Posttraumatic Elbow Stiffness
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CHAPTER 4

Comparison of Acute versus Subacute Treatment of Terrible Triad Injuries of the Elbow
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Abstract

Purpose: To test the null hypothesis that there is no difference in flexion arc or Broberg and Morrey rating between patients treated within 2 weeks of the injury (acute treatment) and those treated 3 weeks or more after injury with persistent or recurrent dislocation or subluxation (subacute treatment).

Methods: The acute cohort consisted of 18 patients treated an average 6 days after injury. The radial head was replaced in 17 patients and repaired with screw in 1, the coronoid was secured with suture in all patients and with an additional screw in 2, and the lateral collateral ligament was reattached in all patients. No external fixators were applied. Four of 14 patients in the subacute cohort had 5 operative procedures before presenting to us. All patients presented with instability and were treated an average 7 weeks after injury. Except for 1 patient who presented with an active infection, all patients were treated with radial head replacement and lateral collateral ligament repair, and fixation or reconstruction of the coronoid occurred in 9 patients. Stability was protected with a hinged external fixator for an average of 6 weeks.

Results: Five patients in the acute cohort and 1 in the subacute cohort had 8 subsequent surgeries (addressing stiffness in 3 patients). Prior to subsequent surgeries, the flexion arc averaged 116° in the acute cohort and 93° in the subacute cohort and improved to an average 119° in the acute cohort and 100° in the subacute cohort after all subsequent surgeries. Broberg and Morrey scores were comparable between cohorts (90 vs 87 points).

Conclusions: Stability and strength were restored with both acute and subacute treatment, but earlier treatment is more straightforward and is associated with a better flexion arc.

Type of study/level of evidence: Therapeutic III.

Key words: Coronoid, dislocation, elbow, fracture, lateral collateral ligament, operative treatment, radial head, terrible triad injury.

Background

The terrible triad injury of the elbow is defined as a posterior dislocation of the elbow joint with fractures of the radial head and coronoid process. The label “terrible” is due to the fact that this injury pattern is prone to redislocation, arthrosis, and stiffness.1,2 Recent papers document improved results using a protocol that addresses each component of the injury.3-5 The complexity of the injury may not be recognized until the patient presents with persistent subluxation and instability weeks after initial treatment2,6,7, and the results of treatment in this setting are less well studied.

In this study, we compare a cohort of patients with terrible triad injuries treated within 2 weeks of the injury (acute treatment) with a cohort of patients who presented in a subacute phase (3 weeks or more after injury) with persistent or recurrent dislocation or subluxation (subacute treatment) to test the null hypothesis that when treated according to protocol
(including the addition of hinged external fixation and selective reconstruction of the coronoid process in the subacute treatment cohort), there is no difference in final flexion arc or elbow functional rating according to Broberg and Morrey between patients treated in the acute and sub acute phases.

Materials and Methods
Between 1999 and 2005, 23 patients who presented to 1 of 2 surgeons with a terrible triad injury of the elbow were treated within 14 days of the injury. Five of these patients were excluded because they had variations in treatment (allograft replacement of the radial head in 1 patient, and no fixation of the coronoid fracture in 4 patients), leaving 18 patients that form the acute treatment cohort: all were treated with fixation or replacement of the radial head, internal fixation of the coronoid, and reattachment of the lateral collateral ligament to the lateral epicondyle of the distal humerus.

In the same period, 14 patients that had a terrible triad fracture dislocation presented with persistent subluxation of the elbow 3 weeks or more after inadequate initial treatment. This subacute treatment cohort had hinged external fixation routinely and reconstruction of the coronoid with a fragment of the excised radial head in 6 patients.

The human research committee at our institution approved a protocol for the retrospective review of medical records and for inviting patients with inadequate follow-up to return for a free evaluation and radiographs. Twenty-nine patients (16 in the acute treatment cohort and 13 in the subacute treatment cohort) returned for a research-specific follow-up. Three patients were evaluated on the basis of the medical record alone. A total of 26 patients were included in at least 1 of 3 previous articles.5,6,8

Acute treatment cohort
The acute treatment cohort consisted of 12 men and 6 women with an average age of 47 years (range, 22–76 years). Six patients were employed as laborers, 6 in a desk-based job, 4 were retired, 1 was unemployed, and 1 was a student.

Nine patients were injured in a fall from standing height and 9 in a fall from a greater height. Ten patients injured their right elbow (8 dominant), and 8 injured their left elbow (1 dominant). All patients had a radial head fracture, a coronoid fracture, and a posterior dislocation of the elbow. The origin of the lateral collateral ligament was avulsed from the lateral epicondyle in all patients. Nine of the radial head fractures were classified as type 2 fractures (more than 2 mm displacement and involving more than 30% of the joint surface) according to the Broberg and Morrey modification9 of the Mason classification10, and 9 were type 3 (comminuted fractures). All coronoid fractures were classified as type 2 (more than a fleck of bone, and involving less than 50% of the coronoid process) according to the Regan
and Morrey classification\textsuperscript{11} and as type 1 (coronoid tip fracture) according to O’Driscoll’s classification\textsuperscript{12}.

All patients were treated by a single surgeon at an average of 6 days after the injury (range, 1–13 days). A straight posterior longitudinal skin incision was used in every patient. The radial head was replaced with a metal prosthesis in 17 patients (in 16 patients the EVOLVE Modular Radial Head System was used [Wright Medical, Memphis, TN], and in 1 patient a Swanson Titanium Radial Head Implant [Wright Medical Technology Inc, Arlington, TN] was used) and repaired with screws in 1 patient. The coronoid fracture was secured with a nonabsorbable suture in all patients, and in 2 of them an additional screw was used to achieve stable fixation. The lateral collateral ligament was reattached to the lateral epicondyle of the distal humerus using a suture anchor in 13 patients and nonabsorbable suture passed through drill holes in 5 patients. The ulnar nerve was released\textit{ in situ} in 3 patients and in 1 patient it was transposed anteriorly. None of the patients had a hinged external fixator applied.

Four patients had ipsilateral arm injuries: 2 patients had wrist fractures (one was treated in a cast, and the other had associated compartment syndrome treated with fasciotomy and internal fixation of the fracture, followed by closure of the fasciotomy 2 weeks later); 1 patient had an extra-articular fracture of the proximal ulna treated with a plate; and 1 patient had an associated carpal tunnel syndrome that was released. Three patients had contralateral wrist fractures (with a concomitant scaphoid fracture in 1 patient), and 1 patient had a posterior Monteggia fracture dislocation of the other arm.

Five patients had 6 additional surgeries after the index procedure. Two patients had a release to address stiffness, with simultaneous transposition of the ulnar nerve in one patient and release of the ulnar nerve and excision of anterior and posterior heterotopic bone blocking flexion and extension in the other patient. Two other patients had transposition of the ulnar nerve, complicated by a wound infection requiring another surgery for irrigation and debridement in 1 patient. None of the patients in whom the ulnar nerve was addressed had had a prior release or transposition of the nerve. Another patient sustained a distal humerus fracture of the same elbow 10 months after the terrible triad injury and was treated with open reduction and internal fixation.

\textit{Subacute treatment cohort}

The subacute treatment cohort consisted of 10 men and 4 women with an average age of 48 years (range, 24–58 years). Eleven patients did desk-based work and 3 were employed as laborers. Ten patients were injured in a fall from a standing height and 4 in a fall from a greater height. Ten patients injured their right elbow (all dominant), and 4 injured their left elbow (2 dominant). Four patients had a type 3 and 10 patients a type 2 fracture of the radial head according to the Broberg and Morrey modification\textsuperscript{9} of the Mason classification.\textsuperscript{10} All
patients had Regan and Morrey\textsuperscript{11} type 2 and O’Driscoll\textsuperscript{12} type 1 fractures of the coronoid process.

Ten patients had initially been treated with closed reduction and cast immobilization. Four patients had had 5 operative procedures prior to presentation to us: in 2 patients the radial head fracture fragments were removed (partial radial head excision) with repair of the lateral collateral ligament in one of them, and in 2 patients the radial head fracture was repaired with screws. One of the patients treated with screw fixation experienced recurrent dislocation and fixation failure and was treated with replacement of the radial head using a metal prosthesis. This patient’s second surgery was complicated by infection and subluxation of the proximal radius. The infection was initially treated with oral antibiotics, but after the infection reactivated 3 months later, this patient was referred to our institution. Three patients had ipsilateral distal radius fractures; 2 were treated in a cast and 1 with internal fixation. One of these patients also had a contralateral distal radius fracture with associated carpal tunnel syndrome and a compartment syndrome treated with release and external fixation of the distal radius. Another patient had a contralateral radial head fracture.

All 14 patients presented with subluxation or dislocation of the ulnohumeral joint. One presented with an active infection. The index operative procedure was performed at an average of 7 weeks after the injury (range, 3–13 weeks). The patient with infection was treated with irrigation and debridement, removal of the prosthesis, excision of heterotopic bone, and application of an external fixator. Except for this patient, all patients had replacement of the radial head with a metal prosthesis (in 10 patients the EVOLVE Modular Radial Head System was used, and in 2 patients the Swanson Titanium Radial Head Implant was used; in 1 patient, the rHeadRECON Implant System [Avanta Orthopaedics Inc, San Diego, CA] was used). The coronoid fracture was reconstructed with a fragment of the radial head secured with a screw in 6 patients, was reduced and secured with a nonabsorbable suture in 3 patients, and was not addressed in 5 patients, including the patient who presented with an infection and 4 other patients in whom the fracture of the coronoid represented less than 30% of the total coronoid height. The lateral collateral ligament was reattached to the lateral epicondyle of the distal humerus with a suture anchor in all patients except for the patient with an infection. The ulnar nerve was released \textit{in situ} in 1 patient and transposed anteriorly in the remaining 13 patients. One patient with an ipsilateral distal radius fracture treated in a cast had a chronic idiopathic carpal tunnel syndrome that was released at the time of the index procedure. A hinged external fixator (in 3 patients, the OptiROM Elbow Fixator [EBI {Biomet}, Parsippany, NJ] was used, and in 11 the Compass Universal Hinge [Smith & Nephew, Memphis, TN] was used) was applied to protect stability and removed after an average of 6 weeks (range, 4–10 weeks).
One patient had 2 subsequent operative procedures to the elbow: capsular release with release of the ulnar nerve 3 months after the index surgery followed by a second release with removal of heterotopic bone 9 months later.

Comparison of cohorts
There were no differences between cohorts in terms of age at injury, gender, limb dominance, laborer versus nonlaborer occupation, associated injuries, and the number of additional surgeries.

Evaluation
The results are reported at 2 time points: (1) immediately prior to any subsequent operative procedures or the most recent evaluation in patients who did not have subsequent surgery, and (2) the most recent evaluation after all subsequent operations—at least 1 year after surgery. All but 3 patients had a physical examination at least 1 year after surgery available in the medical records or research archives. For the remaining 3 patients, we included evaluations performed at 9, 10, and 11 months after surgery. All patients were evaluated according to the rating system of Broberg and Morrey. Sixteen patients in the acute treatment cohort and 13 in the subacute treatment cohort were also evaluated with use of the Mayo Elbow Performance Index (MEPI) and completed the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire. The rating system of Broberg and Morrey is a 100-point system based on the physician’s assessment of motion, strength, stability, and pain. In the categorical rating, 95 to 100 points is rated excellent; 80 to 94, good; 60 to 79, fair; and less than 60 points, poor. The MEPI consists of the physician’s assessment of pain, ulnohumeral motion, stability, and ability to perform functional tasks. Categorical ratings are assigned as follows: 90 to 100 points is excellent; 75 to 89 is good; 60 to 74 points is a fair outcome; and a score of less than 60 points is considered poor. The patient-completed DASH questionnaire evaluates difficulty with performing specific tasks, as well as symptoms, social function, work function, sleep, and confidence. The score is scaled between 0 and 100 with higher scores indicating worse upper extremity function.
Ulnar nerve dysfunction was graded according to the McGowan scale, and arthrosis was rated by an independent observer according to the system of Broberg and Morrey.

Statistical analysis
The 2 cohorts were compared using Student’s t-test for continuous variables and using Fisher’s exact test for dichotomous variables. Differences in motion between the early and late evaluation within each cohort were compared with the paired t-test. P values of less than .05 were considered statistically significant.
Univariate analysis was performed to assess association between independent (or explanatory) variables and dependent (or response) variables. Response variables investigated included the final flexion arc and DASH scores. The association between response variables with continuous explanatory variables (age and follow-up time) was assessed with Pearson correlation, and the association with dichotomous explanatory variables (acute vs subacute treatment, gender, laborer occupation, limb dominance, associated injuries, additional surgeries, arthrosis, and ulnar neuropathy) was assessed with use of Student’s t-test.

Multiple linear regression analysis was used to analyze the ability of the explanatory variables to account for variation in each of the response variables, accounting for any confounding between the explanatory variables. A multiple linear regression model produces a statistic called the adjusted R-squared, which reflects the percentage of the overall variability in the response variable that can be explained or accounted for by the explanatory variables included in the multiple linear regression model. The number of explanatory variables that can be included in a multivariate model is limited by the overall sample size of the study. Therefore, instead of entering all of our potential explanatory variables into the backwards stepwise models, we chose to enter only those variables that were either significant (p < .05) or nearly significant (p < .10) in the univariate analysis, a common cut-off value for inclusion of variables in regression modeling.

Multivariate analysis of variance (MANOVA) was performed to assess statistical significance of the multivariate models, which indicates a linear relationship between at least one of the explanatory variables with the response variable. SPSS software was used for statistical analysis (version 15.0; SPSS Inc., Chicago, IL).

Results

Prior to subsequent surgeries

The result of the index procedure was recorded an average 24 months (range, 3–53 months) after the index procedure in the acute treatment cohort and an average of 38 months after the index procedure in the subacute treatment cohort (range, 2–69 months; p = .09).

In the acute treatment cohort, the flexion arc averaged 116° (range, 60° to 140°) with an average flexion of 132° (range, 90° to 145°) and an average flexion contracture of 16° (range, 0 to 45°). Forearm rotation averaged 153° (range, 100° to 180°) with an average 83° of pronation (range, 50° to 90°) and an average 70° of supination (range, 20° to 90°). Four patients had signs of ulnar nerve dysfunction. None of the patients had unstable elbows.

In the subacute treatment cohort, the flexion arc averaged 91° (range, 10° to 130°) with an average flexion of 125° (range, 90° to 140°) and an average flexion contracture of 34° (range, 10° to 80°). The arc of forearm rotation averaged 125° (range, 20° to 165°) with an average
pronation of 72° (range, 10° to 90°) and an average supination of 53° (range, 10° to 85°). Two patients had signs of ulnar nerve dysfunction.

Patients who had acute treatment of the terrible triad injury did significantly better than did patients who had subacute treatment in terms of flexion arc (p < .05), flexion contracture (p < .01), forearm rotation (p < .05), and supination (p < .05). There were no statistically significant differences in flexion (p = .23), and pronation (p = .08) between cohorts.

After all subsequent procedures

The final evaluation was performed at an average 29 months after treatment (range, 10–53 months) in the acute treatment cohort and at an average 34 months (range, 9–66 months; p = .39) in the subacute treatment cohort.

In the cohort of patients who had acute treatment, the final flexion arc averaged 119° (range, 75° to 145°) with an average flexion of 135° (range, 120° to 145°) and an average flexion contracture of 17° (range, 0 to 45°). The average arc of forearm rotation was 141° (range, 70° to 180°) with an average pronation of 78° (range, 45° to 90°) and an average supination of 63° (range, 20° to 90°). One patient who had had a subsequent transposition of the ulnar nerve had slight symptoms of ulnar nerve dysfunction at the final evaluation (grade 1). None of the patients had an unstable elbow. Nine patients had mild arthrosis (grade 1), and 3 patients had moderate arthrosis (grade 2). The average Broberg and Morrey rating was 90 points (range, 64–100 points) with 5 excellent, 10 good, and 3 fair results. The DASH score averaged 15 points (range, 0–43 points), and the MEPI score averaged 88 points (range, 65–100 points) with 6 excellent, 8 good, and 2 fair results.

In the subacute treatment cohort, the flexion arc averaged 100° (range, 45° to 130°) with an average flexion of 130° (range, 115° to 140°) and an average flexion contracture of 30° (range, 10° to 70°). The average arc of forearm rotation was 126° (range, 60° to 165°) with an average pronation of 75° (range, 50° to 90°) and an average supination of 50° (range, 0 to 85°). Two patients had signs of ulnar nerve dysfunction (both grade 1). One patient had very slight subluxation. Five patients had arthrosis: mild (grade 1) in 4 patients and moderate (grade 2) in 1 patient. The Broberg and Morrey score averaged 87 points (range, 55–98 points) with 3 excellent, 9 good, 1 fair, and 1 poor result. The average DASH score was 18 points (range, 0–49 points). The average MEPI score was 88 points (range, 45–100 points) with a categorical rating of 9 excellent, 1 good, and 1 poor result.

The improvements in motion between the early and late evaluation within the acute and the subacute cohorts were not statistically significant. Patients who had acute treatment of their terrible triad injuries did significantly better in terms of flexion arc (p < .05) and flexion contracture (p < .05) when compared with patients who had subacute treatment. There were no statistically significant differences between cohorts in terms of flexion (p = .10), arc of forearm rotation (p = .23), pronation (p = .58), supination (p = .17), ulnar nerve dysfunction (p
Univariate and multivariate analysis

Flexion arc
In univariate analysis, there was significant association between flexion arc with treatment (acute vs subacute; $p < .05$) and additional surgeries ($p < .05$). After backward regression analysis, the multivariate model included both treatment and additional surgeries and explained 36% of the variation in flexion arc ($p < .001$). A model with acute versus subacute treatment alone accounted for 15% of the variability in flexion arc ($p < .05$).

Patient-perceived disability (DASH)
Univariate analysis revealed significant association between DASH scores and associated injuries ($p < .05$) and near-significant association with age ($p = .07$). The best multivariate model after backward regression analysis included both variables and explained 22% of the variation in DASH scores ($p < .05$).

Discussion
Patients who had treatment under a protocol that addresses each component of the terrible triad injury (ie, radial head and coronoid fractures, and the avulsed lateral collateral ligament) within 2 weeks from the injury had a significantly better flexion arc than did patients who were treated in a subacute phase ($119^\circ$ vs. $100^\circ$; $p < .05$) using additional techniques such as selective coronoid reconstruction and routine hinged external fixation. The relatively high average Broberg and Morrey scores in both the acute and subacute cohort (90 and 87 points) reflect the low average pain scores as well as the successful restoration of strength and stability, irrespective of the timing of surgery. The differences in impairment are related primarily to loss of motion. Based on our findings, prompt recognition and definitive treatment of the fractures of the coronoid and radial head and reattachment of the lateral collateral ligament to the lateral epicondyle resulted in better results than did delayed treatment. Treatment in the subacute setting with hinged external fixation resulted in satisfactory elbow function and motion in most patients but with a greater flexion contracture on average than in patients treated in the acute phase. Of course, our data should be interpreted in light of the fact that these are retrospective and the cohorts are small—a reflection of the relative infrequency of these problems.
Fifteen of 18 patients in the acute treatment cohort and 12 of 14 patients in the subacute cohort had a good or excellent result according to the rating system of Broberg and Morrey. Except for 1 patient with a new distal humerus fracture, all fair and poor results were related
PART II  ELBOW TRAUMA

to ulnar nerve dysfunction or stiffness (related to the formation of heterotopic bone in 2 patients). Although 21 of 32 patients had arthrosis in our study, arthrosis was not significantly associated with flexion arc or disability (DASH). This is more arthrosis than has been noted at similar time points in other studies.3,18 It is difficult to make much of the relatively high rate of arthrosis in this study without knowing more about the reliability of radiographic evaluation of arthrosis—it is possible that we were relatively strict in our ratings. Furthermore, this raises concerns about what will happen in the long-term—although the joint can be made concentric and stable, it may still wear out over time, and it is not clear if this will affect function.

Few articles address the treatment of terrible triad injuries specifically, and no previous studies compared acute versus subacute treatment. The only other large series of patients who had acute treatment of terrible triad injuries by another institution was published by Pugh et al. and McKee et al.3,4 Our results of treatment within 2 weeks from the injury (average flexion arc of 119°) were comparable with the results of their 36 patients (average flexion arc of 112°), whereas our results with subacute treatment (average flexion arc of 100°) were somewhat worse. The treatment protocols3,4 were conceptually the same between studies, except for their tendency to repair rather than replace the fractured radial head: most radial heads in our study were replaced with a metal prosthesis, and we believe that replacement may often be more straightforward than repair with screws and/or plate. In the setting of an elbow fracture dislocation, the fracture of the radial head often has more than 3 fragments, lost fragments, and fragments too small to repair. The percentage of patients who had subsequent surgery was comparable between studies: excluding 1 patient who had open reduction and internal fixation of a new distal humerus fracture in our study, 4 of 18 patients in the acute treatment cohort had 1 or more additional surgeries compared with 8 of 36 patients in their study.

Several studies have addressed treatment of recurrent or persistent instability after different types of elbow fracture dislocations.6,7,17,18 Although postoperative treatment with a hinged external fixator may result in stable elbows in the majority of patients, stiffness and other complications are frequently observed.6,7,17,18 The study by Papandrea and colleagues7 included a relatively large series of 11 patients with a terrible triad injury. The average flexion arc of 105° in these patients was comparable with the average arc of 100° in our subacute cohort; however, the average MEPI score was much lower (average 69 points compared with 88 points in our study), primarily as a result of residual elbow instability. One important difference was the routine restoration of radiocapitellar contact (usually with a metal prosthesis) in our series, although in the series of Papandrea and colleagues, the repair of the medial collateral ligament in all patients may have offered some compensation for the absence of the radial head as a constraint to valgus laxity. The coronoid fractures were repaired or reconstructed with autograft or allograft in 8 of their 11 patients.7 Papandrea et al. also looked
at the timing of surgery: although acknowledging that acute treatment should be the primary objective, they found that when a patient does present with persistent or recurrent instability, early subacute treatment (ie, within 7 weeks of the injury) yields better results than does late subacute treatment—only 1 of 7 patients treated more than 7 weeks from the injury had a satisfactory result.\textsuperscript{7}

Prophylactic decompression or transposition of the ulnar nerve during initial treatment should be considered experimental until verified by additional research. Two of 18 patients who had an \textit{in situ} release (4 patients) or anterior transposition (14 patients) of the ulnar nerve as part of the index treatment in our study (4 in the acute cohort and 14 in the subacute cohort) had persistent ulnar nerve dysfunction at final evaluation, in spite of a subsequent release in 1 of these patients. Four of 14 patients who did not have release or transposition during the index treatment (all in the acute cohort) developed ulnar nerve dysfunction and had surgery to address this dysfunction; only 1 of these patients had dysfunction at the final evaluation. Although this is a substantial number of patients with ulnar neuropathy at relatively short follow-up and merits further study, the value of \textit{in situ} release at the time of the initial surgery remains unclear.

If the terrible triad fracture pattern is not readily recognized, delayed treatment of each component of the injury combined with postoperative protection using hinged external fixation will usually lead to good restoration of stability and strength, but the delay is associated with a diminished arc of flexion on average. Whereas the results of delayed treatment were surprisingly good, there is no question that delayed treatment is suboptimal, and this small, retrospective, short-term study cannot adequately evaluate problems such as arthrosis. Treatment of terrible triad injuries remains challenging, and secondary procedures may be needed in a substantial number of patients to address complications such as stiffness and ulnar nerve dysfunction.

\textbf{References}