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SYMPOSIUM: TRAUMATIC ELBOW INSTABILITY AND ITS SEQUELAE

Fixation Versus Replacement of Radial Head in Terrible Triad

Is There a Difference in Elbow Stability and Prognosis?

Tyler Steven Watters MD, Grant E. Garrigues MD, David Ring MD, PhD, David S. Ruch MD

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Abstract

Background Surgical treatment for terrible triad injuries of the elbow (defined as elbow dislocations with concomitant fractures of the radial head and coronoid) remains a challenging clinical problem. Specifically, the question of whether to repair or replace the radial head remains controversial.

Questions/purposes We compared patients with terrible triad injuries of the elbow whose radial head fracture was treated with either internal fixation and internal fixation (ORIF) or radial head arthroplasty in terms of (1) clinical outcome measures (DASH and Broberg-Morrey scores, ROM), (2) elbow stability and radiographic signs of arthrosis, and (3) complications and reoperation rates.

Methods Retrospective review identified 39 patients with terrible triad injuries and minimum 18-month complete clinical and radiographic followup (mean, 24 months; range, 18–53 months). Patients were managed with a standard algorithm consisting of (1) repair (n = 9) or replacement (n = 30) of the radial head, (2) repair of the lateral ulnar collateral ligament, and (3) repair of the coronoid fracture. During the study period, the radial head generally was internally fixed when there were fewer than four articular fragments; otherwise, it was replaced. Evaluation included the DASH score, the Broberg-Morrey index, measurements of elbow stability and motion, and radiographic assessment for signs of arthrosis; chart review was performed for complications and reoperations. Complete followup was available on 87% (39 of 45 patients).

Results There were no differences between groups in terms of ROM or elbow scores. All patients who underwent radial head arthroplasty at the index procedure had a stable elbow at final followup whereas three of nine patients who underwent ORIF were unstable (p = 0.009). However, 11 patients who underwent arthroplasty demonstrated radiographic signs of arthrosis compared to none in the ORIF group (p = 0.04). Eleven patients (28%) underwent reoperation (seven arthroplasty, four ORIF) for various reasons. With the numbers available, there was no difference in reoperation rate between groups (p = 0.45).

Conclusions For terrible triad injuries, radial head arthroplasty afforded the ability to obtain elbow stability with comparable overall outcomes when compared to ORIF. As these injuries commonly occur in younger patients, longer-term studies will be required to ascertain whether the apparent benefits of radial head arthroplasty are offset by late complications of arthroplasty, such as loosening.

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This work was performed at Duke University Medical Center, Durham, NC, USA.

T. S. Watters (✉), G. E. Garrigues, D. S. Ruch
Department of Orthopaedic Surgery, Duke University Medical Center, DUMC 3000, Durham, NC 27710, USA
e-mail: tyler.watters@dm.duke.edu

D. Ring
Department of Orthopaedic Surgery, Massachusetts General Hospital, Boston, MA, USA

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Introduction

Termed the "terrible triad" by Hotchkiss [9], fracture-dislocations of the elbow traditionally involve three anatomic injuries: coronoid fracture, radial head fracture, and posterior elbow dislocation. This pattern has been well documented in the literature [17, 18]. The loss of the anterior buttress of the coronoid, the valgus buttress of the radial head, and the posterolateral stabilization of the lateral ulnar collateral ligament (LUCL) results in an unstable elbow.

Several recent studies [4, 5, 19, 24] that applied algorithmic approaches to managing each individual injury in the triad have demonstrated more promising results than historical studies [11, 20, 21] that previously documented high rates of persistent pain, posttraumatic arthrosis, contractures, instability, and functional limitations after treatment. These surgical protocols recommend various fixation techniques for each of the three critical aspects of terrible triad pathoanatomy. The radial head fractures were variously addressed with arthroplasty, open reduction and internal fixation (ORIF) with screws, ORIF with site-specific plates, or excision. Previous work by one of us [22] has analyzed the results of ORIF versus arthroplasty in patients with isolated radial head fractures, but in the setting of a terrible triad injury, this question remains unanswered.

We therefore compared patients with terrible triad injuries of the elbow whose radial head fracture was treated with either ORIF or radial head arthroplasty in terms of (1) clinical outcome measures (DASH and Broberg-Morrey scores, ROM), (2) elbow stability and radiographic evidence of arthrosis, and (3) complications and reoperation rates.

Patients and Methods

Study Design

Retrospective chart review was performed at three tertiary referral centers. A perioperative current procedural terminology code database was used to identify patients treated for terrible triad injuries by the two senior authors (DR, DSR) between 1996 and 2008. A subset of the study sample used for this research has been previously presented in other contexts [3, 5, 7]. In the current study, we had a multicenter cohort to broaden the patient sample and evaluate the management of terrible triad injuries in a different context. Patients were treated with a standard surgical algorithm consistent with previously published reports [4, 5, 19, 24]. Briefly, for the radial head fracture component of the triad, the radial head was internally fixed when there were fewer than four articular fragments without traumatic delamination of the articular cartilage and no comminution of the radial neck. In patients not meeting these criteria, the radial head was replaced. Patient charts and radiographs were reviewed to assess details of initial injury, radial head fracture management (ORIF versus arthroplasty), stability intraoperatively and postoperatively, radiographic signs of arthrosis using the scale of Knirk and Jupiter [12], joint incongruency, complications, reoperations, and ROM. At the 18-month visit, prospectively gathered patient response data were used to calculate DASH scores and Broberg-Morrey indexes. Stability was assessed at 18-month followup as a congruent joint on radiographs and absence of dislocation or subluxation events. Patients with open fractures, patients younger than 18 years, and prisoners were excluded. Patients referred after failed closed treatment at other institutions were included.

Study Population

During the study period, 45 patients were treated for terrible triad fracture-dislocations of the elbow at the participating centers in this study. Of those, six (four arthroplasty, two ORIF) were lost to followup before 18 months, leaving 39 patients (87%) with complete followup data (Table 1). There was no differential loss to followup between groups. Mean postoperative followup was 24 months (range, 18–53 months). Twenty-one (54%) were male and 18 (46%) were female. Eleven patients were referred to us after failing initial nonoperative treatment at other institutions. The average age was 48 years (range, 22–76 years). Thirty-four (87%) patients were right-handed. Fifty percent of the injuries occurred on the left and 50% on the right. The majority of patients sustained injuries from a fall, 24 from a standing height (62%) and 14 from more than 6 feet (1.8 m) (36%), with one secondary to motor vehicle trauma. Due to the dislocation, all radial head fractures were Type IV according to the Mason-Johnston classification [10]; otherwise, there were zero Type I, 23 of 39 (59%) Type II, and 16 of 39 (41%) Type III [14]. Nearly all of the coronoid fractures (36 of 39) were classified as Regan-Morrey Type II (a single or comminuted fragment that involves more that just the tip but $< 50\%$ of the coronoid height) [20].

Surgical Technique

The operative technique was similar to that described by Pugh and McKee [15, 19]. Patients were positioned supine with a tourniquet on the proximal arm. A hand table and a

Table 1. Study population demographics and outcomes

Variable	Value
Demographics	
Age (years)*	48 (22–76)
Number of patients	
Total	39
Male	21 (54%)
Female	18 (46%)
Radial head treatment (number of patients)	
ORIF	9 (23%)
Arthroplasty	30 (77%)
Outcomes	
Arc of motion (°)*	115 (75–140)
DASH (points)*	16 (0–43)
Broberg-Morrey index*	90 (64–100)
Arthrosis (number of patients)	
Mild	8 (21%)
Moderate	3 (8%)
Reoperation (number of patients)	11 (28%)

* Values are expressed as mean, with range in parentheses; ORIF = open reduction and internal fixation.

bump across the patient's chest were used to accommodate the elbow in the extended and flexed positions, respectively. Either a posterior global incision or a lateral incision was used. The deep structures were approached through the Kocher interval. The radial head was examined. Indications for arthroplasty in this series were (1) more than three articular fragments, (2) traumatic delamination of the articular cartilage, or (3) comminution of the radial neck. Excised fragments were saved on the back table for radial head prosthetic sizing. If the radial head was not excised, the coronoid was approached medially. Structures were generally addressed in a deep to superficial manner (coronoid, radial head, LUCL) (Fig. 1).

The coronoid was addressed with a suture lasso, suture anchor, or lag screw technique, depending on the size and comminution of the fracture fragment and the discretion of the surgeon. Stability of the elbow was tested with the hanging arm test (Fig. 2). Previous authors have assessed stability by ranging the elbow through various arcs of motion. In our test, the elbow was fully extended with the hand supinated and a bump placed under the humerus. In this position, the weight of the hanging arm produces a dislocating force. We believe, if the elbow remains concentrically located on a lateral fluoroscopic image while hanging in this position, it is stable. This previously published test was the basis of our intraoperative assessment of stability [7]. It was performed both before and after the LUCL was addressed. Stability at followup was radiographically assessed for concentric reduction and the absence of a drop sign [2].

If the radial head was excised, radial head arthroplasty was performed (n = 30) using a modular prosthesis (EVOLVE® Modular Radial Head System; Wright Medical Technology, Inc, Arlington, TN, USA). There was a learning curve for proper head size selection (Fig. 3), resulting in three overstuffed radiocapitellar joints early in the series. Thereafter, the radial head was sized to be even with the articular surface of the coronoid [3]. If arthroplasty was not indicated based on the surgical algorithm (ie, $\leq$ three articular fragments), the patient underwent ORIF of the radial head fracture (n = 9). All Mason II fractures were fixed using countersunk small-fragment screws or headless compressions screws. All Mason III fractures were fixed using modular plates (Synthes® Modular Hand System; Synthes, West Chester, PA, USA). Excision of the radial head without replacement was strictly avoided. After the radial head was addressed, the hanging arm test was performed to assess stability.

The LUCL was repaired using heavy braided nonabsorbable suture with either Mitek® suture anchors (DePuy Mitek, Raynham, MA, USA) (n = 32) or bone tunnels (n = 7). Tunnels were drilled at the isometric point of the lateral epicondyle and at the insertion of the LUCL onto the ulna. More distal placement of the humeral tunnels may increase varus stability and more proximal placement may increase posterolateral rotator stability. In our opinion, in the setting of a terrible triad injury, varus stability usually takes priority. A Number 2 FiberWire® (Arthrex, Inc, Naples, FL, USA) was used placed through the ulnar bone tunnels. Using a free needle, it was then run through the LUCL in a running, locked fashion. It is important to preload each pass of the running locked suture so there is no laxity in the construct when tied. A suture passer was then used to pass the suture to the posterior aspect of the humerus where it was further tensioned with the forearm supinated and tied. The hanging arm test was again performed to assess stability.

If instability persisted at this point, we proceeded to repair the medial collateral ligament (MCL) (n = 2) or apply an external fixator (n = 3). MCL repair was performed in two patients, one from both the ORIF and arthroplasty groups, in a similar fashion to the LUCL repair using a heavy braided nonabsorbable suture with either Mitek® suture anchors or bone tunnels. A hinged external fixator (Orthofix, Lewisville, TX, USA) was applied in three patients, one from the ORIF group and two from the arthroplasty group.

Postoperatively, patients were immobilized with a posterior slab or double sugar tong splint in 90° flexion and neutral forearm rotation. On Postoperative Days 5 through 7, supine, well-arm-assisted passive ROM exercises were introduced to the patient by physical therapy. Well-arm- and gravity-assisted passive flexion was emphasized for the first 3 weeks, and patients were then gradually advanced to active

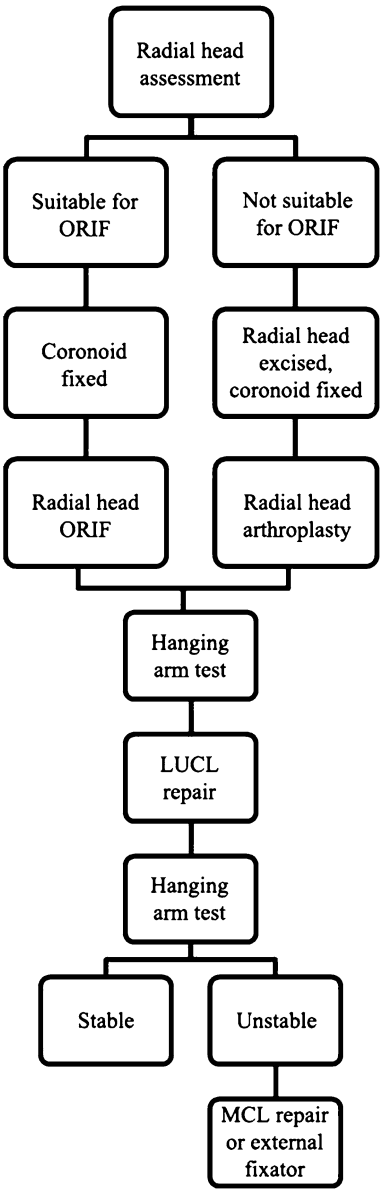

Fig. 1 A diagram outlines the treatment algorithm used for radial head management in the treatment of terrible triad injuries, along with intraoperative assessment of stability with the hanging arm test.

elbow motion under therapy guidance as pain and swelling permitted. The three patients placed in a hinged external fixator were kept static at 90° for 3 weeks. The motion arc was then gradually increased as tolerated until fixator removal at 6 weeks.

Statistical Analysis

Fisher's exact test was used for determining statistical differences for categorical data such as stability, failure of fixation, reoperation rate, contracture, removal of hardware, and arthrosis. The Wilcoxon rank-sum test was used to determine

Fig. 2 A photograph demonstrates the hanging arm test. A bump is placed under the humerus with the elbow extended and forearm supinated. The weight of the hand and forearm acts as a dislocating force in this position of maximal instability. Maintenance of concentric reduction on a lateral fluoroscopic view indicates stability.

statistical differences between the radial head ORIF and arthroplasty groups in ROM, DASH scores, and Broberg-Morrey scores. The intraclass correlation was used to assess agreement between graders. A p value of less than 0.05 was taken as statistically significant. We performed statistical analyses using SAS® 9.2 (SAS Institute, Inc, Cary, NC, USA).

Results

Outcome Scores and ROM

No differences were found in 18-month DASH scores (15.7 versus 16.1, p = 0.71) or the Broberg-Morrey index between groups (Table 2). The mean total arc of elbow motion at 18 months was 118° (range, 75°–140°) for patients with arthroplasty and 106° (range, 80°–130°) for patients with ORIF (p = 0.09). The arthroplasty group demonstrated greater ROM in flexion at 137° (range, 120°–150°) versus 130° in the internal fixation group (range, 120°–140°; p = 0.02), though the clinical significance of this difference is questionable. Overall, the mean arc of elbow motion was 115° (range, 75°–140°), the mean DASH score was 16 (range, 0–43), and the mean Broberg-Morrey index was 90 (range, 64–100).

Fourteen of 39 (36%) patients received a static progressive extension splint postoperatively (JAS® splint; Joint Active Systems, Effingham, IL, USA) to treat a lack of full extension. This included seven of 30 elbows with arthroplasty versus seven of nine elbows with ORIF (p = 0.02), indicating that the arthroplasty group's extension was less impaired at earlier time points. However, this did not bear out statistically at final followup, as there was no significant difference between

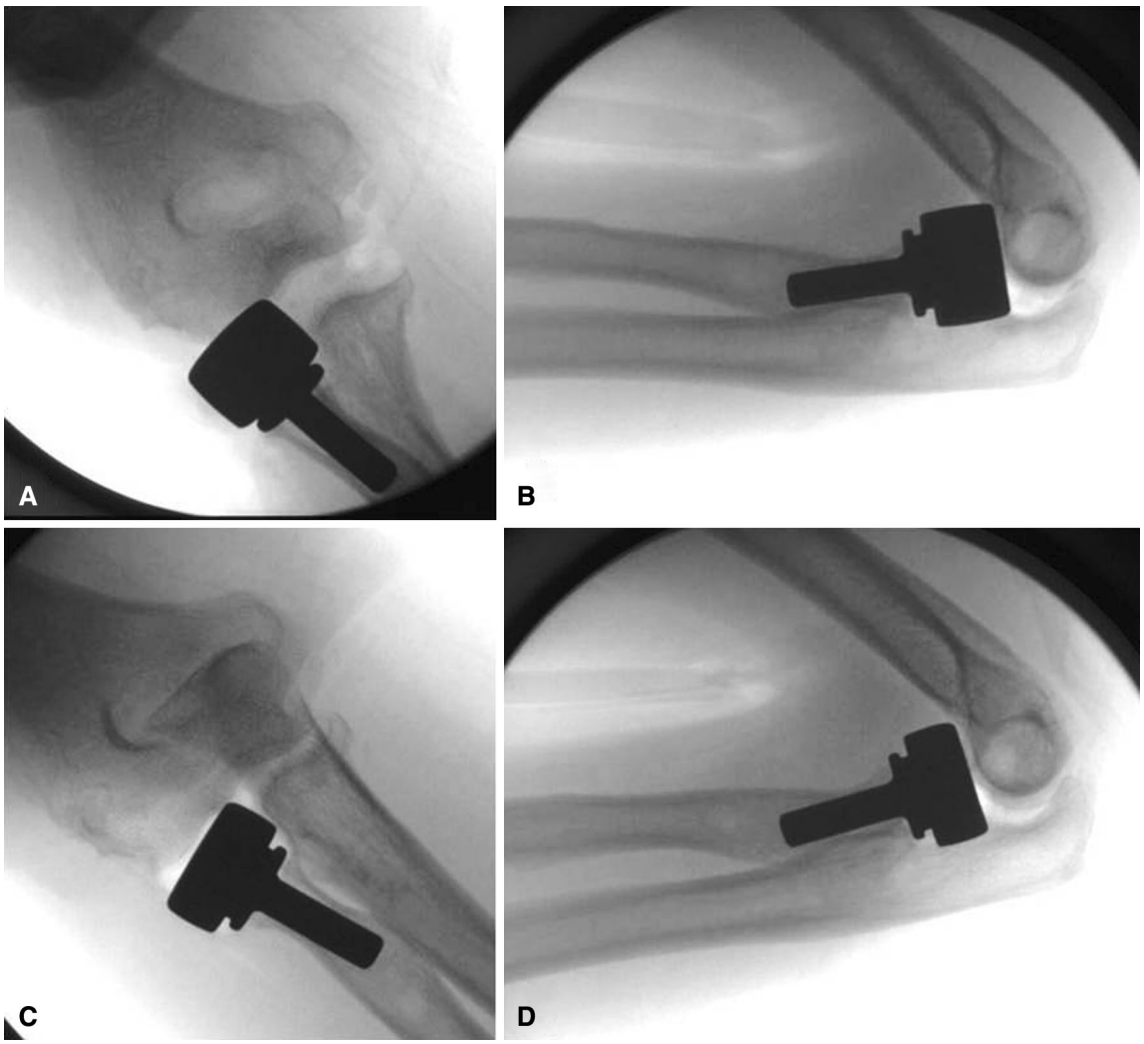

Fig. 3A–D (**A**) AP and (**B**) lateral radiographs show a 22 + 4 mm head clearly overstuffed with gapping of the humeroulnar joint and prosthesis protruding proximal to the lateral edge of the coronoid articular surface. (**C**) AP and (**D**) lateral radiographs show a 22 mm neutral head with a much better fit.

extension after arthroplasty (mean, 20°; range, 0°–45°) and ORIF (mean, 24°; range, 10°–40°).

Elbow Stability and Arthrosis

Patients who underwent radial head arthroplasty were more likely to be stable than patients who underwent ORIF before LUCL repair ($p = 0.02$), after LUCL repair ($p = 0.01$), and at 18-month followup ($p = 0.01$) (Table 2). Only three of 30 elbows treated with radial head arthroplasty were unstable before LUCL repair compared with four of nine treated with ORIF. After LUCL repair, only one of 30 remained unstable, while all four of nine remained unstable in the ORIF group. This difference again transferred to the 18-month followup where no elbows in the arthroplasty group were unstable, and three of nine in the ORIF group were unstable.

Arthrosis was more common in the arthroplasty group than in the ORIF group. On final radiographs, eight of 39 (21%) patients had mild arthritic changes and three of 39 (8%) had changes described as moderate according to scale of Knirk and Jupiter [12]; all 11 of these patients had undergone arthroplasty as opposed to ORIF ($p = 0.04$). Interestingly, neither the DASH nor the Broberg-Morrey index differed in the group with arthritis compared to those without it.

Complications and Reoperations

Reoperation was performed in 11 of 39 (28%) patients; with the numbers available, there was no difference in the frequency of reoperation between those patients treated with arthroplasty ($n = 7$) and those treated with ORIF ($n = 4$) ($p = 0.45$). It should be noted, early in the series, three of the

Table 2. Results of radial head treatment: ORIF versus arthroplasty

Variable	ORIF group	Arthroplasty group
Total number of patients	9	30
Mason type (number of patients)		
II	5 (56%)	18 (60%)
III	4 (44%)	12 (40%)
Instability (number of patients)		
Before LUCL repair	4 (44%)	3 (10%)
After LUCL repair	4 (44%)	1 (3%)
At 18 months	3 (33%)	0 (0%)
External fixation (number of patients)	1 (11%)	2 (7%)
MCL repair (number of patients)	1 (11%)	1 (3%)
Progressive extension splinting (number of patients)	7 (78%)	7 (23%)
Mean ROM at 18 months (°)		
Flexion	130	137
Extension	24	20
Total arc	106	118
Hardware failure (number of patients)	2 (22%)	NA
Overstuffed (number of patients)	NA	3 (10%)
Mean DASH at 18 months (points)	15.7	16.1
Arthrosis (number of patients)		
No	8/8 (100%)*	19 (63%)
Mild	0/8 (0%)*	8 (27%)
Moderate	0/8 (0%)*	3 (10%)

* Denominator is 8 due to one patient with ORIF who required conversion to total elbow arthroplasty; ORIF = open reduction and internal fixation; LUCL = lateral ulnar collateral ligament; MCL = medial collateral ligament; NA = not applicable.

radial head prostheses were overstuffed, requiring revision. Similarly, early in the series, two of the radial head fixations failed, one in conjunction with a failure of the LUCL repair that did not require a repeat operation and one in conjunction with a failure of coronoid fixation (screw) that required revision to a total elbow arthroplasty. Two other patients in the ORIF group underwent reoperation for residual instability. Both of these patients had undergone ORIF of a Mason III radial head fracture with a plate. After the first 10 patients, the only revision operations were for contracture release. Only two of 30 patients in the arthroplasty group developed coronoid nonunion or malunion, whereas four of nine elbows in the ORIF group developed nonunion/malunion. There were no infections in this series.

Discussion

A systematic approach to management of elbow fracture-dislocations that surgically addresses each individual component of the terrible triad pathoanatomy has resulted in improved results in terms of pain and functional outcomes [4, 5, 19, 24], but instability, contracture, reoperation, and progression to arthrosis remain clinically important problems. One recent study analyzed the important role of the treatment of the radial head fracture within the framework of a larger protocol [13]. We found that patients who received radial head arthroplasty as part of an algorithmic approach to the management of terrible triad injuries had comparable pain and functional scores to those treated with ORIF. In assessing elbow stability at short-term followup, patients treated with arthroplasty generally had more stable elbows and, naturally, required fewer subsequent procedures for symptomatic instability. However, patients who underwent radial head arthroplasty had similar rates of reoperation, specifically related to technical complications of the arthroplasty (ie, overstuffing) and, furthermore, had significantly higher incidence of radiographic arthrosis.

We have previously published a report on this series of patients, specifically evaluating surgical outcomes based on the fixation method of the coronoid fracture fragment [7]. That analysis revealed that a suture lasso technique was superior to suture anchors or lag screws before and after LUCL repair. Additional analyses of that series are presented in the current study, specifically comparing the pain, function, arthrosis, and complications in patients based on radial head management. Our analysis suggests that the treatment strategy to address the radial head fracture may also have an independent effect on outcome, specifically in terms of elbow stability, incidence of arthrosis at short-term followup, and the nature of postoperative complications or reoperations.

As with any retrospective study, this investigation has several limitations that warrant consideration. While the surgical algorithm described in the Patients and Methods section was generally followed, it is possible that variations in surgical management may have occurred based on unique case-by-case factors that could introduce bias. Terrible triad injuries are relatively rare and complex. Understandably, a cohort of patients with elbow fracture-dislocations can display a fair amount of heterogeneity based on patient factors and injury mechanisms that make precise, matched comparison difficult to obtain. Moreover, it must be understood, by following a surgical algorithm such as ours, patients are essentially preselected to one treatment or another based on variation in the injury pattern, in this case the radial head fracture. Thus, the two patient groups, while generally similar, are subtly different. Therefore, differences seen in the outcomes of the two groups, notably stability, radiographic arthrosis, and the nature of reoperations should not be interpreted as favoring one treatment over the other but instead serve to provide important prognostic information about what to expect for patients in each group treated under this algorithm. While

mean followup in this series was 24 months, we included patients at a minimum of 18 months, and clearly this study represents short-term results. Nonetheless, we believe this is adequate time to assess functional outcome measures, elbow stability, and certain implant-related complications requiring reoperation. It may not allow sufficient time to elapse to assess the clinical significance of the differences seen in radiographic evidence of arthrosis at final followup, which should be understood as it may provide important prognostic information for patients requiring arthroplasty based on the severity of the radial head fracture in the triad complex. Furthermore, while the time frame of this study is sufficient to capture short-term complications related to arthroplasty, such as overstuffing, it does not provide adequate time to assess late complications, such as prosthetic loosening. Additionally, six patients in this series were lost to followup, and while there was no differential loss to followup, out results must be interpreted as a best-case scenario, as some of the patients lost to followup might have undergone reoperation elsewhere. Lastly, while appropriate statistical methods were used to compare groups, an appropriate level of caution should be employed when drawing conclusions from a study with small sample sizes between groups.

We found no differences in clinical outcome measures between the two groups, including the DASH score, Broberg-Morrey index, and total arc of motion. A recent study by Leigh and Ball [13] including 23 patients (24 elbows) also compared outcomes of terrible triad injuries based on either radial head repair or replacement [13]. In that study, the radial head arthroplasty group had a slight but statistically significant advantage in terms of DASH scores (10.3 versus 9.16); however, the authors acknowledged that such a small difference may be of little, if any, clinical significance. They also found no significant difference in patient satisfaction, American Shoulder and Elbow Society (ASES) scores, and ROM or associated arcs, although interestingly they noted a trend toward better final ROM and ASES scores in the radial head arthroplasty group. However, in their conclusion, the authors favored radial head repair, especially in younger patients, citing increased complications and reoperations in the arthroplasty group of their study. They also reported no postoperative instability in any patient.

We theorize that several technical factors may influence our results when comparing the improved stability of patients having undergone radial head arthroplasty versus ORIF in this series. First, removal of the radial head for planned arthroplasty allows for better visualization of the coronoid fracture fragment. The importance of adequate coronoid fixation in terrible triad injuries has been documented previously [5, 7, 8, 11, 21]. Improved visualization through the existing lateral incision may potentially allow for better reduction and fixation, regardless of fixation technique. Second, radial head arthroplasty requires cutting at the neck of the radius, but no distal soft tissue exposure is required as may be necessary with ORIF. Thus, decreased soft tissue stripping may lead to less disruption of the annular ligament and the radial collateral ligament portions of the LUCL, ultimately leading to improved overall elbow stability from a soft tissue perspective after bony stability is achieved.

In our series, 23% of patients with arthroplasty required progressive extension splinting, compared with 78% of the patients with ORIF. Nevertheless, at final followup, the difference in extension between the two groups was negligible. One potential pitfall in radial head arthroplasty, as seen in this series, is overstuffing, necessitating reoperation. Properly sizing the radial head prosthesis can be challenging. Sizing is often performed with the elbow in extension, but the radiocapitellar joint is tighter in flexion than extension, which can lead to overstuffing [1]. Van Glabbeek et al. [23] also showed how overstuffing the radiocapitellar joint by even 2.5 mm resulted in increased joint pressures. Frank et al. [6] reported that intraoperative visualization of a gap in the medial ulnohumeral joint may indicate overstuffing. Doornberg et al. [3] recommended sizing the radial head so that it was even with the articular surface of the coronoid, and we have found better results using this guideline. After an initial learning curve, resulting in three overstuffed radial heads, sizing was appropriate and no further overstuffing or revision occurred.

Radial head arthroplasty has been shown to be a reliable technique for reconstruction of the radial head [8, 16]. While potentially confounded by the fact that the radial head fractures selected for arthroplasty tend to result from higher-energy injuries with more comminution, the radial head prostheses interestingly were more stable and had a greater ROM when compared to ORIF. However, there was a trend toward an increased risk of arthrosis radiographically at final followup for those patients who underwent radial head arthroplasty. One of us previously [22] has recommended arthroplasty for isolated radial head fractures with four or more articular fragments. While larger, prospective trials are needed to conclusively define the optimum surgical algorithm for this difficult injury, our findings suggest that patients who receive a radial head arthroplasty under this algorithm can expect to have better stability than those treated with ORIF, despite having more severe initial injury patterns. As these injuries commonly occur in younger patients, longer-term studies will be required to ascertain whether the apparent benefits of radial head arthroplasty are offset by the late complications of arthroplasty, such as loosening.

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