior direction. If it is anticipated that the majority of work can be done on the lateral side (radial head, lateral ligament), an extended lateral approach is our first incision. It is often possible to restore stability to the elbow to allow early motion through this approach alone. If there is associated ulnar nerve pathology, then exploration of the nerve is required and can be done through a separate medial approach. This also provides an opportunity to explore and repair the medial soft-tissue injury (medial collateral ligament and/or flexor–pronator origin). With either approach it must be remembered that the goal of surgery is to establish sufficient stability to allow early motion, because prolonged elbow immobilization after open-surgical repair in this situation will result in elbow stiffness.

Anesthesia/Positioning

We use general anesthesia for these cases. For the lateral/medial approach, patients are positioned supine, and the limb is free-draped on an arm table. A tourniquet is applied on the upper arm and inflated to 250mm Hg. A pad is placed under the elbow to elevate it from the table and ease the planned dissection. When a posterior approach is planned, we place the patient in the lateral decubitus position with the aid of a positioning beanbag. A foam pad and axillary roll are used on the down side, as the case may be prolonged. After application of the tourniquet, the arm is free-draped over a padded bolster that is attached to the operating-room table.

Surgical Approach

For the lateral approach, a lateral incision is used, and the superficial muscular interval between anconeus and extensor carpi ulnaris (Kocher's interval) is developed. The lateral soft tissues deep to the myofascia are invariably disrupted with this injury. We have noted that the most common pattern of this injury is the stripping of the lateral capsule and the ligaments off of the posterolateral aspect of the humerus, which leaves a characteristic "bare spot" on the bone.[14] Less common patterns include midsubstance rupture of the lateral collateral ligament and capsule, or a lateral humeral bony avulsion. The common extensor origin is disrupted approximately 60% of the time. If possible, it is important to gain access to the joint through the interval created by the injury, rather than creating a separate arthrotomy or surgical plane of dissection. This will make the closure easier and the soft-tissue repair stronger. Through this lateral approach the anterior aspect of the joint including the radial head and coronoid process can be visualized.

Persistent instability to valgus stress or ulnar nerve pathology suggests medially based pathology that should be addressed. If a medial approach is required, it is done through a separate medial incision. The ulnar nerve is mobilized and protected throughout the case. If nerve palsy was present before surgery, the nerve is transposed anteriorly in the subcutaneous plane. If necessary, the flexor–pronator origin, which may be disrupted, is identified and tagged for later repair. The medial collateral ligament (MCL) is typically disrupted and can be tagged for repair. If it is torn, the coronoid can be found by reflecting the flexor–pronator mass; if it is intact, the coronoid can be found by splitting the flexor–pronator mass. If it is large enough, the base of the coronoid fragment may contain the insertion of the MCL. The coronoid can then be repaired under direct vision if it has been impossible to fix from the lateral side.

Radial Head

The radial head is carefully evaluated, and dissection is carried distally to visualize the entire fracture site. If there is an associated radial neck fracture, the posterior interosseous nerve is in close proximity and should be explored and protected throughout the case. It can be found proximally between the brachialis and the brachioradialis and traced distally. Keeping the forearm pronated helps maximize the distance between the nerve and the operative field. After fixation or replacement of the radial head, the posterior interosseous nerve should be checked before closure. One must be very careful when placing any retractors around the radial head or neck; they should be placed right on the bone as straying into the soft tissues may injure the adjacent nerve.

Even though resection of radial head fragments generally is not recommended alone, it is occasionally possible to remove small peripheral fragments that comprise 25% or less of the head with good results. The main goal of managing the radial head fracture in the patient with the "terrible triad" is to restore elbow stability and allow early motion.[15,16] Thus, the surgeon must ensure that resecting this fragment does not affect the stability of the elbow joint (Fig. 3). If it does, then a different approach is required.

Our primary goal is to internally fix the radial head/neck fracture in these cases. However, this is not always possible. Fixation must be secure enough to allow early motion and not interfere with the proximal radioulnar joint. What may appear to be a very simple fracture pattern on radiographs may in fact be significantly more complex than anticipated. It should be remembered that most series of radial head fracture fixation report that in approximately 20%–40% of cases in which fixation was planned, unanticipated comminution or other difficulty resulted in some other method (i.e., replacement) being

FIG. 3. This female patient had a "terrible triad" type of elbow injury and was treated by joint debridement and radial head excision. This anteroposterior radiograph taken after surgery reveals early instability with medial subluxation of the joint. We believe that radial head excision alone (without replacement) is suboptimal in this situation.

used. In our practice, the most common reasons for proceeding to replacement arthroplasty include fracture comminution (often with severe cartilagenous damage), associated radial head and neck fractures, osteoporosis, or previous radial head resection by another surgeon.[17]

Fractures of the radial head that are repairable are managed in a similar fashion to the management of other fractures. The fracture site is cleaned and debrided of any debris. Typically, there is very little if any soft-tissue attachment to the fracture fragment. Despite this fact, avascular necrosis is rare if stable fixation is achieved and bony union occurs.[18] A fragment is provisionally fixed with either a Kirschner wire or fracture clamp. Our implant of choice for these fractures is the Herbert screw; its small diameter and contersunk head are attractive features in this area. Screws inserted in the "nonarticular" portion of the circumference of the radial head (the so-called "safe zone") can be left proud if necessary. This is the portion that does not articulate with the proximal ulna. This can be determined intraoperatively by direct inspection by rotating the forearm after radial head fixation occurs. This area is the same as the arc subtended by perpendicular lines drawn through the radial styloid and Lister's tubercle.

If there is an associated radial neck fracture, than this can be fixed with a mini-fragment "T" or buttress plate. Again, it is important to place this plate along the circumference of the radial head that does not articulate with the proximal ulna to maximize motion after surgery. Anatomic reduction of the neck fracture is critical; If there is an angulatory deformity after fixation, it can cause a "cam" effect, and the radial head rotates through a much greater arc in an eccentric fashion, severely limiting forearm rotation.[19] If the neck fracture is fixed in a shortened position, then instability may result (Fig. 4).

The decision to proceed to radial head replacement is an individual one based on the operating surgeon's ability to restore stability to the radial head. If this is not possible, we believe that excision of the head alone is contraindicated in the setting of the "terrible triad." The radial head is an important structure that resists posterior displacement of the elbow and is critical to valgus stability if the MCL is torn.[20–22] The authors have seen numerous cases of early and recurrent instability in patients with this injury pattern who have had injudicious radial head excision.

Older silastic or rubber implants had poor biomechanic characteristics and, over the long term, produced wear debris. We prefer metallic radial head arthroplasty. The recent introduction of modular radial head implants has improved the ability to accurately restore the dimensions of the proximal radius, allowing independent adjustment of head diameter and height and stem size. The head size is determined by piecing together the bony

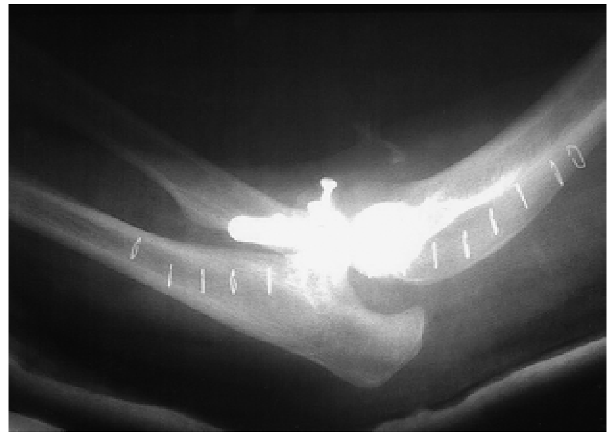

FIG. 4. This patient experienced bilateral "terrible triad" injuries in a fall off of a building. The lateral radiograph taken before surgery of the right elbow reveals posterior subluxation of the joint. The treating surgeon fixed the complex radial head/neck fracture in a shortened position and did not repair the lateral soft-tissue structures. It is this revision situation that an articulated hinge fixator is most useful.

fragments to ascertain radial head diameter. This step also serves to confirm that all fragments have been removed from the joint. Trial reductions are then performed to choose the radial head height, diameter, and stem size. It has been our experience that the correct height of the prosthesis is critical to restoring stability, in terms of anteroposterior and valgus stress. The height of the head used will also depend on the level of the resection line on the radial neck; a lower neck cut (due to the position of the fracture) will require a thicker radial head.[20,21]

Coronoid Process

The fixation of the coronoid fracture is typically the most-demanding technical aspect of the case and depends on the size of the fragment and associated injuries. Because it is the "deepest" structure, especially if the approach has been from the lateral side, it is dealt with first so that there is a sequential repair from deep to superficial.

In terms of approach, there are essentially two methods that can be used to visualize and fix the coronoid. Through the lateral approach described previously, it is typically possible to see the coronoid. Useful maneuvers to improve exposure include placing a retractor over the medial side of the distal humerus and extending the incision distally. If there has been a fracture of the radial head, then working through the defect will improve exposure. If the radial head requires excision, then the excision dramatically improves the visualization of the coronoid and augments fixation.

If inadequate exposure of the coronoid is seen from the lateral side, then a separate medial approach can be used. It is important to remember that there is typically a significant amount of soft-tissue damage medially (MCL, flexor–pronator origin, etc.), and surgical dissection may need to be adjusted to take advantage of preexisting exposure, rather than rigidly adhering to conventional approaches. The ulnar nerve is identified and protected. We do not routinely transpose the nerve unless there is a nerve palsy or injury that occurs before surgery, in which case an anterior transposition is performed. Reflecting or splitting the flexor–pronator mass finds the coronoid. The MCL can also be identified in this fashion. The coronoid can then be reduced and fixed under direct vision. Soft-tissue repair is important upon closure. We use interrupted #1 nonabsorbable sutures for the capsule and ligament and absorbable suture for the flexor–pronator origin.

If the coronoid fracture is part of a more complex proximal ulnar fracture pattern, then it is important to fix the fracture fragments in correct sequence. If the "main" transverse proximal ulnar fracture is fixed first, then access to the coronoid fragment is lost. The coronoid fragment is reduced (usually to the distal shaft) and provisionally fixed with lag screws or Kirschner wires, and then the main fracture is reduced. A posterior plate contoured around the proximal ulna is applied. The coronoid fragment fixation can then be augmented with screws placed through the plate if necessary.

Type I coronoid fractures are too small to provide any significant increase in stability through fixation and are routinely debrided, especially if they are free within the joint. However, there is often a significant degree of soft-tissue injury present in the anterior capsule, and the anterior capsule is stripped off of the remaining intact coronoid. In this situation, suture repair of the anterior capsule through drill holes in the proximal ulna can significantly increase stability. This is performed by placing a large #2 nonabsorbable suture through the anterior capsule at the site of detachment. The depth of the suture pass is sufficient to gain purchase in the capsule, but not deep enough to pierce the brachialis muscle and overlying neurovascular structures. This suture is then passed through drill holes in the ulna. Correct position of the drill holes can be confirmed by direct visualization through the anterior aspect of the joint. Use of an eyed straight needle allows the suture placed in the anterior capsule to be pulled through the ulna where it can be tied over the posterior surface of the ulna through a separate small incision. This is done after managing the radial head fracture, because it can limit exposure.

Type II and III coronoid fractures are larger fragments than the fragments that can contribute significantly to stability (especially anteroposterior) when fixed.[7,23] The type III fracture is also important in that it may contain the insertion of the MCL at its base. Our preferred method of fixation for these fractures is to reduce them and hold the reduction with a dental pick's manual pressure, or, if possible, a fracture-reduction clamp. The fragment is then temporarily fixed with guide wires from a small-fragment cannulated screw set (Fig. 5). These wires are inserted through stab incisions on the posterior border of the ulna, and their exit from the coronoid fragment can be seen under direct vision. One and preferably two screws are then inserted over these guide wires as definitive fixation. We use partially threaded screws so that compression is obtained at the fracture site. Care must be taken not to leave these screws proud or they will impinge in the coronoid fossa during elbow flexion. Alternatively, it may be possible to fix the coronoid directly with screws inserted from the lateral aspect of the fragment into the proximal ulna; this is usually possible if the radial head has been resected as there is improved access in this situation.

If there is comminution of this fragment that makes screw fixation impossible, then a tension-band technique similar to the technique that is used for the anterior capsule in type I fractures, is used. Rather than wire, a #5 nonabsorbable suture is used. This material is easier to manipulate than wire.

Lateral Soft-Tissue Repair

The lateral soft tissues are then evaluated. Usually the lateral ligamentous complex, specifically the lateral band of the ulnar collateral ligament, has avulsed off the distal humerus.[14] This tissue can be located and repaired back to the distal humerus using either suture anchors or drill holes in the lateral epicondyle using nonabsorbable sutures. Ligament reconstruction using an autogenous tendon graft is not necessary in the acute setting as the local tissues are generally of good quality. In the chronic or recurrent setting, reconstructive techniques can be used to gain rotational stability, although, we prefer to use a hinged fixator.

Articulated External Fixation

Elbow stability is then evaluated. With the forearm pronated the elbow is taken through a flexion–extension arc. The radial head capitellar articulation can be palpated beneath the lateral soft tissues. If the radial head tends to sublux posteriorly or if rotational instability of the ulna is present, then consideration must be given to the hinged external fixation. Likewise, if rotational instability is noted in supination with the elbow at 90° of flexion, then sufficient instability to preclude early active motion is present. Rarely does this degree of instability occur in the acute setting. We prefer to use the "Compass Elbow Hinge" (Smith & Nephew Inc., Germantown, WI,

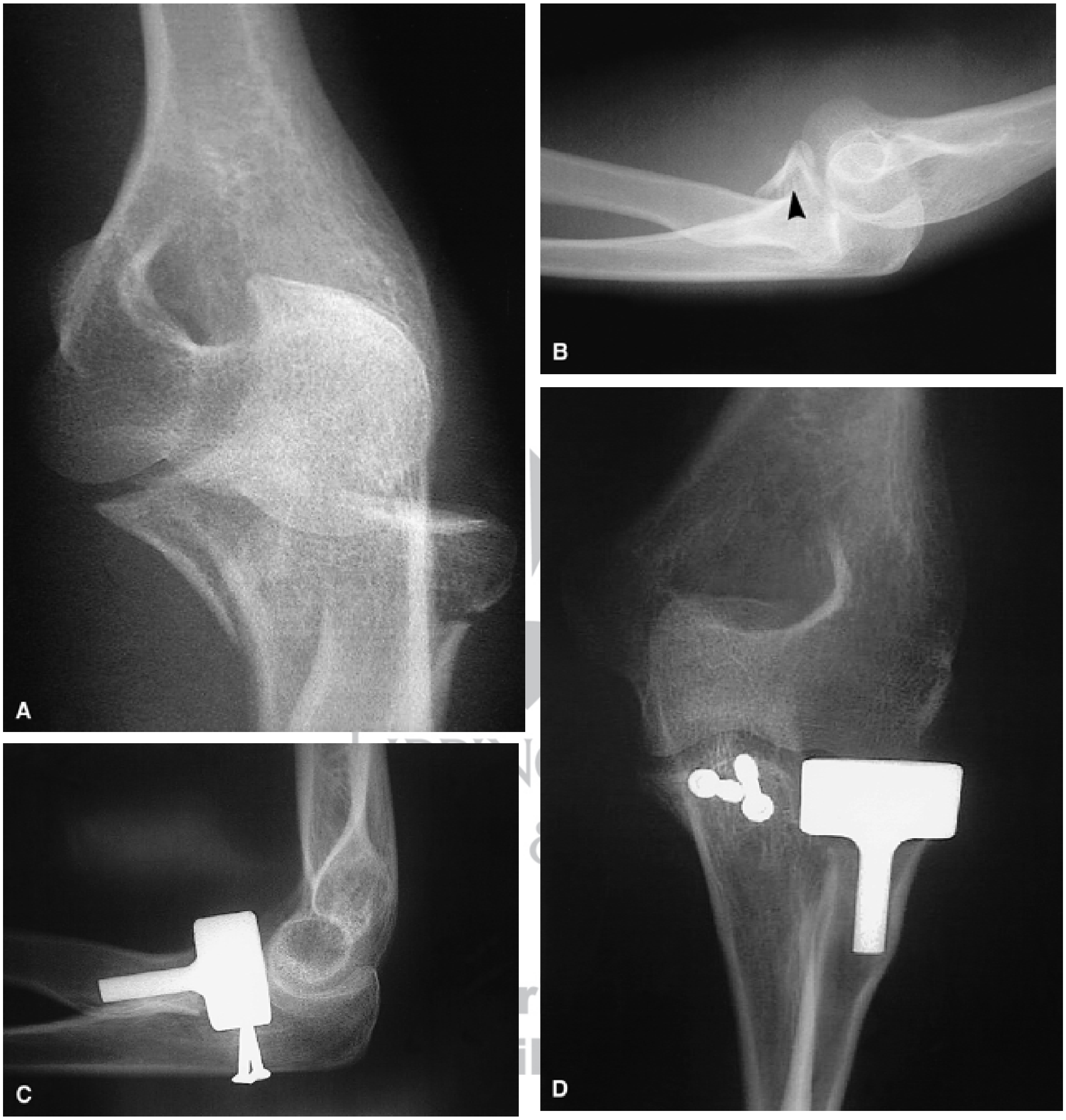

FIG. 5. Anteroposterior **(A)** and lateral **(B)** radiographs of a young female patient with a partially reduced posterior elbow dislocation, radial head/neck fractures, and coronoid fracture (arrow). The operative repair consisted of coronoid fracture fixation with two cannulated screws inserted from the posterior surface of the ulna and, after failed attempts at fixation, metallic radial head replacement. The lateral collateral ligament complex was avulsed from the distal humerus and was repaired to bone. Early motion was instituted 9 days after surgery. Follow-up radiographs **(C,D)** reveal concentric reduction of the joint with coronoid union. The patient had a Mayo Elbow Performance score of 95 at 1 year.

U.S.A.) to allow early motion and maintain a concentric reduction.[2,11]

The hinge is applied with the patient in a lateral decubitus position and the arm over a padded bolster. Fluoroscopy is very helpful to confirm instability and guide hinge application. The hinge is applied after open-joint reconstruction and management of the radial head, coronoid process, and lateral ligaments as previously outlined (see "Radial Heal," "Coronoid Process," and "Lateral Soft-Tissue Repair"). A 2.5-mm transfixion pin is placed through the center of the distal humerus' rotation and its position confirmed radiographically. With the joint anatomically reduced, another pin is placed through the olecranon to transfix the ulnohumeral articulation. The incision is then closed in standard fashion. The Compass Elbow Hinge (Smith & Nephew Inc.) is set up for the appropriate side and applied to the transcondylar pin. Two half pins are placed in the humerus with care taken to perform blunt dissection down to the bone to protect the radial nerve. Two additional half pins are placed in the ulna and the fixator secured. The presence of a congruous reduction is confirmed fluoroscopically.

REHABILITATION

Before closure, a careful examination of the elbow is performed so that the operating surgeon has a clear concept of the elbow's stability and instability positions. Wound closure is standard, and drains are not used. A well-padded posterior slab splint is applied. The arm is positioned at 90° of flexion with the forearm in full pronation; this is usually the most stable position and helps prevent posterolateral subluxation. The splint is removed, and supervised motion is begun 7–10 days after surgery. The position and time of immobilization may vary depending on the injury pattern, but what is described here applies to the majority of cases. The position of maximal instability is usually extension and full supination, and this position is avoided. For the first 6 weeks, we allow flexion and extension exercises to be done with the forearm in pronation, and we allow active forearm rotation exercises to be done with the elbow at 90° to protect the lateral soft-tissue repair. Unrestricted motion is then begun, and strengthening is initiated at 8 weeks. Flexion/extension splinting can be used in cases where return of motion is delayed. Return to regular occupation depends on the degree of physical activity required, and it typically takes 3 months for heavy physical laborers to return to work.

COMPLICATIONS

Complications are numerous after the treatment of patients with this complex injury. In the past, recurrent instability, prolonged immobilization, infection, and mal- or nonunion have contributed to the high incidence of unsatisfactory results.[3,4] The main goal of surgical intervention is to establish sufficient stability so early motion can be instituted. This maximizes functional outcome and range of motion. If an extensive open repair is performed and the elbow subsequently immobilized in flexion as a result of residual instability, a disabling flexion contracture will often result. We have found that a brief (7–10 day) period of immobilization can contribute to skin and soft-tissue healing and help reduce swelling. This is followed by the institution of a rehabilitation program as described above (see "Rehabilitation").

A typical patient treated with the surgical methods described above rarely has a "normal" range of motion, but a mean arc of flexion–extension of 115° and forearm rotation of 135° can be reasonably expected, on average, in a series of such individuals. If severe stiffness results in a nonfunctional range of motion, delayed elbow release is usually successful if concentric joint stability has been maintained.

Recurrent instability is managed with the application of a hinged external fixator, rather than prolonged immobilization in a position of extreme flexion.[2,11] Even with optimal surgical techniques, fracture comminution, poor-quality soft-tissue structures (especially after failed previous attempts at surgical repair), or patient noncompliance may precipitate this complication. The complication is typically diagnosed on the lateral radiograph that is taken after surgery, as posterior subluxation of the radial head and/or widening of the ulnohumeral joint space are observed. It is very difficult to maintain motion with the joint's nonconcentric reduction. If not managed promptly, stiffness and pain will result, and, as a result of abnormal load distribution, rapid articular cartilage wear and early osteoarthritis can occur. Occasionally, recurrent posterolateral rotatory instability develops as a late consequence of this injury.[6] Instability can be managed in the standard fashion with ligament reconstruction if it is symptomatic.

Radial head nonunion or malunion can occur if radial head fixation has been chosen as the initial treatment of patients with radial head fracture and manifests itself as laterally-based elbow pain and stiffness in rotation.[15] Unless the articular cartilage and anatomy of the radial head are near normal (a rare occurrence), we typically manage this complication with radial head excision and insert a metallic prosthesis. This is done out of concern for recurrence of instability, especially proximal migration of the radius and posterior subluxation of the elbow. At the present time, there is a paucity of reliable information regarding when sufficient (soft-tissue) healing has occurred to allow radial head excision alone in this situation, and we have seen cases of forearm and elbow instability after late radial head excision. For this reason, we are aggressive in using a replacement arthroplasty after excision.

Suprisingly, clinically significant heterotopic ossification is relatively uncommon after this injury, especially if the patient's primary treatment is successful. Whereas ossification or calcification of the medial and lateral ligament complexes is often seen, heterotopic ossification alone is sufficient to restrict motion and is usually seen in patients with concomitant head injury, or those who have failed initial surgical treatment. We reserve the use of indomethacin for such patients.

Infection is uncommon, but may occur especially after revision surgery. If the infection is superficial, parenteral antibiotics are usually sufficient, but if the joint is involved, then prompt irrigation and debridement are indicated. The principles of surgical infection are followed, and loose hardware is removed while rigid fixation is maintained. It is usually possible to retain radial head implants if prompt and thorough lavage of the joint is performed, and systemic antibiotics are administered.

RESULTS

It is rarely possible to provide the patient with a completely normal elbow after the "terrible triad" injury pattern.[8] However, with modern knowledge of injury patterns and improved fracture-fixation methods, reasonable, if not perfect, results can be anticipated. Our own experience with this injury would suggest the mean arc of flexion extension to be from 20°–135° (115° arc) with forearm rotation averaging 135°. This corresponds to a good–excellent rating (as measured by the Mayo Elbow Performance Index [1]) in approximately 80% of patients. Delayed treatment of patients with the injury or requirement for revision surgery results in a relative loss of motion of approximately 20% as compared with the acutely treated patients. Reoperation is required in 15%–25% of patients, usually for stiffness, recurrent instability, or late hardware removal.

REFERENCES

1. Broberg MA, Morrey BF. Results of treatment of fracture-dislocations of the elbow. *Clin Orthop* 1987;216:109–19.
2. Cobb TK, Morrey BF. Use of distraction arthroplasty in unstable fracture dislocations of the elbow. *Clin Orthop* 1995;312:201–10.
3. Heim U. Combined fractures of the radius and the ulna at the elbow level in the adult: analysis of 120 cases after more than 1 year. *Rev Chir Orthop Reparatrice Appar Mot* 1998;842:142–53.
4. Hotchkiss RN. Fractures and dislocations of the elbow. In: Rockwood CA, Green DP, Bucholz RW, Heckman JD, eds. *Rockwood and Green's Fractures in Adults*, 4th ed., vol. 1. Philadelphia: Lippincott-Raven, 1996:929–1024.
5. Josefsson PO, Gentz CF, Johnell O, et al. Dislocations of the elbow and intraarticular fractures. *Clin Orthop* 1989; 246:126–30.
6. O'Driscoll SW, Jupiter JB, King GJW, et al. The unstable elbow. *J Bone Joint Surg [Am]* 2000;82:724–38.
7. Regan W, Morrey B. Fractures of the coronoid process of the ulna. *J Bone Joint Surg [Am]* 1989;719:1348–54.
8. Amis AA, Miller JH. The mechanisms of elbow fractures: an investigation using impact tests *in vitro*. *Injury* 1995; 26:163–8.
9. Neill Cage DJ, Abrams RA, Callahan JJ, et al. Soft tissue attachments of the ulnar coronoid process: an anatomic study with radiographic correlation. *Clin Orthop* 1995; 320:154–8.
10. Terada N, Yamada H, Seki T, et al. The importance of reducing small fractures of the coronoid process in the treatment of unstable elbow dislocation. *J Shoulder Elbow Surg* 2000;9:344–6.
11. McKee MD, Bowden SH, King GJ, et al. Management of recurrent, complex instability of the elbow with a hinged external fixator. *J Bone Joint Surgery [Br]* 1998;80: 1031–6.
12. Josefsson PO, Johnell O, Wendeberg B. Ligamentous injuries in dislocations of the elbow joint. *Clin Orthop* 1987; 222:221–5.
13. O'Driscoll WW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. *J Bone Joint Surg [Am]* 1991; 73:440–6.
14. McKee MD, Sala M, Schemitsch EH. The pathoanatomy of lateral soft-tissue injury in complex elbow trauma. Presented at the 2nd Biennial Shoulder and Elbow Meeting, Miami FL, May 6, 2000.
15. Morrey BF. Radial head fracture. In: Morrey BF, ed. *The Elbow and Its Disorders*, 2nd ed. Philadelphia: W.B. Saunders, 1993:383–405.
16. Morrey BF, Chao EY, Hui FC. Biomechanical study of the elbow following excision of the radial head. *J Bone Joint Surg [Am]* 1979;61:63–8.
17. Sanchez–Sotelo J, Romanillos O, Garay EG. Results of acute excision of the radial head in elbow radial head fracture-dislocations. *J Orthop Trauma* 2000;14:354–8.
18. Frankle MA, Koval KJ, Sanders RW, et al. Radial head fractures associated with elbow dislocations treated by immediate stabilization and early motion. *J Shoulder Elbow Surg* 1999;8:355–60.
19. Schatzker J. Fractures of the radial head. In: Schatzker J, Tile M, eds. *The Rational Basis of Operative Fracture Care*. New York: Springer Verlag, 1987:97–101.
20. Harrington IJ, Sekyi–Otuu A, Barrington TW, et al. The functional outcome with metallic radial head implants in the treatment of unstable elbow fractures: a long-term review. *J Trauma* 2001;50:46–52.
21. Popovic N, Gillet Ph, Rodriguez A, et al. Fracture of the radial head with associated elbow dislocation: results of treatment using a floating radial head prosthesis. *J Orthop Trauma* 2000;14:171–7.
22. Ring D, Jupiter JB. Fracture-dislocation of the elbow. *J Bone Joint Surg [Am]* 1998;80:566–80.
23. Closkey RF, Goode JR, Kirschenbaum D, et al. The role of the coronoid process in elbow stability. *J Bone Joint Surg [Am]* 2000;82:1749–53.