Clin Orthop Relat Res (2014) 472:2269–2275
DOI 10.1007/s11999-014-3591-0

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

CLINICAL RESEARCH

Heterotopic Ossification of the Elbow Treated With Surgical Resection: Risk Factors, Bony Ankylosis, and Complications

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Received: 15 August 2013 / Accepted: 18 March 2014 / Published online: 8 April 2014

Abstract

Background Heterotopic ossification is the most common extrinsic cause of elbow contracture and may lead to clinically important stiffness, and rarely, complete bony ankylosis. Surgery sometimes is performed to treat this problem, and published reports differ regarding the factors that are associated with success or failure after this operation and whether the procedure is effective for patients with elbow ankylosis.

Questions/purposes We wished (1) to identify potential patient characteristics and modifiable risk factors that are associated with improvements in ROM after surgery for heterotopic ossification of the elbow; (2) to compare ROM gains between patients with complete ankylosis and partially restricted ROM; and (3) to characterize the complications of elbows treated by surgical release and excision of heterotopic ossification followed by a standardized rehabilitation program.

Methods We reviewed the records of all patients treated operatively for heterotopic ossification of the elbow from September 1999 to February 2012 at one institution by one surgeon. General indications for the surgery were clinically symptomatic or debilitating heterotopic ossification of the elbow. Each patient received prophylaxis postoperatively consisting of indomethacin (or single-shot radiation for patients with sensitivity to antiinflammatory medications). All patients received a physical therapy regimen and used a continuous passive motion machine for 6 weeks. Patient demographics, mechanism of injury, time between injury and surgery, and medical history were reviewed for comparison. Followup was at a mean of 13 months (range, 3–106 months); no patients were lost to followup. Thirty-nine patients (46 elbows) with heterotopic ossification treated with excision were identified: 10 patients (16 elbows) had burns, 28 patients (29 elbows) had trauma, and one patient (one elbow) had a closed head injury. Eight of the 39 patients (12 of 46 elbows [26%]) had complete ankylosis at the time of surgery.

Results Hypertension, obesity, and absence of intraoperative anterior ulnar nerve transposition were associated with an adverse effect on change from preoperative to final arc of motion. The group with ankylosis had greater preoperative to postoperative gain in arc compared with the group with partial restriction (96°, 95% CI, 84°–107° and 59°, 95% CI, 46°–72°, respectively). For the entire cohort there was an overall improvement in mean flexion-extension arc of

One of the authors certifies that he (GM), or a member of his or her immediate family, has or may receive payments or benefits, during the study period, an amount of less than 10,000 USD from Zimmer Inc (Warsaw, IN, USA).
All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.
Each author certifies that his or her institution approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
This work was performed at Loyola University Medical Center, Maywood, IL, USA.

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motion from 35° to 103° at final followup ($p < 0.001$; 95% CI, 57°–80°), with a 17% rate of complications (three patients [three elbows] with heterotopic ossification, three patients [three elbows] with nerve palsies, one patient [one elbow] with deep wound infection, and one patient [one elbow] with an unstable elbow).

Conclusions Patients with partially and completely restricted ROM showed substantial improvement in postoperative ROM. Hypertension, obesity, and absence of intraoperative anterior ulnar nerve transposition were negative predictors of outcome in our series. Surgery combined with postoperative prophylaxis and a regimented rehabilitation program are feasible modalities to treat patients with heterotopic ossification of the elbow.

Level of Evidence Level IV, therapeutic study. See the Instructions for Authors for a complete description of levels of evidence.

Introduction

Heterotopic ossification is the formation of mature lamellar bone in extraosseous soft tissues. It can result from local or systemic insults. Patients who sustain direct trauma, central nervous system trauma, and thermal burns are at an increased risk for development of heterotopic ossification [1]. The incompletely understood pathophysiology of this condition is likely multifactorial [7, 8]. The elbow is the most common site for heterotopic ossification in patients with thermal burns [9, 12, 17, 25]. Because heterotopic ossification about the elbow usually is localized and runs a self-limited course without long-term symptoms or permanent impairment, its incidence may be underreported [25]. By contrast, extensive heterotopic ossification of the elbow can lead to clinically important contractures, and rarely, complete ankylosis [3]. Complete ankylosis of the elbow can be debilitating to patients and as a result of its relative rarity, recurrence rates, and complications, poses a substantial challenge to treating surgeons [10, 15, 19].

Owing to the uncommon nature of symptomatic elbow heterotopic ossification and ankylosis requiring surgical resection, there is a paucity of large clinical trials. Therefore it is unclear if patient-specific modifiable risk factors exist that affect postoperative gains in ROM and overall outcome. In addition, there have been only a few small studies exploring the results of patients treated surgically for complete bony ankylosis of the elbow [2, 4, 22, 24].

The purposes of our study, therefore, were to (1) identify potential patient characteristics and modifiable risk factors that are associated with improvements in ROM after surgery for heterotopic ossification of the elbow; (2) compare ROM gains between patients with complete ankylosis and partially restricted ROM; and (3) characterize complications in elbows treated by surgical release and excision of heterotopic ossification followed by a standardized rehabilitation program.

Patients and Methods

After institutional review board approval, retrospective analysis of medical records and imaging was performed for all patients who underwent surgical excision of ectopic bone around the elbow from September 1999 to February 2012 by an experienced shoulder and elbow surgeon (GM). General indications for this procedure during the period in question included painful or restricted ROM causing functional debilitation that was attributed to heterotopic ossification after a complete history, physical examination, and radiographic workup. We identified 40 patients (47 elbows) who potentially were eligible. Of those, 39 of 40 (97%) patients were available for followup at the defined minimum of 3 months. This left 39 patients (46 elbows) treated with surgical excision of ectopic bone around the elbow for analysis at a mean of 13 months (range, 3–106 months).

The 39 subjects included 27 men and 12 women. The patients' mean age was 41 years (range, 18–71 years), with 10 patients (16 elbows) having burns, 28 patients (29 elbows) having trauma, and one patient (one elbow) having a closed head injury. There were nine patients (14 elbows) with thermal burns and one patient (two elbows) with chemical burns. The mean body surface area affected was 58% (range, 30%–87%). The right elbow was involved 57% (26 of 46) of the time and the left elbow 43% (20 of 46), with seven of the 39 patients having bilateral involvement.

All surgeries were performed on an inpatient basis at a Level I trauma hospital. Preoperative radiographs and CT scans were obtained for each patient. Diagnosis and evaluation of the maturation of heterotopic ossification were established using orthogonal views on plain elbow radiographs. CT was performed to establish the relationship between the ectopic bone and neurovascular structures and for preoperative planning. Patient demographic data, including age, sex, mechanism of injury, history of tobacco use, and preexisting medical conditions, were recorded and used for comparisons.

Surgery

All surgeries were performed with the patient under general anesthesia, and an indwelling interscalene catheter was used to aid with intraoperative and postoperative pain control. Surgical approaches were individualized considering the location of the burn scar, previous incisions, skin condition, and extent of heterotopic ossification.

Surgical resections were planned by anatomic location and the extent of the ectopic bone to maximize heterotopic ossification resection while protecting and preserving important structures. Rongeurs, osteotomes, and a motorized burr were used to resect ectopic bone down to the level of the joint. An initial capsulotomy was performed in all cases after removal of impinging ectopic bone. If a persistent contracture was present a capsulectomy was performed. The collateral ligaments were identified and protected as the remaining heterotopic ossification was removed. After removal of the heterotopic ossification, intraoperative ROM in the flexion-extension arc was recorded. A sterile goniometer was used to measure all intraoperative ROM.

The joint was irrigated and bleeding cancellous bone surfaces were covered with bone wax to minimize postoperative hematoma. The ulnar nerve was decompressed, and after this, the decision to perform an anterior transposition was based on the extent of skin grafting along the medial aspect of the elbow. If substantial skin and subcutaneous scarring were present, an anterior subcutaneous transposition of the ulnar nerve and minimal medial epicondylectomy were performed. Drains were placed and the muscle, fascia and skin were closed. A bulky dressing was applied to the extended limb.

Postoperative Management and Prevention

The dressing and drains were discontinued on postoperative Day 2. After removal of the drains, patients were started on continuous passive motion machines (Kinetec 6080, Patterson Medical, Warrenville, IL, USA) for 12 hours per day. Indwelling interscalene anesthesia catheters were used to aid with pain control during the immediate postoperative period. The catheters were discontinued 24 hours before discharge to ensure patients had adequate pain control with an oral narcotic regimen and could tolerate passive ROM. Patients were discharged home with a continuous passive motion machine and the regimen was continued for 6 weeks postoperatively. At discharge, all patients were accompanied by a representative of the device manufacturer to ensure that all continuous passive motion machines had been delivered, were in working order, and that the family and patient understood how to use the machine properly.

Two weeks postoperatively, patients were seen in the outpatient office to perform a wound check, remove sutures, and measure ROM. All ROM measurements were performed by the senior author (GM) using a goniometer to maximize the reliability and reproducibility. Therapist-guided active, active-assisted, and passive ROM now were started five times per week. Use of the continuous passive motion machines was continued but decreased to 6 hours per day. Six weeks after surgery, continuous passive motion therapy was discontinued completely and therapist-guided physical therapy was reduced to three times per week. At 12 weeks, patients were discharged from therapy and given a home therapy regimen that included simple ROM exercises.

For prevention of heterotopic ossification recurrence, all but three patients underwent a 6-week course of 75 mg per day oral indomethacin. Nonsteroidal antiinflammatory medications were contraindicated in the three patients secondary to a known drug allergy. Therefore, radiation was substituted for indomethacin. They were treated with a one-time dose of radiation therapy (700 cGy) within 48 hours after surgery. Patients were called weekly for the first 4 weeks by either a resident physician or clinical nurse on the research team to monitor compliance with the continuous passive motion therapy, physical therapy, and heterotopic ossification prophylaxis.

Statistical Analysis

Patient baseline characteristics of the two groups also were compared using Fisher's exact test for nominal variables and t-test for continuous variables. The primary end point of interest was flexion-extension ROM. Other outcomes scores were not considered in this analysis. To identify patient characteristics and modifiable risk factors, we subdivided the cohort into two groups, patients with complete ankylosis and patients with partially restricted ROM. These characteristics and factors of the two groups and differences in arc were compared using Student's t-tests for continuous variables. Observed differences between preoperative and postoperative ROM and between patients with partial and complete restriction of flexion-extension of the elbow were determined with independent t-tests or Mann-Whitney nonparametric tests when the sample size was small. Paired t-tests analyzed differences at each time for each of the two groups. We performed regression analysis against improvement in overall flexion-extension ROM and continuous variables such as age and injury to intervention. SPSS Version 20.0 (SPSS Inc, Chicago, IL, USA) was used; a p value less than 0.05 was considered significant.

Results

The baseline comparison of cohort characteristics and complete bony or partial bony ankylosis showed no differences between the two groups on factors of age, gender, tobacco use, diabetes, workman's compensation, BMI

Table 1. Comparison of patient characteristics and risk factors

Factor	Present			Absent			p value
	N*	Mean change in arc of motion (degrees)	95% CI	N*	Mean change in arc of motion (degrees)	95% CI	
Workers Compensation	17	56	37–76	29	76	62–90	0.08
Tobacco use	22	71	54–87	24	67	50–83	0.70
Diabetes	6	71	30–111	40	68	56–80	0.87
Obesity	12	39	19–59	34	79	67–91	< 0.001
Hypertension	9	41	11–70	37	75	63–86	0.01
Chronic obstructive pulmonary disease	2	48	−46 to −141	44	70	58–81	0.42
Capsulotomy/capsulectomy	25	68	56–81	21	69	48–89	0.98
Anterior nerve transposition	28	80	31–70	18	50	68–92	0.01
Operative complication	8	54	17–90	38	72	60–84	0.22
Peripheral vascular disease	1	0	_	45	70	59–81	0.06
Coronary artery disease	1	0	_	45	70	59–81	0.06

* Number of elbows treated with each of the variables. Seven patients had bilateral involvement, but for analysis each elbow is considered separately.

Table 2. Comparison of flexion and extension arcs

Variable	Ankylosis (n* = 12)		Restricted (n* = 34)		p value
	Mean	95% CI	Mean	95% CI	
Preoperative					
Flexion	59	41–77	94	84–104	.01
Extension	59	41–77	46	37–56	.20
Arc	0	0	47	33–61	< .001
Intraoperative					
Flexion	116	105–128	131	128–135	.01
Extension	18	18–29	12	7–17	.20
Arc	98	80–116	119	112–126	< .001
Postoperative					
Flexion	114	104–125	123	118–129	.09
Extension	18	11–26	17	11–23	.10
Arc	96	84–107	106	97–115	.21
Preoperative to postoperative change					
Flexion	−40	−59 to −20	−29	−39 to −20	.26
Extension	55	36–75	29	20–39	.01
Arc	96	84–107	59	46–72	.01

* Number of elbows; seven patients had bilateral involvement, but for analysis each elbow was considered separately.

Table 3. Comparison of intervals between groups

Variable	Ankylosis (n* = 12)		Restricted (n* = 34)		p value
	Mean	95% CI	Mean	95% CI	
Age (years)	42	31–52	41	36–46	.89
Time from clinic to surgery (days)*	285	184–384	150	91–207	.02
Time from injury to surgery (days)**	527	378–676	378	303–453	.053
Postoperative followup (months)	18	6 –31	14	8 –22	.53

* Time from initial outpatient clinic visit to date of surgery, rounded to nearest day; **time from date of initial injury to date of surgery rounded to nearest day.

(dichotomized at 30), coronary artery disease, peripheral vascular disease, COPD, or complications.

Patient characteristics and modifiable risk factors associated with improvements in ROM hypertension, obesity (defined as BMI greater than 30 kg/m^2), and absence of intraoperative anterior ulnar nerve transposition showed an adverse affect on change from preoperative to final arc of motion ($p = 0.01$, $d = .80$; $p < 0.001$, $d = 1.08$; and $p = 0.01$, $d = .86$, respectively). We identified no variables that were associated with a larger degree of ROM improvement after surgery (Table 1).

Comparison of Flexion-extension Gains

When evaluating all patients in the study, there was an overall improvement in mean flexion-extension arc of motion from 35° (range, 0°–110°) to 103° (range, 53°–150°) at final postoperative followup ($p < 0.001$). Patients with ankylosis had a larger return of ROM after surgery than patients whose elbows were not fully ankylosed. For patients with complete ankylosis, the flexion-extension arc improved from 0° to a mean of 96° (SD, ± 18°; range, 60°–130°) at final followup. For the partially restricted group, the mean

preoperative flexion-extension arc was 47° (SD, ± 40°; range, 5°–110°), which improved to a mean of 105° (SD, ± 25°; range, 53°–150°) at final followup (Table 2). In addition, there was a difference in time from initial visit ($p = 0.02$) to surgery between the two groups (Table 3). When comparing patients with complete ankylosis with patients with some retained preoperative motion, the two groups were similar with respect to sex, tobacco use, diabetes, obesity, hypertension, coronary artery disease, peripheral vascular disease, chronic obstructive pulmonary disease, and length of postoperative followup (Table 4).

Complications

In our series there was a 17% (eight of 46) rate of postoperative complications (Table 5). Three patients had clinically significant recurrence of heterotopic ossification that continued to restrict ROM, three experienced postoperative nerve palsies (two ulnar nerve and one musculocutaneous nerve), one had postoperative elbow instability that required reoperation and conversion to a total elbow arthroplasty, and one had a deep surgical wound infection with methicillin-resistant *Staphylococcus aureus* that presented 6 weeks after surgery. When comparing the patients with complete ankylosis with patients with residual preoperative flexion-extension motion, there was no difference regarding the rate of postoperative complications ($p < 0.2$).

Discussion

Extensive heterotopic ossification of the elbow leads to clinically relevant stiffness, and rarely, complete ankylosis, which can impede performing activities of daily living,

Table 4. Comparison of patient characteristics

Variable	Ankylosis group		Restricted ROM group		p value
	Number of patients	Percentage	Number of patients	Percentage	
Total number of patients in group	12		34		
Workers' compensation	3	25%	14	41%	< 0.3
Smoking	6	50%	16	47%	< 0.6
Diabetes	3	25%	3	9%	< 0.2
Obesity*	1	8%	11	32%	< 0.2
Hypertension	3	25%	6	18%	< 0.5
Coronary artery disease	0	–	1	3%	< 0.8
Peripheral vascular disease	0	–	1	3%	< 0.8
Chronic obstructive pulmonary disease	1	8%	1	3%	< 0.5
Anterior nerve transposition**	10	83%	18	53%	< 0.1
Postoperative complication	1	8%	7	21%	< 0.4

* Defined as BMI greater than 30; **intraoperative anterior ulnar nerve transposition was performed.

Table 5. Patients with postoperative complications

Patient	Complication	Sex	Preoperative Arc (degrees)	Final followup arc (degrees)	Followup (months)	Heterotopic ossification prophylaxis	Reoperation
1	Symptomatic heteroptopic ossification redeveloped	Male	110	150	29	Indomethacin	No
2	Ulnar nerve palsy	Male	40	132	26	Indomethacin	No
3	Ulnar nerve palsy	Female	20	135	10	Indomethacin	No
4	Symptomatic heterotopic ossification redeveloped	Male	50	65	21	Indomethacin	No
5	Musculocutaneous nerve palsy	Male	110	121	3	Indomethacin	No
6	Elbow instability	Female	20	87	106	Radiation	Yes
7	Infection	Male	10	80	8	Indomethacin	Yes
8	Symptomatic heterotopic ossification redeveloped	Male	0	60	38	Indomethacin	No

especially when the dominant extremity is affected [3]. Functional elbow ROM for activities of daily living has been defined as an arc of 100° (30°–130° flexion and 50° pronation to 50° supination) [20]. The purpose of our study was to identify potential patient characteristics and modifiable risk factors that are associated with improvements in ROM after surgery for heterotopic ossification on the elbow. In addition, we wished to compare ROM gains between patients with complete ankylosis and partially restricted ROM, and characterize the complications treated by surgical release and excision of the heterotopic ossification followed by a standardized rehabilitation program.

A limitation of this study is that it is retrospective. Elbow contractures secondary to heterotopic ossification and bony ankylosis are uncommon, and thus, large prospective comparative studies are unlikely; even so, we acknowledge that our findings would be strengthened by the use of validated outcomes scores for elbow function, inclusion of pronation-supination ROM, and long-term followup. In addition, the observers (GM, DS) in the study were not blinded and simple goniometers were used for ROM measurements [6], which although cost effective and readily available to most clinicians, may not be the most accurate method for measurement. Future studies should be aimed at identifying treatment algorithms and postoperative regimens that maximize improved functional outcomes, patient safety, and cost.

Owing to the paucity of Level I evidence, identification of independent risk factors for poor prognosis has proven difficult in this patient population. In a previous study of a consecutive series of patients with elbow stiffness caused by posttraumatic heterotopic ossification treated operatively, Koh et al. [16] reported that recurrence of heterotopic bone and delay in surgery greater than 19 months were associated with less favorable results. In our series the variables of hypertension, obesity, and absence of intraoperative anterior ulnar nerve transposition each had an adverse affect on outcome, measured as a diminished postoperative change in total flexion-extension arc. It is unclear why patients with these three characteristics had smaller gains in postoperative ROM. Although, to our knowledge, our study consists of one of the largest cohorts reported to date, future studies are necessary to reproduce and validate our findings.

Restoration of elbow motion with complete ankylosis can be difficult, time-consuming, and costly [2]. Although restoration of normal motion is unlikely, some series have had improved outcome scores and increased ROM after operative treatment [2, 4, 22, 24]. In a retrospective study of 18 patients with complete ankylosis of the elbow treated with resection, the mean postoperative arc of flexion and extension averaged 95° and the mean DASH score was 28 at an average of 22 months after surgery [4]. In our series, both groups showed considerable improvements in ROM. In the complete ankylosis group, the mean arc of motion at final followup was 96° (SD, ± 18°; range, 60°–130°), whereas in the partially restricted group, it was 106° (SD, ± 25°; range, 53°–150°). In addition, the complete ankylosis group had a substantial increase in time from initial visit to surgery. We hypothesize that surgery may have been delayed in this patient population because of the relative complexity of their presentation and increased potential for medical comorbidities affecting their ability to undergo surgery. The overall mean flexion-extension arc of motion improved from 35° preoperatively to 103° at final followup ($p < 0.001$). Although restoration of normal motion is unlikely, improved elbow outcome scores and increased ROM after operative treatment have been reported [3–5, 11–14, 18, 21–23, 26]. Lee et al. [17], in a recent systematic literature review of outcomes after surgical resection of heterotopic ossification about the elbow, reported that the average gain was approximately 71° for the flexion-extension arc and 40° for the pronation-supination arc. Increased preoperative arc of motion, burn etiology, and postoperative use of continuous passive motion therapy were associated with improved outcomes [17].

We had an overall complication rate of 17% (eight of 46), which was comprised of recurrence (three), postoperative nerve palsy (three), instability (one), and deep infection (one). Lee et al. reported that the overall complication rate was 22.6%,with patients having sustained brain injury having poorer outcomes [17]. Complications included recurrence, fracture, infection, wound complications, and nerve palsies [17]. Our series is one of the larger cohorts of patients treated operatively for debilitating heterotopic ossification of the elbow. We found that patients with partially and completely restricted ROM had substantial improvement in postoperative ROM. Hypertension, obesity, and absence of intraoperative anterior ulnar nerve transposition were associated with adverse outcomes in our series. The standardized protocol for pain management, heterotopic ossification prophylaxis, and rehabilitation allows for comparison and greater reproducibility of our outcomes. Thus, surgery, postoperative prophylaxis, and a rehabilitation program are feasible for treating patients with heterotopic ossification of the elbow. Although osseous ankylosis and contractures of the elbow secondary to heterotopic ossification can be severely disabling, attempts to regain mobility are worthwhile.

Acknowledgments We thank Bayan Aghdasi MD, Orthopaedic Surgery, The Methodist Hospital, Texas Medical Center for help with data collection and his extraordinary commitment to this project.

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