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Anteromedial coronoid facet fractures with associated injuries have inferior outcomes to isolated fractures: a clinical outcomes comparison

Olawale A. Sogbein, MD, MSc, FRCSC[a,b,*], Yibo Li, MD, FRCSC[c], Robert Chan, MD, MSc, FRCSC[c,d], Kenneth J. Faber, MD, MHPE, FRCSC[a], George S. Athwal, MD, FRCSC[a], Graham J.W. King, MD, MSc, FRCSC[a], Armin Badre, MD, MSc, FRCSC[c,d]

[a]*Roth McFarlane Hand and Upper Limb Centre, London, Ontario, Canada*
[b]*Division of Orthopaedic Surgery, Western University, London, Ontario, Canada*
[c]*Faculty of Medicine and Dentistry Surgery Department, University of Alberta, Edmonton, Alberta, Canada*
[d]*Western Hand & Upper Limb Facility, Sturgeon Hospital, Edmonton, Alberta, Canada*

Background: Varus posteromedial rotatory instability typically results in an isolated anteromedial coronoid (AMC) fracture without an associated radial head fracture or elbow dislocation. However, recent series have shown concomitant radial head fractures, and elbow dislocations may be seen in association with AMC fractures in other injury patterns with an unclear effect on patient outcomes. Therefore, our objective was to compare postoperative patient outcomes in AMC fractures with and without concomitant radial head fractures or elbow dislocations.

Methods: A retrospective review of patients who underwent operative fixation of AMC fractures at 2 academic medical centers from 2004 to 2022 was performed. Patients ≥18 years of age who sustained AMC fractures with or without elbow dislocations and/or radial head injuries were included. Our primary outcome was the Mayo Elbow Performance Index. Secondary outcomes were joint congruence, range of motion, complications, revision surgeries, and the incidence of heterotopic ossification (HO).

Results: A total of 61 AMC fractures met our inclusion criteria. The mean age of our cohort was 44 ± 16 years of which 66% were males. The average length of follow-up was 23 ± 34 months. Patient demographics were similar between groups. Thirty-two patients had no concomitant radial head fracture or elbow dislocation, and 29 patients had either a concomitant elbow dislocation and/or radial head fracture (14 isolated dislocations, 5 radial head fractures without apparent dislocation, and 10 radial head fractures with a dislocation). There were significantly more high-energy injury mechanisms in patients with concomitant injuries ($P = .001$). Coronoid subtype and fragment size did not differ between groups. The postoperative mean Mayo Elbow Performance Index score was significantly lower for patients with concomitant injuries (89 ± 10 vs. 96 ± 8, $P = .006$). Patients with concomitant elbow dislocation and/or radial head fracture had significantly less flexion and supination at final follow-up ($P = .04$), had a significantly higher incidence of HO ($P = .008$), and a higher grade of HO ($P = .004$). Significantly more patients with concomitant injuries underwent reoperations (19% vs. 0%, $P = .007$). Ulnar neuropathy, nonunion, and infection did not differ between groups.

The Western University Health Science Research Ethics Board (HSREB) approved this study (# 13677).

*Reprint requests: Olawale A. Sogbein, MD, MSC, FRCSC, Division of Orthopaedic Surgery, Western University, 339 Windermere Road, London, Ontario N6A 5A5, Canada.

E-mail address: olsogbein@gmail.com (O.A. Sogbein).

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Conclusion: While the overall clinical outcomes of surgically managed AMC fractures were good, concomitant radial head fractures and/or elbow dislocations were associated with significantly worse patient-reported outcomes, greater stiffness, more reoperations, and a higher incidence and grade of HO. Larger cohorts are needed to confirm these findings.

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: Anteromedial facet fractures; coronoid process; elbow dislocation; radial head fracture; varus posteromedial rotatory instability; clinical outcomes

The coronoid process is the primary bony stabilizer against varus instability.[18,19,27] In conjunction with the radial head, it also provides stability against posterior instability with axial loading and has a posterolateral stabilizing effect.[9,28] The coronoid process has 2 bony prominences, the tip and the sublime tubercle as well as 2 facets. The anterolateral facet is located lateral to the tip of the coronoid. The anteromedial facet is the part of the articular surface of the coronoid between the tip and the sublime tubercle.

Isolated fractures of the AMC have been associated with varus posteromedial rotatory instability (VPMRI). In a VPMRI injury, the anteromedial coronoid (AMC) is fractured as a result of the impaction of the medial trochlea, which results in a specific pattern of AMC fracture.[1,3] In the majority of cases of VPMRI, there is no evidence of radial head fracture or apparent elbow dislocation.[1,6,22,33]

More commonly, coronoid fractures occur in association with other bony and ligamentous injuries particularly in association with radial head/neck fractures and elbow dislocation, such as the terrible triad pattern of elbow instability or bifacet coronoid fracture with a radial head fracture as a result of a posteriorly directed force.[11] Classically, terrible triad injuries have been shown to result in fracture of the anterolateral facet of the coronoid. However, recent series have shown that some cases of terrible triad injuries may have larger coronoid fractures that extend to the anteromedial facet.[8,15,20,26]

Available series have not compared the outcomes of patients with isolated AMC fractures to those with concomitant elbow dislocation and/or radial head fractures. Therefore, the objective of this study was to compare the postoperative outcomes of anteromedial coronoid fractures with (AMC+) and without concomitant radial head fractures and/or elbow dislocations (AMC). We hypothesized that patients who sustained anteromedial coronoid fractures with associated injuries would have worse postoperative outcomes compared to patients without associated injuries.

Materials and methods

A retrospective review of AMC fractures treated with open reduction and internal fixation (ORIF) by 6 fellowship trained surgeons at 2 academic medical centers over a period from 2004 to 2022 was performed. This study was approved by both institutional research ethics boards.

Inclusion and exclusion criteria

Patients $\geq$18 years of age who sustained AMC fractures with or without concomitant elbow dislocations and/or radial head injuries were included. Fractures without accessible CT imaging were excluded as localizing and delineating coronoid fracture morphology based solely on radiographs is difficult and unreliable.[22] Patients included in the study had operative treatment of their AMC fracture and had at least 1 year of follow-up. Patient charts and perioperative imaging were reviewed by the investigators. Imaging was accessed through the Picture Archiving Communication System. Patient demographics, injury mechanism, associated bony and ligamentous injuries, coronoid subtype as per O'Driscoll classification, coronoid fragment size, operative management, postoperative outcomes, and complications were recorded.[22]

When analyzing injury mechanism, fall from standing height and slips on ice were grouped as low-energy mechanisms. Sports injury was grouped as medium energy, and MVC and fall from large height were grouped as high energy.

Surgical interventions

All surgeries were performed by or under the direct supervision of a subspecialist upper extremity surgeon. Intravenous prophylactic antibiotics were administered preoperatively. All patients underwent a general anesthetic. A standard medial incision centered over the MCL or a posterior skin incision with a full-thickness fasciocutaneous medial flap was developed. The ulnar nerve was identified, neurolyzed, and protected throughout the procedure. At the conclusion of the procedure, the ulnar nerve was either left in-situ or transposed anteriorly in the subcutaneous tissue at the surgeon's discretion.[10] The deep surgical exposures used for fixation of the coronoid fractures included the flexor carpi ulnaris split (46%), flexor-pronator split (41%), Taylor & Scham (11%), and the extended medial elbow approach (2%).[12,14,29,32] Concomitant lateral collateral ligament (LCL) and/or medial collateral ligament (MCL) repair was performed based on the fracture pattern and intraoperative elbow stability. Either a second lateral incision was used or the posterior skin flap was elevated laterally to manage concomitant LCL and radial head injuries. In patients with radial head injuries, ORIF or arthroplasty was performed based on intraoperative assessment of the number and size of the fracture fragments. If radial head fractures were nondisplaced, they were not addressed operatively.

Postoperative care

A posterior splint was applied at the conclusion of the operation with the elbow at 90-degrees of flexion and forearm in neutral rotation. Although a standard rehabilitation protocol was not used in all cases among all surgeons, in general, the splint was removed at 10-14 days postoperatively progressing to a seated or overhead rehabilitation protocol focusing on active range of motion (ROM). An above elbow removable thermoplastic splint was also provided to the patient to be used between exercises for the first 6 weeks. At 6 weeks, if there was no evidence of fixation failure or joint incongruity on imaging, active-assisted and passive ROM were permitted, and the resting splint was discontinued. Strengthening exercises were started at 3 months postoperatively.

Outcome assessments

Our primary outcome was pain, stability, and function measured using the Mayo Elbow Performance Index (MEPI) at final follow-up. The MEPI outcome measure assesses pain, motion, instability, and function. It uses a 100-point scale and scores are graded as excellent ($\geq$90), good (75-89), fair (60-74), or poor ($<$60).[21] Secondary outcomes were joint congruity, complications, ROM, and the incidence and severity of heterotopic ossification (HO). Postoperative joint congruity was assessed radiographically at first and final postoperative follow-up. Elbow and forearm ROM was measured using a goniometer at final follow-up. The presence of HO was assessed on radiographs at final follow-up. The Brooker classification system was used to grade HO radiographically with grade I defined as heterotopic bone formation within soft tissue; grade II as HO with $>$1 cm between opposing bony surfaces, grade III as HO with $<$1 cm between opposing bony surfaces, and grade IV demonstrates joint ankylosis.[5] Finally, measurement of coronoid fragment height was performed from the CT scan using the largest articular height of the AMC fragment in the sagittal plane.[24,25,31]

Statistical plan

Descriptive statistics are presented as mean values and standard deviations. For categorical data, a chi-squared or Fischer exact test was used. The level of significance was set at $P < .05$. Data analysis was performed using IBM SPSS for Mac OS X (version 23; IBM Corp., Armonk, NY, USA).

Results

A total of 163 patients who underwent ORIF for coronoid fractures were reviewed. Ninety-one fractures had available CT imaging. Of these, 61 were AMC fractures who met our inclusion criteria and underwent ORIF from 2004 to 2022 between 2 centers. The mean age was 44 ± 16 of which 66% were male. Thirty-two patients (53%) had no concomitant elbow dislocation or radial head fracture (AMC group), and 29 patients (48%) had either a concomitant elbow dislocation and/or radial head fracture (AMC+ group). The mean length of follow-up was significantly longer in the AMC+ group (29 ± 31 months) compared to the AMC group (17 ± 34 months), $P = .01$. Patient demographics were similar between groups and are presented in Table I. Injury characteristics are also presented in Table I. There were significantly more high-energy injury mechanisms in the AMC+ group (AMC+ 35% vs. AMC 0%, $P = .002$). Furthermore, there were significantly higher reports of low energy mechanisms in the AMC group (AMC 78% vs. AMC+ 48%, $P = .001$). Overall, there were no statistically significant differences in fracture subtypes between the 2 groups (Table I). The majority of fractures were O'Driscoll anteromedial subtype 2 in both groups (Table I). A larger incidence of subtype 3 injuries (38% vs. 22%) occurred in the AMC+ group. The mean maximum coronoid fragment size was not significantly different between groups; with 13 mm ± 4 mm in the AMC+ group and 10 mm ± 5 mm in the AMC group, $P = .1$. In the AMC+ group, 24 had dislocations, of these 10 (42%) had radial head fractures, and 14 (58%) did not. The remaining 5 patients had radial head fractures without dislocations. Of the patients with radial head fractures, 47% (n = 7) were treated with arthroplasty, 20% (n = 3) with ORIF, and 33% (n = 5) were managed nonsurgically (Table II), Figures 1-4 represent these injuries. The incidence of MCL (AMC 19%, AMC+ 38%) and LCL injuries (AMC 97%, AMC+ 86%) was not statistically different between groups (Table I; $P = .09$ and $P = .13$ respectively). The intraoperative ulnar nerve management was similar in both groups (Table I; $P = .93$). Six (AMC n = 4 vs. AMC+ n = 2, 10%) of the coronoids were treated with screws and the remainder underwent plate fixation (AMC n = 28 vs. AMC+ n = 27, 90%).

At final follow-up, the mean MEPI score was significantly lower (mean difference, 7 ± 2.3 [95% confidence interval = 1.89-11.05], $P = .006$) in the AMC+ group (89 ± 10) compared to the AMC group (96 ± 8). In the AMC group, this correlated with a "good" outcome in 5 (16%) patients and an "excellent" outcome in 27 (84%) patients. In the AMC+ group, this correlated with a "good" outcome in 12 (41%) patients, "excellent" in 16 (55%) patients, and "fair" in 1 patient (3%). No patients reported a "poor" outcome. ROM was significantly greater in the AMC group compared to the AMC+ group in all planes with flexion (138° ± 10 vs. 132° ± 11, $P = .04$) and supination (82° ± 2 vs. 73° ± 4, $P = .04$) reaching statistical significance. Extension (11° ± 11 vs. 17° ± 17, $P = .1$) and pronation (79° ± 8 vs. 73° ± 17, $P = .08$) did not reach statistical significance. (Table III). There was a significantly higher incidence ($P = .008$) of postoperative HO in the AMC+ group (43%) compared to the AMC group (13%) at the final follow-up. The mean Brooker grade was also significantly higher in the AMC+ group (2.4 ± 0.5) compared to the AMC patients (1.0 ± 0), $P = .004$. The rates of nonunion, infection, and ulnar nerve symptoms were similar between groups. However, all cases of infection (n = 2, 6%) and nonunion/delayed union

Table I Demographics and injury characteristics

	Anteromedial fracture (n = 32)	Anteromedial fracture + concomitant injuries (n = 29)	*P* value
Male	20 (63%)	20 (69%)	.59
Mean age, yr	43 + 15	47 + 16	.47
Mean follow-up (mo)	16 + 36	26 + 31	.01
Hand dominance			
Right	27 (84%)	21 (72%)	
Left	4 (13%)	5 (17%)	
Not specified	1 (3%)	3 (11%)	
Injury mechanism:			
Low energy	25 (78%)	14 (48%)	.02
Medium energy	7 (22%)	5 (17%)	.65
High energy	0	10 (35%)	.001
Anteromedial subtype:			
1	1 (3%)	0	.034
2	24 (75%)	18 (62%)	.28
3	7 (22%)	11 (38%)	.26
Mean coronoid fragment size, mm	10 ± 5	13 ± 4	.1
MCL injury	6 (19%)	11 (38%)	.09
LCL injury	31 (97%)	25 (86%)	.13
Ulnar nerve management			.93
In situ	15 (47%)	14 (48%)	
Transposition	17 (53%)	15 (52%)	

MCL, medial collateral ligament; *LCL*, lateral collateral ligament.

Table II Associated injuries characteristics

	Anteromedial fracture + concomitant injuries (n = 29)
Documented elbow dislocation	24 (83%)
Isolated radial head fractures	5 (17%)
Dislocation + radial head fractures	10 (34%)
MCL injury	11 (38%)
LCL injury	25 (86%)
Radial head treatment	
Nonsurgical management	5 (33%)
Fixation	3 (20%)
Arthroplasty	7 (47%)

MCL, medial collateral ligament; *LCL*, lateral collateral ligament.

(n = 3, 10%) occurred in the AMC+ group (Table III). There were 2 cases of coronoid union, and one case of delayed union of the coronoid which eventually united.

Significantly more patients in the AMC+ group (n = 6, 19%) underwent reoperations compared to none in the AMC group ($P = .007$) (Table III). In the AMC+ group, 3 patients underwent revision fixation for persistent ulnohumeral malalignment. Of these, 2 patients underwent revision lateral ulnar collateral ligament repair with bridge plate application following persistent ulnohumeral subluxation on postoperative imaging. The third patient underwent revision plate fixation of the coronoid after redisplacement with additional MCL reconstruction and external fixator application. Additionally, one patient underwent removal of hardware and irrigation and débridement for infection, and one underwent ulnar nerve neurolysis and transposition secondary to persistent paresthesia. This patient had an in-situ ulnar nerve decompression during their initial surgery. Lastly, one patient in the AMC+ group underwent removal of hardware for irritation. There were no reoperations in the AMC group.

Discussion

Our study compared patient-reported pain, stability, and function in operatively treated AMC fractures with and without concomitant radial head fractures and/or elbow dislocations. While the clinical outcome was good to excellent in both groups, we observed that the patients with concomitant injuries had significantly lower mean MEPI score, lower ROM, higher incidence of HO with an increased Brooker grade, and more reoperations. However, other postoperative complications, and fracture fragment size were similar between groups. While both groups were similar demographically, significantly more high-energy injury mechanisms occurred in the concomitant injury group and lower energy injury mechanisms in the non-concomitant injury group.

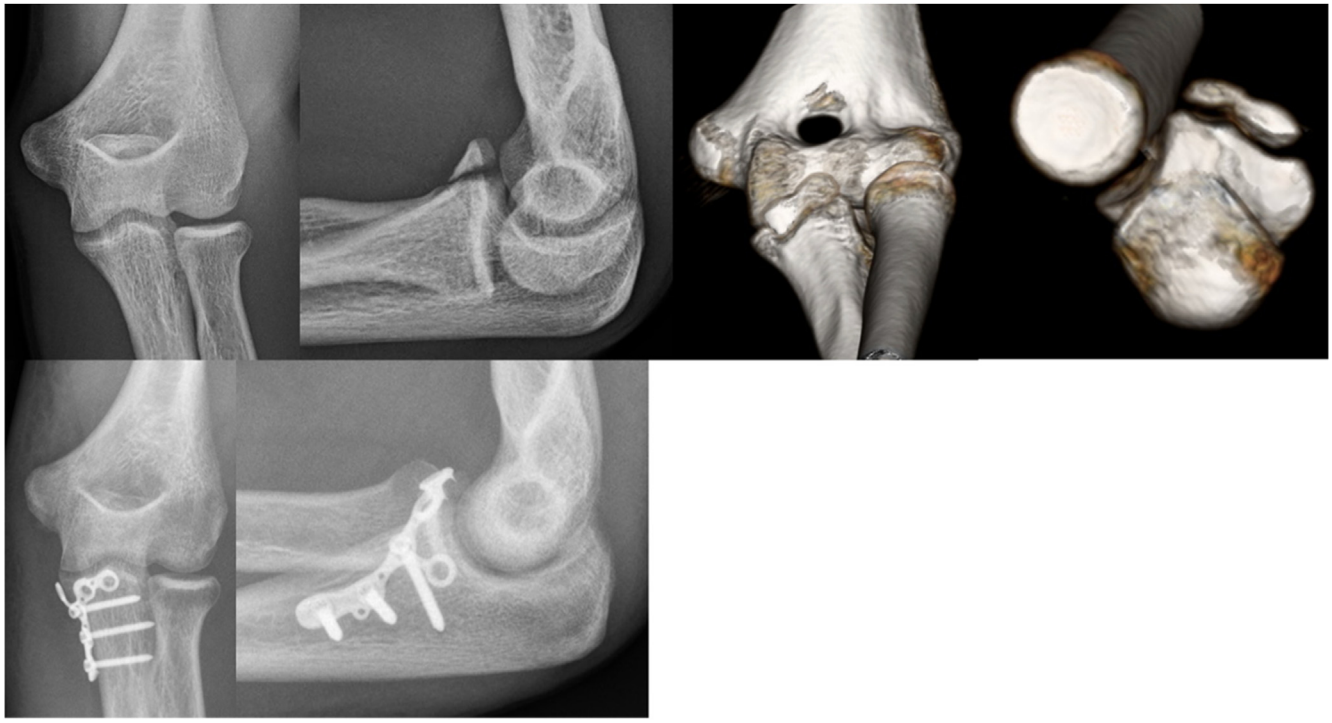

Figure 1 Isolated anteromedial coronoid facet fracture. Radiographs and 3D reconstructions demonstrating fracture morphology. Postoperative radiographs demonstrating plate fixation.

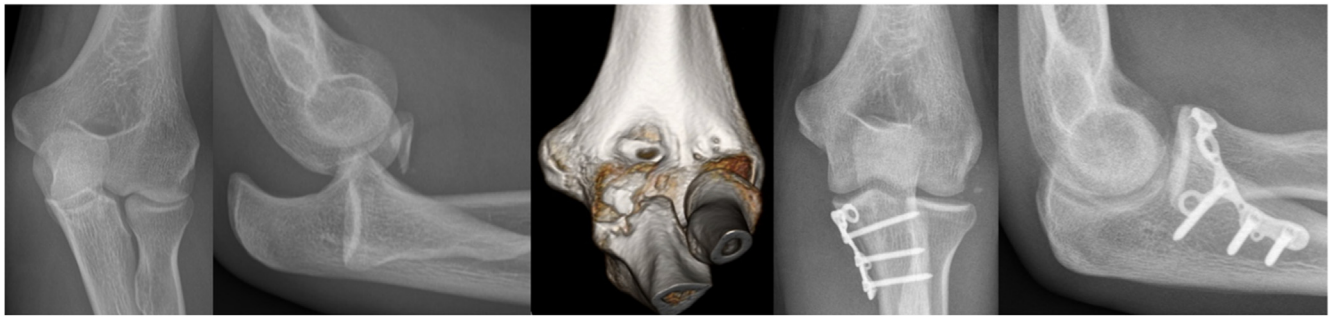

Figure 2 Anteromedial coronoid facet fracture with an isolated dislocation. Radiographs and 3D reconstructions demonstrating fracture morphology. Postoperative radiographs demonstrating plate fixation.

Multiple prior studies have reported that operative fixation of isolated AMC fractures results in good outcomes.[7,16,18,23,25,31] This was also observed in our isolated AMC cohort with a mean postoperative MEPI score of 96, interpreted as ''excellent.''[21] Lanzerath et al.[18] performed a systematic review investigating postoperative outcomes in 128 patients with isolated AMC injuries from 10 retrospective studies. Of these, 114 patients (89%) were treated surgically with a similar mean MEPI score to ours of 92 points. Furthermore, they demonstrated that the postoperative outcome was similar regardless of fracture subtype.

We did observe a significantly higher rate of reoperations in the AMC+ group, which is not surprising given the further loss of stabilizers of the elbow, and potentially greater surgical exposure. It is plausible that concomitant injuries lead to greater difficulty in achieving a stable elbow as revisions for recurrent instability were more common in this group. The overall incidence of concomitant radial head fractures and/or elbow dislocations with AMC fractures is unknown. We found an incidence of 48% in our patient population of operatively treated AMC fractures at 2 tertiary referral centers. Few studies have reported on the incidence of dislocations and/or radial head fractures in their cohorts of AMC injuries while most have reported the outcomes of AMC injuries in isolation.[23,31] Syed et al.[31] reported an incidence of 47% of concomitant radial head injuries in their cohort of 43 AMC fractures, similar to this

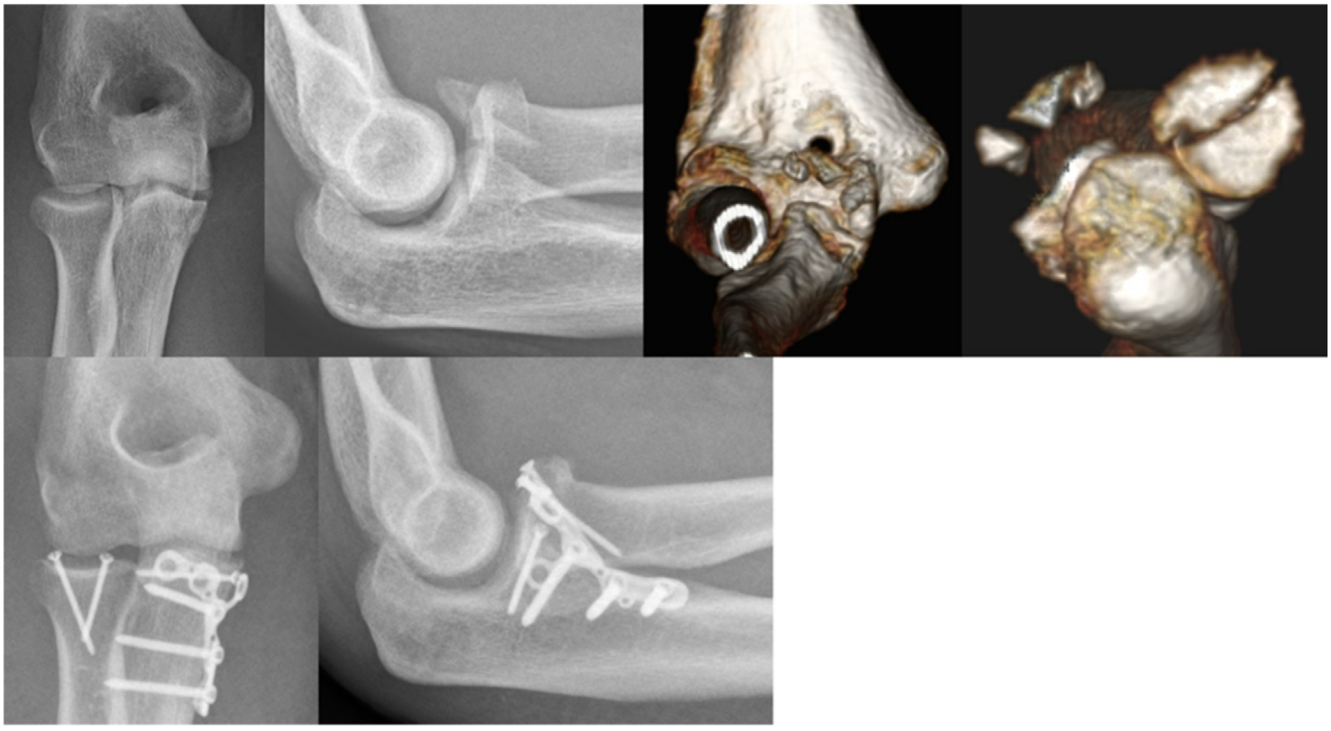

Figure 3 Anteromedial coronoid facet fracture with radial head fracture. Radiographs and 3D reconstructions demonstrating fracture morphology. Postoperative radiographs demonstrating fixation.

Figure 4 Anteromedial coronoid facet fracture with associated dislocation and radial neck fracture. Radiographs and 3D reconstructions demonstrating fracture morphology. Postoperative radiographs demonstrating coronoid fixation.

series. However, they did not report on the outcomes of their AMC with and without concomitant injuries separately. Most AMC injuries in our cohort were anteromedial subtype 2. However, we did note a larger incidence of subtype 3 injuries (38%) in the AMC+ group. O'Driscoll et al.[22] eluded to this in his original description of these injuries noting that radial head injuries may occur in more severe subtype 3 injuries. It is difficult to ascertain whether patients with concomitant injuries have a different injury mechanism. We did observe statistically that the highest energy injury etiologies, including all motor vehicle collisions and falls from height, were in the AMC+ group.

Fracture fragment size was not significantly different between our groups. Yet, both groups had mean fracture fragment sizes of 10 and 13 mm, respectively, which is larger than previously described thresholds of instability in biomechanical studies.[24,31] This further reinforced the operative necessity of our fracture cohort of AMC injuries. Our cohort of AMC+ injuries had comparable postoperative outcomes as seen in terrible triad injuries. Recently, a large systemic review analyzing terrible triad injuries comprising 43 studies and 1,749 elbows demonstrated that current surgical treatment for terrible triad injuries has led to improved outcomes relative to what has been reported in the past.[30] More specifically, they reported a mean postoperative MEPI score of 90 in a total of 1,609 patients with terrible triad injuries across 37 studies, indicating excellent return to function.

Table III Range of motion, complications, and joint congruence

	Anteromedial fracture (n = 32)	Anteromedial fracture + Concomitant injuries (n = 29)	*P* value
ROM(°)			
Flexion	138 ± 10	132 ± 11	.04
Extension	11 ± 11	17 ± 17	.10
Supination	82 ± 12	73 ± 20	.04
Pronation	79 ± 8	73 ± 17	.08
Complications			
Ulnar nerve symptoms	8 (25%)	5 (17%)	.17
Nonunion/delayed union	0	3 (10%)	.06
Infection	0	2 (6%)	.12
Heterotopic ossification			.008
N (%)	4 (13%)	12 (43%)	
Grade 1	4 (100%)	0	
Grade 2	0	4 (33%)	
Grade 3	0	8 (67%)	
Grade 4	0	0	
Joint incongruence			
First follow up	3	5	.24
Final follow up	0	0	
Reoperation	0 (0%)	6 (19%)	.007

ROM, range of motion.

Patients with concomitant injuries in the AMC+ group had a significantly higher incidence of HO and Brooker grade in our cohort. This was approximately 43% of our identified cohort with concomitant radial head fractures and/or elbow dislocations. The reported incidence of HO in the literature is variable ranging from 0% to 52% in injuries including ulnohumeral dislocations or distal humerus fractures.[2,4,13,17] The higher incidence seen with the AMC+ group may be related to a higher energy injury mechanism. Furthermore, no patients in our study cohort sustained burns or a documented head injury, but one patient had an associated cervical spine fracture and facial injuries. This patient did not go on to develop HO. Finally, there was no standardized prophylaxis with indomethacin used in our study cohort. We do not believe this influenced our findings as a recent study of 164 patients with elbow trauma that were randomized to receive either postoperative indomethacin prophylaxis or placebo, showed no difference in the incidence of HO or Brooker grade at 1 year.[2]

This study has limitations that are inherent to its retrospective design and as such only associations can be concluded. Patients in our study cohort were treated by surgeons with high-volume elbow practices. It is unclear whether similar postoperative outcomes would be reproduced by lower volume surgeons. Furthermore, our mean follow-up period was 23 months and complications, such as post-traumatic arthritis, may not be clinically apparent. Additionally, 37% of the patients did not have a 1-year follow-up and were excluded from the analysis. Although surgical approaches and rehabilitation protocols were not standardized, this added to the generalizability of our results as these injuries are commonly treated with the various approaches used in this series. Additional studies would be worthwhile to assess the long-term sequelae of AMC fractures with and without concomitant injuries.

Conclusion

This retrospective cohort study demonstrated that AMC fractures may be seen more commonly with concomitant radial head fractures and/or elbow dislocations than previously reported. While the overall clinical outcomes of surgically managed AMC fractures were good to excellent, additional injuries can be associated with worse outcomes, less ROM, a higher incidence and grade of HO, and more reoperations. Larger cohorts are needed to confirm these findings.

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