Complex distal humerus trauma
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Citation for published version (APA):
Brouwer, K. M. (2012). Complex distal humerus trauma
CHAPTER 8
Resection of Heterotopic Ossification of the Elbow: a Comparison of Complete and Partial Ankylosis
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Abstract

Purpose: This study tests the hypothesis that the results of release of elbow stiffness related to heterotopic ossification (HO) are comparable whether there is partial or complete restriction (ankylosis) of flexion and extension.

Methods: Eighteen patients who had surgical release of complete bony ankylosis between the humerus and ulna were retrospectively compared to 27 matched patients who had surgical release of partial restriction of elbow flexion and extension related to HO. Patients were evaluated a minimum of 10 months after surgery, using the Disabilities of the Arm, Shoulder, and Hand questionnaire and the Broberg and Morrey rating system.

Results: An average of 22 months after surgery (range, 10 to 62 mo), the arc of flexion and extension averaged 95° in the ankylosis cohort and 93° in the partial HO cohort. Forearm rotation averaged 131° versus 134°; the mean Disabilities of the Arm, Shoulder, and Hand score was 28 versus 30 points; and the mean Broberg and Morrey score was 81 versus 84 points, respectively.

Conclusions: After controlling for other factors, patients with elbow stiffness related to HO can recover comparable motion after surgical release at short-term follow-up whether they have complete ankylosis or only partial restriction of motion.

Type of study/level of evidence: Therapeutic III.

Key words: Ankylosis; elbow motion; heterotopic ossification; release
Background
The results of surgical elbow contracture release are better (more motion and fewer reoperations) when there is a discrete block to motion from heterotopic ossification (HO) than when there is capsular contracture alone.\textsuperscript{1, 2} It is not clear that this holds true in cases of complete ulnohumeral ankylosis from heterotopic bone—a particularly complex subset of patients with HO.\textsuperscript{3, 4} The complete absence of joint motion might be harmful to the articular cartilage, and the surgery is more complex, with greater difficulty finding the limitations of heterotopic and native bone, frequent ossification of the medial collateral ligament, and occasional entrapment of the ulnar nerve in bone.\textsuperscript{3, 4} We tested the null hypothesis that, controlling for other factors, patients with complete bony ankylosis and patients with HO causing partial limitation of motion have similar motion after elbow contracture release.

Methods
Using a billing database, we identified patients who had elbow contracture release with removal of HO by one of 2 surgeons between January 2000 and July 2006. The following inclusion criteria were applied: (1) skeletal maturity, (2) posttraumatic or post-burn contracture, (3) arc of elbow flexion and extension less than 100°, (4) no prior contracture release, (5) no active infection, (6) no diagnosed nonunion of the supracondylar humerus or proximal ulna at the time of HO excision (nonunion of the medial epicondyle was acceptable), and (7) no advanced articular injury or arthritis.

Nineteen patients had complete ankylosis of the ulnohumeral joint due to HO. Eighteen of these 19 patients had a minimum of 10 months of follow-up in the medical record or agreed to return for a research-related visit using a protocol approved by the human research committee, and one declined participation. We attempted to match each of these 18 patients with 2 patients who had partial restriction of elbow motion due to HO. Matching was according to age, gender, mechanism/etiology (eg, severe burn vs trauma) and fracture type (if applicable). For 9 of the patients with ankylosis, we were able to identify only one suitable control. Therefore, the cohort of control patients with partial HO consisted of 27 patients.

Complete ankylosis cohort
The complete ankylosis cohort consisted of 12 men and 6 women with an average age of 39 years (range, 20–62 y). The left arm was involved in 10 patients (all right-handed) and the right arm in 8 patients (6 right-handed). One patient developed ankylosis from HO after injury to her cervical spinal cord, resulting in hemiplegia. Another developed HO after a severe closed head injury. In 2 patients, the ankylosis followed severe burn injuries. Fourteen patients developed ankylosis due to HO after an elbow fracture. Eight fractures occurred in motor vehicle collisions, 3 in falls from a height, 2 from gunshot, and 1 in a crushing injury. There were 6 fracture–dislocations, 7 fractures of the distal humerus (1 with concomitant injury to the proximal ulna, and 1 with concomitant injury to the proximal radius), and 1 fracture of the proximal ulna. Four fractures were open. Ten patients had ipsilateral arm injuries. The
initial treatment was surgical in 12 patients and nonsurgical in 2 patients. Two patients with fractures had serial irrigation and debridement for infection after the index procedure to repair the fracture.

The interval between the initial injury/event and the index surgery for release of the bony ankylosis averaged 13 months (range, 4–66 mo). The average angle of the ankylosis was 58° (range, 15 to 100°). The mean preoperative arc of forearm rotation was 55° (range, 0° to 180°), with an average pronation of 24° (range, 20° supination to 90° pronation) and an average supination of 31° (range, 0° to 90°). Twelve patients had motor and sensory ulnar nerve dysfunction recorded in the medical record.

The contracture release was performed using combined medial and lateral muscle intervals in 17 patients and a lateral muscle interval in one patient who had ulnar nerve transposition and sural nerve grafting at a prior procedure and had limited heterotopic bone on the medial side. A single posterior skin incision was used unless prior incisions made separate medial and lateral incisions more favorable. The ulnar nerve was transposed anteriorly in 17 patients and had been transposed at a prior surgery in the remaining patient. Fifteen patients received a single 7 Gy dose of preoperative radiation as prophylaxis for the recurrence of heterotopic bone. Two of these patients and one additional patient were prescribed indomethacin, 25 mg 3 times a day for 2 weeks after surgery. Two patients did not receive any prophylaxis for the recurrence of HO.

Partial restriction cohort
The cohort of control patients with partial restriction of motion consisted of 21 men and 6 women with an average age of 42 years (range, 18 to 62 y). The left arm was involved in 9 patients (one left-handed) and the right arm in 18 patients (13 right-handed). Twenty-three patients developed HO after an elbow fracture, 2 after severe burns, and 2 after closed head injuries.

Among the 23 patients with HO after fracture, 6 were injured in motor vehicle collisions, 8 in falls from a standing height, 7 in falls from a greater height, 1 by a gunshot injury, and 1 patient by a crushing injury. There were 7 fracture–dislocations, 13 fractures of the distal humerus (2 with concomitant injury to the proximal ulna and the proximal radius, 2 with concomitant injury to the proximal radius alone), and 3 fractures of the proximal ulna. Four fractures were open. The initial fracture treatment was surgical in 19 patients and nonsurgical in 4 patients. Fourteen patients had additional surgeries before the index surgery for revision of internal fixation or irrigation and debridement.

The average time between the injury/event and the index elbow contracture release was 13 months (range, 2–32 mo). The surgery was done 2 months after the original surgery was performed at that early time to address possible deep infection and an errant screw. The average arc of flexion and extension before release was 47° (range, 30° to 95°), with an average flexion of 98° (range, 10° to 130°) and an average flexion contracture of 51° (range, 10° to 90°). The average
arc of forearm rotation was 108° (range, 0° to 180°), with average supination of 52° (range, 0° to 90°) and average pronation of 56° (range, 0° to 90°). Twelve patients had motor and sensory ulnar nerve dysfunction recorded in the medical record.

In the partial motion restriction cohort, the releases were performed using a lateral muscle interval in 6 patients, a medial muscle interval in 5 patients, and combined intervals in 16 patients. Ulnar nerve transposition was performed in all patients, through a medial or combined interval. Seven patients received irradiation before surgery, and one patient was prescribed indomethacin.

**Postoperative management**

Self-assisted and gravity-assisted active hand, wrist, elbow, and shoulder motion exercises were initiated the morning after surgery. Brachial plexus catheters and continuous passive motion were used inconsistently by one of the surgeons. Six patients in the partial restricted motion cohort had brachial plexus catheters for an average of one day (range, 1–2 d). Continuous passive motion was used in 15 patients, 14 in the partial restricted motion cohort and 1 in the complete ankylosis cohort. Fourteen patients who had difficulty regaining the motion that was obtained in the operating room despite active exercises began using static progressive or dynamic splints between 4 and 6 weeks after surgery: 7 in the complete ankylosis cohort and 7 in the partial restricted motion cohort.

**Statistical comparison of cohorts**

The cohorts were comparable in terms of age, gender, limb dominance, etiology, open injuries, dislocation, initial injury type, distal humerus fractures, ipsilateral upper extremity injuries, number of surgeries after the initial treatment and before the index release, preoperative ulnar nerve dysfunction, occupation and mechanism of injury, and time of follow-up, confirming adequate matching (all \( p > .05 \)). Patients in the ankylosis cohort were treated significantly more often with radiation (82% vs 29%, \( p < .005 \)), used continuous passive motion less frequently (6% vs 58%, \( p < .005 \)), and had worse preoperative forearm rotation than patients in the partial restriction cohort (\( p < .01 \)).

**Complications and subsequent surgeries**

Four patients in the partial restriction cohort had one or more elbow surgeries after their initial HO excision. One patient had a total of 5 subsequent surgeries: repeat elbow contracture release (capsule only); several debridements to treat a deep infection after the second contracture release; and finally, open reduction internal fixation and autogenous cancellous bone grafting of a nonunion of the proximal ulna. Another patient had a total of 3 subsequent surgeries: open reduction internal fixation and autogenous cancellous bone grafting of a nonunion of the proximal ulna; release of a proximal radioulnar synostosis; and finally, a radial head excision. A third patient had a subsequent surgery to address recurrent heterotopic bone. A fourth patient had 2 subsequent surgeries: one for implant removal and a second for debridement of an infection that followed the implant removal.
Four patients in the complete ankylosis cohort had one or more subsequent elbow surgeries. Two patients had irrigation and debridement of a deep infection and implant removal, and 2 patients had surgery to address recurrent heterotopic bone.

**Evaluation**
Seven patients with fewer than 10 months follow-up in the medical record were asked to return for a research–specific follow-up visit. All patients completed the Disabilities of the Arm, Shoulder, and Hand® (DASH) questionnaire, either at that visit or by phone. Arthritis was rated according to the system of Broberg and Morrey: grade 0 (a normal joint), grade 1 (slight joint-space narrowing with minimum osteophyte formation), grade 2 (moderate joint-space narrowing with moderate osteophyte formation), or grade 3 (severe degenerative change with gross destruction of the joint).

**Statistical analysis**
Differences between continuous variables were evaluated using Student's $t$-test. Differences in dichotomous variables were evaluated using Fisher’s exact test.

**Results**
The average follow-up for evaluation of final motion was 26 months (range, 10–62 mo) among patients with complete ankylosis and 20 months (range, 10–56 mo) in the partial restriction cohort. The average follow-up for evaluation of DASH scores was 34 months (range, 14–72 mo) among patients with complete ankylosis and 28 months (range, 12–66 mo) in the partial restriction cohort.

In the complete ankylosis cohort, the final average arc of flexion and extension was 95° (range, 25° to 140°), with an average flexion of 121° (range, 65° to 145°) and average flexion contracture of 26° (range, 0° to 50°). The average arc of forearm rotation was 131° (0° to 180°), with an average pronation of 73° (range, 0° to 90°) and an average supination of 59° (range, 0° to 90°). Seven patients had ulnar nerve dysfunction recorded in the medical record at final follow-up, of which 5 patients had ulnar nerve dysfunction before their release. We are not confident that ulnar nerve dysfunction was consistently or reliably noted in the preoperative medical record. The average DASH score was 28 (range, 1–64) and the average Broberg and Morrey score was 81 (range, 50–100). Categorical ratings according to the Broberg and Morrey system were 2 poor, 5 fair, 9 good, and 2 excellent results. Eight patients had grade 1 arthritis, 2 patients had grade 2 arthritis, and 2 patients had grade 3 arthritis, according to the Broberg and Morrey system.

In the partial restriction cohort, the average arc of flexion and extension was 93° (range, 20° to 140°) with an average flexion of 122° (range, 90° to 145°) and an average flexion contracture of 29° (range, 0° to 80°). The average arc of forearm rotation was 134° (range, 20° to 180°), with an average pronation of 73° (range, 10° to 90°) and an average supination of 61° (range, 0° to 90°). Five patients had postoperative ulnar nerve dysfunction. The average DASH score was 30 (range, 3–84), and the average Broberg and Morrey score was 84 (range, 66–100). Categorical ratings were 9 fair, 15 good, and 3 excellent results. Twelve patients
had grade 1 arthritis, 1 patient had grade 2 arthritis, and 2 patients had grade 3 arthritis.

Statistical analysis
There were no significant differences between the complete ankylosis and partial HO cohorts in final flexion (p = .89), final extension (p = .54), final arc of flexion and extension (p = .79), pronation (p = .99), supination (p = .84), arc of forearm rotation (p = .88), DASH score, (p = .78), or Broberg and Morrey Functional Rating Index (p = .41). According to the Fisher's exact test, there were no statistical differences in arthritis (p = .08) or ulnar nerve dysfunction (p = .16) at final evaluation.

Discussion
The study of elbow stiffness is complicated by variability in—among other things—the etiology of the contracture; associated problems including heterotopic bone, nonunion, and ulnar neuropathy; and surgical release technique. Prospective study designs and adequate control for the numerous sources of variation in pathophysiology and treatment are difficult to achieve because specific types of elbow stiffness are relatively uncommon. The strengths of this series are that 2 surgeons used similar surgical techniques to release a complete bony ankylosis in a relatively large number of patients with this uncommon problem and that we were able to match these patients with comparable patients who had heterotopic bone with reduced range of motion but without bony ankylosis. This case-control study design is intended to limit the sources of bias and variability inherent in retrospective studies of uncommon conditions. These data should be interpreted in light of the fact that patients who had other surgeries and problems after the contracture release (eg, nonunion and infection) were included as if the study were done prospectively according to intent-to-treat principles. The rationale was that patients with complex posttraumatic contractures can be expected to have additional problems and surgeries, and this should be considered an integral part of their management. The patients with nonunions did not do appreciably worse than the other patients. Considered in light of the limitations of this study (including small numbers of patients, mixed contracture types and patient characteristics, non-standard postoperative protocols, chart-based retrospective evaluation, imperfect evaluation of ulnar nerve function, relatively short follow-up, and difficulties with patient matching) our data suggest that the results of release of complete bony ankylosis are comparable to those for partial restriction of motion from HO.

It is difficult to compare the improvements in motion and impairment in this series with those observed in prior series, because so few prior authors separated the patients with posttraumatic complete bony ankylosis. Djurickovic and colleagues reported poor results in the 3 patients with burn contractures who had complete ankylosis. Ring and Jupiter reported a final average arc of elbow flexion and extension of $81^\circ$ for 7 patients with burn-related complete bony ankylosis and $94^\circ$ for 9 patients with trauma-related complete ankylosis. Most series describe the surgical release of contractures of mixed etiologies, with improvements in the arc of flexion and extension of approximately $45^\circ$ to $60^\circ$—comparable to the results in
Our series\textsuperscript{1, 5-7, 10} The relatively lower improvements in the partial HO cohort of this series compared to a prior series\textsuperscript{1} might be a result of the matching, resulting in a subset of patients with more complex and difficult contractures. Recurrence of HO sufficient to merit surgery was uncommon in this and prior series.

It is also difficult to sort out the influence of etiology on the results of contracture release. Ring and Jupiter found slightly worse, but comparable, results of release of bony ankylosis in patients with burn-related ankylosis when compared to patients with trauma-related ankylosis\textsuperscript{4}. Tsionos and colleagues reported an average final flexion–extension arc of 123° among 35 elbows with burn-related HO and an average preoperative flexion–extension arc of 22°\textsuperscript{11}. Itoh and colleagues reported improvement after release of heterotopic bone of 59° in patients with trauma, 72° in patients with quadriplegia, and 127° in patients with severe closed head injury.\textsuperscript{12}

Study of the surgical treatment of elbow stiffness will be advanced by multicenter prospective cohorts that can accumulate sufficient numbers of patients treated using comparable techniques to allow us to sort out the influence of etiology and associated problems such as HO on the final result. The data to date suggest that HO is a good prognostic factor in general and that complete ankylosis by bone is not a negative prognostic factor, at least when controlling for other aspects of the contracture. Additional investigation is needed to confirm these findings and further clarify the treatment of elbow stiffness.

References