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Radial head reconstruction versus replacement in the treatment of terrible triad injuries of the elbow

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Introduction: Dislocation of the elbow with associated fractures of the radial head and the coronoid process of the ulna have been referred to as the terrible triad of the elbow because of the difficulties in treating this injury and the poor outcomes.

Materials and methods: There were 23 patients (24 elbows) available for evaluation with this injury during a 7-year period at Auckland City Hospital.

Results: There were 11 women and 12 men with an average age of 43.5 years. The mean duration of follow-up was 41 months. The mean range of flexion was 135° (range, 110°-145°), extension was 8° (range, 0°-40°), supination was 75° (range, 15°-85°), and pronation was 80° (range, 20°-90°). No patients reported ongoing symptoms of instability. We compared the radial head repair group (13 patients) and the radial head replacement group (11 patients), which showed no significant difference between the variables of age, length of follow-up, American Shoulder and Elbow Surgeons score, satisfaction score, range of motion (flexion, extension, supination, pronation), and the associated arcs of motion. Only one significant difference was noted: the radial head replacement group scored higher values on the Disabilities of Arm, Shoulder, and Hand assessment.

Conclusions: Elbow fracture-dislocations are difficult injuries to treat. Our study shows that with operative repair or replacement of the radial head to restore stability through radiocapitellar contact, coronoid, and lateral ligament repair, good range of movement and stability can be achieved at short-term follow-up.

Level of evidence: Level III, Retrospective Case Control Design, Treatment Study.

Keywords: Elbow; terrible triad injuries; radial head repair; radial head replacement

Dislocations of the elbow with associated fractures of the radial head and the coronoid process of the ulna have been referred to as terrible triad injuries because of difficulties in treatment and poor reported outcomes (Fig. 1).[1,7,19] Treatment recommendations have varied from closed reduction and nonoperative management to surgical treatment using external fixation, open reduction and internal fixation, excision arthroplasty of the radial head, or radial head replacement.[8,19] An increased understanding of elbow biomechanics and the constraints that aid stability, as well as improvements in fixation options, has led to significant improvements in th treatment of this uncommon injury.[13] The application of systematic algorithms and standardized surgical protocols to treat this difficult injury pattern results in improved patient outcomes.[9,15,22]

The purpose of this study was to determine the clinical and radiologic outcomes of a consecutive group of patients with terrible triad injuries of the elbow treated at a single

This study was approved by the Northern Regional Ethics and Auckland City Hospital Ethics Committees.

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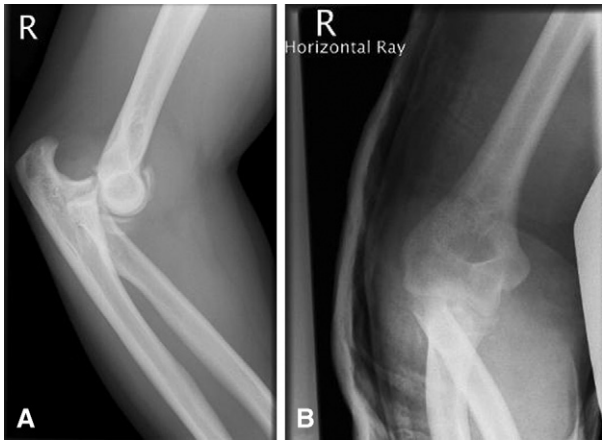

Figure 1 Lateral (**A**) and anteroposterior (**B**) radiographs show a terrible triad injury.

institution. In addition, by grouping patients into those treated with open reduction and internal fixation of the radial head or those treated with radial head arthroplasty, we were able to compare the outcomes of these 2 treatment options for addressing the radial head fracture.

Materials and methods

The Orthopaedic Database (Orthoscope) at Auckland City Hospital was used to identify all patients with dislocation of the ulnohumeral joint and fracture of both the head of the radius and the coronoid process of the ulna who were seen and treated during a 7-year period. Of 30 patients who were identified and invited for clinical and radiologic review, 6 had moved overseas and were lost to follow-up, and 1 patient declined to participate. This left 24 elbows in 23 patients who were available for evaluation.

All patients completed the Disability of Arm, Shoulder and Hand (DASH)[5] and the American Shoulder and Elbow Society (ASES)[17] assessments and underwent a standardized clinical and radiologic assessment of the involved elbow. Follow-up radiographs were compared with initial radiographs and those taken immediately after the definitive surgery.

Operative technique

All elbows in this study were treated using a surgical protocol based on restoring anatomy and providing stability to allow early movement. The elbow dislocation was initially reduced closed in the emergency department under conscious sedation or in the operating room under general anaesthesia. The limb was immobilized in a posterior plaster-of-paris cast, with definitive surgery occurring within 10 days. One compound fracture dislocation was treated with definitive surgery on the day of admission.

Operations in 18 patients were by or under the direct supervision of one of the primary authors involved in the study. The technique used for all patients was to repair the injured structures from deep to superficial, with the aim being to restore bony anatomy and soft tissue stability to allow early mobilization.

A direct lateral or a universal posterior skin incision was used in all patients. The typical operative finding was an avulsion of the lateral soft tissues deep to fascia, with disruption of the lateral collateral ligament from the lateral epicondyle. All coronoids were fixed. This was performed first, using screw fixation, sutures through drill holes tied over the dorsum of the olecranon, or suture anchors, depending on the type of fracture and size of the bony fragment.

The radial head fracture was then assessed and treated. Where possible, this was repaired using screws or a small proximal radial plate and screws, or both, if the radial neck was also involved in the fracture. If fixation was not possible, the radial head was replaced using an Avante (Avanta Orthopaedics, San Diego, CA, USA), or Evolve (Wright Medical Technology, Arlington, TX, USA) radial head replacement. The decision to repair or replace and the implant choice was according to surgeon preference. In general, however, the younger the patient, the greater the effort undertaken to repair the radial head.

Finally, the lateral ligament complex was repaired back to the isometric point at the lateral epicondyle. In patients early in the study, the ligament was repaired through drill holes in the epicondyle using heavy nonabsorbable suture. The ligament repair in patients later in the study was with suture anchors placed at the isometric point. The elbow was then examined under an image intensifier to confirm reduction and to assess stability through a range of motion. Stability was assessed in the plane of flexion and extension. As long as elbows were stable out to 45° flexion, no surgery was required on the medial side.

Postoperatively, the elbow was placed in a padded posterior plaster-of-paris cast with the arm at 70° of flexion and slight pronation to protect the lateral ligament repair. This cast was removed at 7 to 10 days to allow patients to begin a supervised rehabilitation protocol focusing primarily on early active and active assisted range of motion.

Our hypothesis was that patients with radial head replacement would have a poorer outcome. Statistical analysis was performed using a Mann-Whitney U test to evaluate the difference between groups. A level of $P < .05$ was considered significant.

Results

There were 11 women and 12 men, with an average age of 43.5 years (range, 19-67 years). There were 13 right and 11 left elbows. The dominant elbow was involved in 58%. The most frequent mechanism of injury was a fall from a height onto the outstretched arm. Follow-up was a mean duration of 40.6 months (range, 16-73 months).

Orthogonal radiographs at presentation were reviewed to assess the injury pattern. Coronoid fractures were categorized according to the Regan and Morrey classification,[19] comprising 14 type 1, 8 type 2, and 2 type 3 coronoid fractures. Radial head fractures were classified according to the Mason classification,[10] consisting of 3 type 1, 9 type 2, and 12 type 3 radial head fractures.

A direct lateral skin incision was used in 18 patients and a universal posterior skin incision was used in 6. A lateral approach to the elbow joint was then undertaken in all patients, usually through the injured lateral structures, and the interval between the anconeus and extensor carpi ulnaris was used. The radial head was repaired in 15 patients and

replaced in 9 (all cases where the radial head was deemed unrepairable). There were no radial head excisions. We believe that the radial head is important as a secondary stabilizer when the collateral ligament is disrupted and prevents proximal radial head migration.

Of those in the radial head repair group, a symptomatic nonunion of the radial neck developed in 2 elbows, which were subsequently revised to a radial head replacement. The elbows were included in the radial head replacement group to allow comparison of the outcome of radial head replacement or radial head repair at final follow-up. Two elbows required an additional medial incision. In 1 patient, a compound fracture wound extended through to the medial side of the joint and was explored to allow adequate debridement. In another patient, a piece of the fractured radial head had ''button-holed'' through the anteromedial soft tissues and was removed through a small medial incision. No patient required medial collateral ligament repair or the application of a dynamic external fixator.

The mean outcomes for ranges of motion were flexion, 135° (range, 110°-145°); extension, 8° (range, 0°-40°); supination, 75° (range, 15°-85°); and pronation, 80° (range, 20°-90°). No patients reported ongoing symptoms of instability.

When differences between the radial head repair group (Fig. 2) and the radial head replacement group (Fig. 3) were compared, the data analyzed with the Mann-Whitney *U* test ($P < .05$) showed no significant difference between the variables of age, length of follow-up, ASES score, satisfaction score, range of motion (flexion, extension, supination, pronation), and the associated arcs of motion. There was, however, a significant difference in the DASH scores, with a score of 10.3 in the radial head replacement group vs 9.16 in the repair group (Table I).

There was a definite trend toward a better final range of motion (especially supination/pronation arc) and better ASES scores in the radial head replacement group, but with the numbers available, this did not reach statistical significance.

Radiographs

At final follow-up, all coronoid and radial head fractures treated with open reduction and internal fixation showed evidence of bony union. Two patients in the radial head repair group developed a symptomatic nonunion of the radial neck fracture and were subsequently revised to a radial head replacement. All 24 elbows maintained a concentric reduction of both the ulnotrochlear and radiocapitellar articulations. Two patients had a small amount of heterotopic ossification around the elbow but neither had significant impairment in their range of motion. There were radiolucent lines around 2 uncemented radial head replacements. This has previously been reported and does not appear to affect outcome.[9] There was no subsidence of the radial head implants or evidence of significant capitellar bone loss.

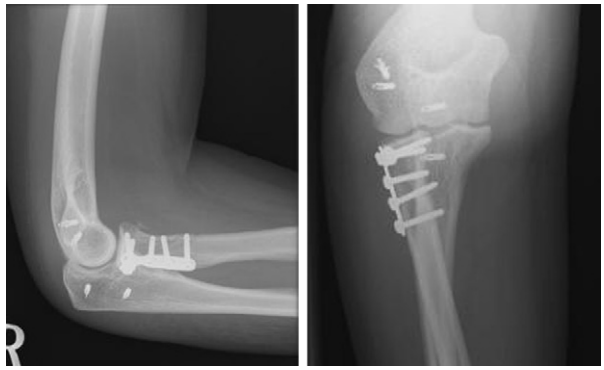

Figure 2 (**A**) Lateral and (**B**) anteroposterior radiographs show an elbow from the repair group. Two additional anchors have been used in the ulna insertion of the ulnar collateral ligament.

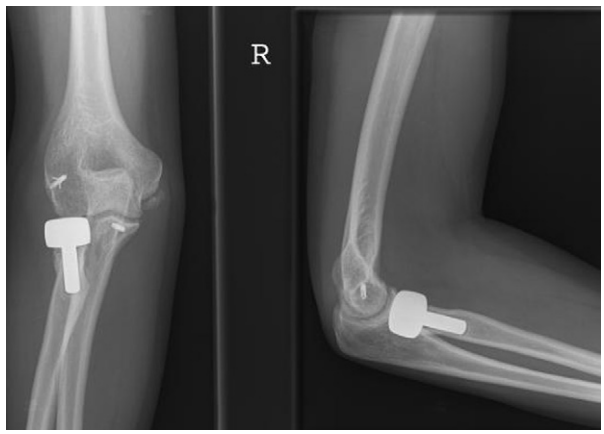

Figure 3 (**A**) Anteroposterior and (**B**) lateral radiographs show an elbow from the from the replacement group.

Complications

There were 7 complications in 6 patients that required repeat surgery (29%). Two patients developed a symptomatic nonunion of a repaired radial head and neck fracture and underwent revision to a radial head replacement. One patient presented at final follow-up with radiographic evidence of migration of a threaded Kirschner wire used for radial head fixation. Although entirely asymptomatic, after discussion with the patient, it was decided to remove the Kirschner wire.

One patient, who had undergone coronoid repair and radial head replacement, but did not initially have a formal repair of the lateral collateral ligament complex, had persistent joint subluxation on postoperative radiographs. This patient subsequently underwent revision surgery by one of the senior authors with repair of the lateral collateral ligament complex and downsizing of the radial head implant. The same patient developed a deep infection that required a repeat surgical washout and antibiotic treatment. The radial head was retained and the infection was cleared. At final follow-up, there were no long-term sequelae and the patient regained an excellent range of motion.

Table I Characteristics of patients in repair and replacement groups

Variables*	Repair group (n = 13)	Replacement group (n = 11)
Sex		
Male	6	6
Female	7	5
Age, years	42.2 (29-56)	45.5 (19-67)
Follow-up, months	40.5 (16-73)	40.7 (17-73)
Side		
Right	8	6
Left	5	5
DASH score	9.16 (0-18.3)	10.83 (6.7-37.9)
ASES score (max, 100)	81 (41-100)	89 (69-100)
Satisfaction score	8 (7-10)	9 (5-10)
Range of motion,°		
Flexion	135 (110-145)	135 (125-140)
Extension	15 (0-40)	5 (0-20)
Flexion/extension arc	115 (70-140)	128 (110-135)
Pronation	70 (20-90)	80 (40-90)
Supination	75 (15-85)	75 (50-85)
Pronation/supination arc	120 (35-175)	150 (100-175)

ASES, American Shoulder and Elbow Surgeons; *DASH,* Disabilities of the Arm, Shoulder and Hand.
* Categoric variables are shown as numbers and continuous variables are shown as mean (range).

Two patients who had undergone radial head repair were unable to regain a functional range of motion despite prolonged and intensive rehabilitation for at least 6 months postoperatively. Both were managed with revision open surgery with metalware removal and a circumferential capsular release. At final follow-up both patients had regained a satisfactory range of motion.

Discussion

The elbow is one of the most congruous joints in the body, with normal stability provided by a complex interaction between the articular surfaces and soft tissue constraints. Most elbow dislocations do not have an associated fracture, but problems can arise when one or more of the articular supporting structures are disrupted.[19] With articular disruption, surgical treatment is usually required for recurrent instability, and the risk of subsequent arthrosis is substantial.[13,15]

The early literature regarding the outcome of patients after surgical management of fracture dislocation of the elbow is limited by small patient numbers, short-term follow-up, and high complication rates.[3,14,15,16,18] Until recently, few published studies have specifically addressed the terrible triad injury pattern. As our understanding of the functional anatomy of the elbow and how this relates to stability and the pathomechanics of elbow injuries has improved, the results of surgical management of these injuries have become more predictable. This is reflected in the recent literature, which has shown an increasingly positive outcome for this particular injury pattern.[3,11,15]

In 2004, Pugh et al[15] reviewed 36 consecutive patients undergoing a standard surgical protocol that included fixation or replacement of the radial head, fixation of the coronoid fracture, repair of associated capsular and ligamentous injuries, and in selected cases, repair of the medial collateral ligament or adjuvant hinged external fixation, or both.[15] At an average of 34 months, they reported 15 excellent results, 13 good results, 7 fair results, and 1 poor result. Concentric stability was restored in 34 elbows. The mean arc of flexion-extension was 112° ± 11°, and the mean arc of forearm rotation was 136° ± 16°. They felt that the surgical protocol described resulted in improved outcomes compared with those previously published. The authors only proceed to the medial side for ligament repair if instability persists after the other structures have been addressed. Other authors have supported this approach.[20] No patient in our series required repair of the medial collateral ligament or the application of a hinged external fixator to maintain stability.

This is in contrast to a 2008 report from Zeiders and Patel[22] of 32 patients with elbow fracture dislocations, in which 6 patients had an intact radial head, 7 radial heads were repaired, and 19 radial heads were replaced. A lateral ligament repair alone was undertaken in 18 patients, a medial ligament repair alone in 2, and a combined repair of both medial and lateral ligaments in 12. Twenty-one elbows had protection in a hinged external fixator. At a mean follow-up of 3 years, all elbows were reported to have a functional arc of motion. The average DASH score was 23 (range, 19-28). No comment was made regarding complications associated with the use of the external fixator. Previous

authors have pointed out that this is a specialized technique with a high complication rate and that successful primary management is greatly preferable.[2,12]

Lindenhovius et al[9] in the same year reported acute vs subacute management of terrible triad injuries. Of their 29 patients, 16 were included in the acute treatment cohort and 13 in the subacute (greater than 3 weeks since injury) treatment cohort. All patients were managed with a standard surgical protocol addressing all aspects of the terrible triad injury, with the addition of a hinged external fixator in the subacute group to protect stability. Patients treated in the acute group had a significantly better flexion arc than those treated in the subacute group (119° vs 110°; $P < .05$). Irrespective of the timing of surgery, all patients had high Broberg and Morrey scores (90 and 87, respectively) reflecting low average pain scores and successful restoration of strength and stability.[1] At an average follow-up of 29 months in the acute group and 34 months in the subacute group, 21 of 32 patients were noted to have arthrosis on plain radiographs, more than has been noted at similar time points in other studies.[12,15]

The results of the present study also demonstrate that reliable outcomes are possible after treatment of terrible triad injury patterns by using a surgical protocol and addressing all aspects of the injury. The combination of bone and soft tissue damage makes for a difficult reconstruction. Surgical treatment to restore the bony anatomy (by repair of the coronoid and repair or replacement of the radial head) and repair of the lateral collateral ligament allowed for a stable joint with functional range of motion in most patients, with an average range of motion arc of 115° in the radial head repair group and 128° in the radial head replacement group.

In contrast with previous studies, no patient in our series required repair of the medial collateral ligament or placement of a hinged external fixator to obtain stability. However, stability must be ensured before the patient leaves the operating room. When replacing the radial head with modular implants, head size is determined by sizing the removed head fragments (with a slight undersizing being preferable). Neck length is determined by the lesser sigmoid notch and ensuring that the implanted head does not project proximal to the level of the lesser sigmoid articulation when the joint is reduced. Head height in some implants is linked to diameter, so one needs to be aware of this, and with larger heads, more neck needs to be removed to ensure that the joint is not overstuffed. Once stable surgical repair is obtained, an early, supervised rehabilitation program can be instituted to decrease the incidence of elbow stiffness.

A further aim of the present study was to assess any difference in outcome between patients whose radial head fracture was repaired and those who required radial head replacement. The different treatment groups were similar in all other variables. There was a significant difference in the DASH scores, with the radial head replacement group scoring 10.83 vs 9.16 in the radial head repair group ($P < .05$). Although significant, this small difference may not be clinically relevant. With the numbers available, other variables in outcome between the 2 different treatment groups did not reach statistical significance. However, there was a definite trend toward the radial head replacement group having a better final arc of motion (especially in pronation/supination) and improvement in ASES scores. Complications were also more common in the radial head repair group and the reoperation rate was higher, with 5 complications in 5 patients (33%) requiring revision surgery.

In patients with comminuted radial head fractures involving 3 or more fragments, the experience with open reduction and internal fixation has been less favorable.[21] Insecure fixation should be avoided because this will result in a high incidence of early failure due to the stresses across the radial head during the postoperative period. In the setting of an elbow dislocation, the stresses across the radial head and neck fixation are greater, making metallic radial head arthroplasty a more reliable option in these patients.[4] Use of a modular prosthesis is preferable because it allows modification of head and stem diameters and heights to ensure optimal fit.

Even with concentric reduction and stable fixation allowing early mobilization, stiffness can develop in these patients. In the current series, 2 patients (8.3%) in the radial head repair group required revision surgery to regain a functional range of motion. Postoperative loss of forearm rotation due to scarring is not uncommon after plate fixation for radial head and neck fractures, even when these are placed in the nonarticular area of the radial head.[6] Of note, the 2 patients in this series with radial neck nonunions were successfully revised to a radial head replacement. This suggests that there is a satisfactory ''fall-back'' operation available for those patients with comminuted fractures of the radial head and neck where repair is originally attempted but subsequently fails. Further outcome studies are required to determine whether the presence of a metallic radial head replacement in the long-term will see deterioration in patient outcome scores and the need for revision surgery.

Conclusion

Terrible triad injuries remain a difficult injury to treat. Appreciating the bony and soft tissue pathology involved in the injury allows appropriate surgical planning. The importance of a systematic approach addressing the bony and soft tissue components of this injury pattern is now well recognized. Satisfactory results can be achieved in most patients, and the injury rarely requires medial incisions or the application of a hinged external fixator. Our study confirms that comparable results can be obtained with repair or replacement of the radial head in this injury pattern in

the short-term. Hence, we still prefer to try to repair the native radial head, especially in younger patients, even though the complication and reoperation rate is higher than when radial head replacement is undertaken at the primary surgery. The long-term outcome for this injury is not yet known.

Disclaimer

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