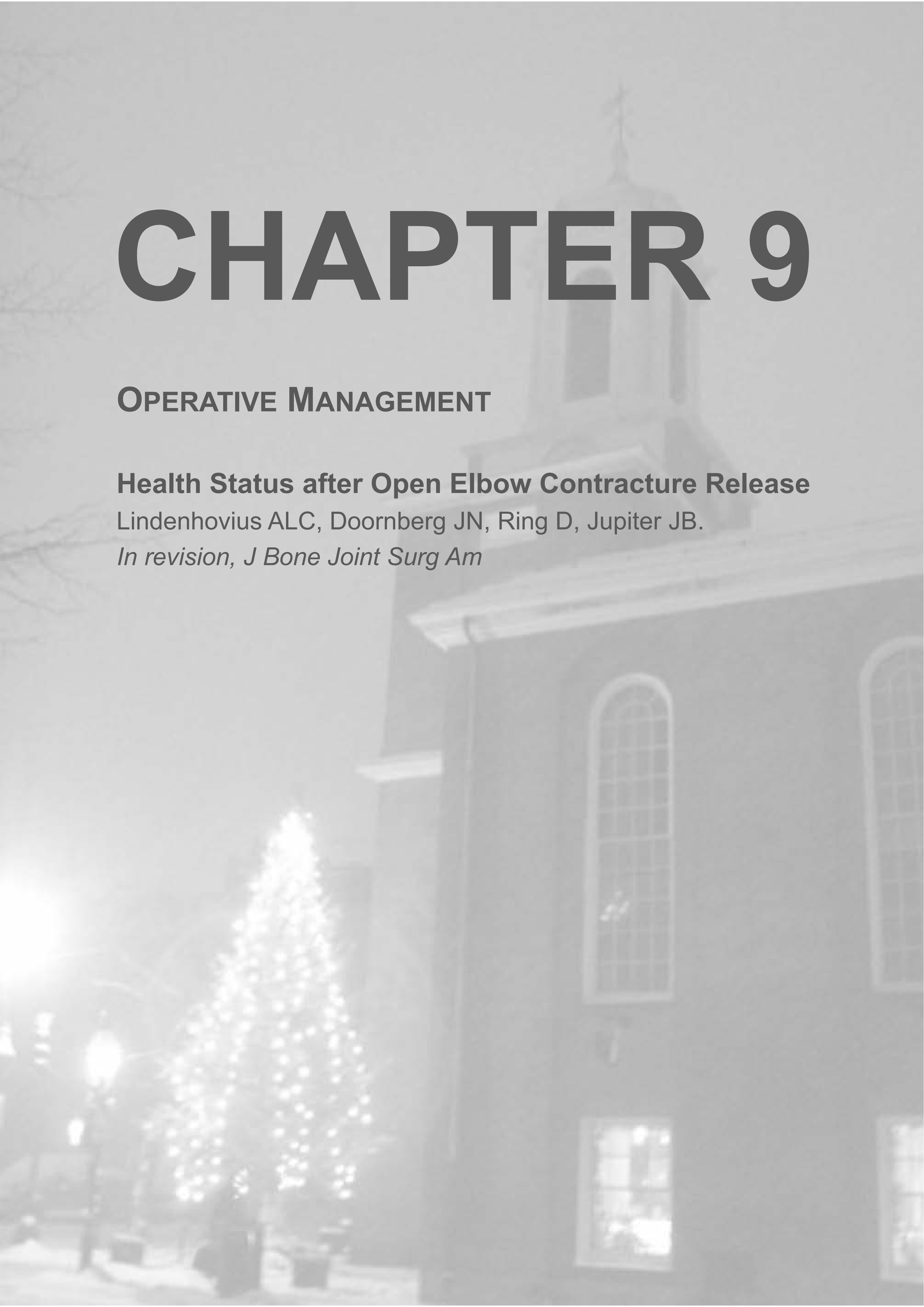
Posttraumatic Elbow Stiffness

Lindenhovius, A.L.C.

Publication date
2009



CHAPTER 9

OPERATIVE MANAGEMENT

Health Status after Open Elbow Contracture Release

Lindenhovius ALC, Doornberg JN, Ring D, Jupiter JB.

In revision, J Bone Joint Surg Am

Abstract

Background: Operative contracture release may improve motion in the posttraumatic stiff elbow. This study tests the hypothesis that improvement in ulnohumeral motion after elbow contracture release leads to improvement in general health status and upper extremity-specific disability.

Methods: Twenty-three patients with posttraumatic loss of 30 degrees or greater in elbow flexion or extension that elected open elbow capsulectomy completed the Disabilities of Arm Shoulder and Hand questionnaire (DASH) and Short-Form-36 (SF-36) pre-operatively and one year post-operatively. The pain score of the American Shoulder and Elbow Surgeons Elbow evaluation instrument (ASES) was used to measure pain. Four patients underwent additional subsequent procedures to address residual elbow stiffness.

Results: The average arc of flexion and extension improved from 50 degrees to 105 degrees, the DASH from 40 point to 19 points, the SF-36 Physical Component Score (PCS) from 39 points to 50 points, and the SF-36 Mental Component Score (MCS) from 49 points to 55 points (all $p < 0.05$). There was no correlation between improvement in arc of flexion and extension with improvement in DASH score ($p = 0.63$), PCS ($p = 0.63$), or MCS ($p = 0.14$). Neither was there correlation between the final arc of flexion and extension and the final DASH score ($p = 0.23$), PCS ($p = 0.57$), or MCS ($p = 0.12$).

Conclusions: Health status and disability improve after open elbow contracture release, but the improvements do not correlate with improved elbow motion. Among multiple objective and subjective factors, pain was the best predictor of final general health status and arm-specific disability.

Level of Evidence: Level I, prognostic study with > 80% follow-up

Introduction

Stiffness is a common complication following elbow trauma. If nonoperative treatment with exercises and splinting fails to restore a functional arc of motion, operative contracture release may improve motion.[1] Many previous investigations documenting the results of operative elbow contracture release focused on the objectively measurable result: restoration of range of motion, with the assumption that more motion would lead to improved disability and health status. A recent literature review reported average improvements in ulnohumeral motion ranging from 21 degrees to 66 degrees after operative contracture release.[1] However, in a retrospective investigation, the final range of motion after elbow contracture release did not correlate with arm-specific disability as measured by the DASH.[2] To further investigate the relationship between motion, health status and arm-specific disability, we undertook a prospective cohort study. The primary study question is whether improvement in elbow motion results in improvement in health status and disability. Specifically this study tests the hypothesis that there is medium correlation between improvements in flexion and extension arc and improvements in general health status and disability after open release of a post-traumatic elbow contracture. The secondary study question is whether final flexion and extension arc correlates with final health status and final disability.

Methods

Participants

The Human Research Committee at our institution approved this prospective study. All adult patients presenting to one of two orthopaedic upper extremity surgeons of a tertiary care institution with a loss of flexion or extension of at least 30 degrees, measured with a hand-held goniometer at least four months after elbow trauma, and that had an inadequate response to supervised exercises and splinting (defined as no measurable gains in the active range of flexion and extension over a 30-day period) were eligible for enrollment. Exclusion criteria included severe burns, severe injury to the central nervous system with residual motor or cognitive deficits, non-traumatic arthrosis, active infection, and severe articular injury requiring interposition arthroplasty or a total joint arthroplasty. The protocol was designed to evaluate all patients prior to the operative elbow contracture release and one year after the release (between 10 and 18 months) and to record motion, disability and general health status measures at both time points.

Evaluation Prior to and One Year after Operative Contracture Release

Both prior to and one year after the contracture release, anteroposterior and lateral elbow radiographs were taken. Patients completed the Disabilities of Arm Shoulder and Hand (DASH) questionnaire[3] and the Short Form-36 (SF-36)[4]. In addition, we recorded patients' age, gender and occupation, the dominant and affected limb, the type of injury, associated ipsilateral injuries, initial treatment, ulnar neuropathy, the number of surgeries prior to the release, time between injury and release, time between the release and one year evaluation, the number of additional surgeries between the release and one year evaluation, and arthrosis at the one year evaluation. All evaluations were performed by an independent observer not involved with patients' care.

The DASH questionnaire[3] is an arm-specific disability measure that evaluates difficulty with performing specific tasks, as well as symptoms, social function, work function, sleep and confidence. The score is scaled between zero and 100 with higher scores indicating worse upper extremity function. The SF-36[4] is a widely used general health status questionnaire that consists of a physical component and a mental component. The physical component summary score (PCS) and the mental component summary score (MCS) are norm-based scores that range from 0 to 100 points with 50 points being the average Unites States Score and with 10 points representing one standard deviation. Norm-based scoring equates all scores, so scores above 50 are better than the general population average for both summary measures, while scores below 50 are worse. It facilitates comparison and interpretation of summary scores and their subscales.[5]

As a quantitative measure of pain, we recorded the pain subscales of the American Shoulder and Elbow Surgeons Elbow Evaluation Instrument (ASES)[6]. Patients rated their pain from zero, indicating no pain, to 10, indicating the worst imaginable pain, on five scales: 1) pain when it is at its worst; 2) pain at rest; 3) pain lifting a heavy object; 4) pain when doing a task with repeated elbow movements; 5) pain at night. The summary pain score ranges from zero to 25 points, with 25 points indicating no pain.

Ulnar neuropathy was graded according to the McGowan scale[11]: grade 1, paresthesias in the ulnar nerve distribution with no detectable motor weakness of the hand; grade 2, intermediate lesions with weak interossei and muscle wasting; grade 3, severe lesions, with paralysis of the interossei and marked muscle weakness.

Arthrosis was rated by an independent observer according to the system of Broberg and Morrey[7]: Grade 0: normal joint; Grade 1: slight joint-space narrowing with minimum osteophyte formation; Grade 2: moderate joint-space narrowing with moderate osteophyte formation and Grade 3: severe degenerative change with gross destruction of the joint.

Statistical Analysis

Primary Study Question

Continuous data are presented in terms of mean and range. Improvements in the arc of flexion and extension, forearm rotation, and differences between pre-operative and post-operative PCS, MCS and DASH scores were evaluated using paired t-tests. To answer our primary study question, correlation between improvement in the arc of flexion and extension with improvement in disability (DASH) and general health status (PCS and MCS) was assessed using Pearson correlation. Power analysis indicated that a total sample size of 24 patients would provide 80% power to detect significant correlation with rho = 0.4 ($\beta = 0.20$, $\alpha = 0.10$) between improvement in flexion and improvement in disability and health status. A two-tailed $p < 0.05$ was considered statistically significant. To account for a possible loss to follow-up of 20% we anticipated enrolling 29 patients.

In order to account for confounding with other variables, we also performed bivariate and multivariable analyses. The number of explanatory variables that can be included in a multivariable model is limited by the overall sample size of the study. Therefore, instead of entering all potential explanatory variables into multivariable models, we ran a bivariate analysis first. Only those variables that were either significant ($p < 0.05$) or nearly significant ($p < 0.10$) were entered in the multivariable analysis.

Bivariate Analysis

Pearson correlations (r) were used to assess the association between continuous variables (age, number of surgeries prior to the release, time between injury and release, number of additional surgeries between the release and final evaluation, arc of flexion and extension, forearm rotation, improvement in the arc of flexion and extension, improvement in forearm rotation, and pain) with improvement in PCS, MCS, and DASH score, and final PCS, MCS, and DASH score. Differences in improvement in PCS, MCS, DASH and in final PCS, MCS and DASH scores between dichotomous variables (gender, laborer vs. non-laborer occupation [any person employed to do physical or heavy manual work was considered laborer], limb dominance, distal humeral fracture, associated ipsilateral injuries, arthrosis and ulnar neuropathy) were compared by unpaired Student's t-tests.

Multivariable Analysis

Backwards stepwise multiple linear regression analysis was performed to determine the best predictors of improvement in PCS, MCS, DASH scores and the arc of flexion and extension, and final PCS, MCS, DASH scores and arc of flexion and extension, thereby accounting for confounding between explanatory variables. A backwards stepwise multiple regression model initially includes all the entered variables and then iteratively removes variables from the model until the best-fit model is achieved. Multiple linear regression models produce a statistic called the adjusted R-squared, which reflects the percentage of the overall variability in the dependent (outcome) variable that can be explained or accounted for by the predictor (explanatory) variables included in the multiple linear regression model. If "pain" was among the variables in the best model, an additional model with the variable pain entered only was run. Comparison of the variability accounted for by each model (the adjusted R-squared) provides a measure of the relative influence of each explanatory variable on the overall variation in the response variable.

Multivariable analysis of variance (MANOVA) was performed to assess significance of the models, where significance indicates a linear relationship between at least one of the predictor variables in the model with the dependent variable.

Secondary Study Question

Pearson correlation was used to analyze the association between the final arc of flexion and extension with final disability and health status scores (DASH, PCS, and MCS).

Source of Funding

No funding was received in direct support of this study.

Results

Patients

Between January 2004 and May 2006, twenty-eight of 29 eligible patients were enrolled in this study. Five patients did not return for the one-year follow-up (three patients declined, one patient was terminally ill, and one patient could not be located), leaving 23 patients that are included in the current analysis. Three patients were evaluated more than 18 months after the index contracture release (at 20, 21, and 25 months) because they requested their research appointments to be postponed several times for work-related and travel-related reasons. It was decided to accept these deviations from the intended protocol.

Pre-Operative Evaluation

Patient and injury characteristics as well as information on initial treatment and additional procedures prior to the index contracture release are presented in Table 1. The pre-operative and post-operative evaluations (elbow function, DASH, SF-36 and pain scores, as well as radiographic data) are reported in Table 2.

Table 1. Patient, Injury and Initial Treatment Characteristics

Gender	16 male, 7 female
Age	46 years (range, 17 to 71 years)
Occupation	10 deskbased, 6 laborer, 1 student, 1 soldier, 5 unemployed (3 retired)
Injury Type	11 distal humerus fractures (1 with concomitant radial head fracture, 1 with concomitant olecranon fracture), 6 elbow fracture-dislocations, 5 radial head fractures , 1 olecranon fracture
Injury Mechanism	9 fall from greater height, 5 fall from standing height, 7 motor vehicle accident, 1 gunshot injury, 1 explosion injury
Injury Side	13 right elbow (11 dominant arms), 10 left elbow (3 dominant arms)
Open Injury	6 open injuries
Additional Injuries	2 ipsilateral distal radius fracture, 9 skeletal injuries at other sides
Initial Treatment	17 ORIF*, 2 external fixation followed by internal fixation + bone graft, 1 radial head replacement, 3 non-operatively
Additional Surgeries *(prior to index release)*	1 patient had 3 surgeries for an infected nonunion, stiffness, and instability 2 patients had 1 surgery for nonunion with loose implants 2 patients had 1 surgery for stiffness 1 patient had 1 surgery for instability 1 patient had manipulation for stiffness

**ORIF = Open Reduction and Internal Fixation*

Operative Treatment

The time between the initial injury and the operative contracture release averaged 22 months (range, 4 to 210 months). Combined medial and lateral intervals through a posterior incision were used in 12 patients, lateral and medial intervals through separate incisions in 2 patients, a lateral interval through a lateral or previous posterior incision in 8 patients[8-10], and a medial interval through a medial incision[11] in one patient. The ulnar nerve was addressed in fourteen patients: it was transposed anteriorly in six patients and released in eight patients in whom the nerve had already been transposed during a previous surgery. Heterotopic bone was excised in seventeen patients including three patients that had resection of a proximal radioulnar synostosis. Seven patients had removal of implants. In one patient, elbow stability (after excision of massive heterotopic bone with a proximal radioulnar synostosis) was protected with a hinged external fixator that was removed six weeks after the index contracture release. In the three patients that had a nonunion of the distal humerus, the release of the capsules and the ulnar nerve was followed by debridement of the fracture site, removal of loose implants, fixation of the nonunion, and in the two patients with supracondylar nonunions, autogenous bone grafting.

Five patients received pre-operative irradiation (a single dose of 7Gy) on the morning of surgery as a prophylaxis against formation or recurrence of heterotopic bone. None of the patients were prescribed non-steroidal anti-inflammatory drugs (NSAIDs) after surgery. Patients began with passive and active assisted exercises on the first postoperative day and eleven patients were put on a continuous passive motion device. Thirteen patients began using a splint between three and six weeks after surgery to help regain motion (11 were static progressive splints and 2 were dynamic splints).

Additional Surgeries

Five patients had a total of eight additional surgeries after the index contracture release and prior to the one-year evaluation: one patient had three procedures to treat a forearm compartment syndrome, and four patients had five subsequent elbow releases, with excision of recurrent heterotopic bone in three patients (four surgeries) and anterior transposition of a previously released ulnar nerve in one of them, and with an interposition arthroplasty and hinged external fixation in another patient. The three patients that had subsequent surgery for excision of heterotopic bone had pre-operative irradiation with a single dose of 7Gy. Among these patients there was one patient that had two surgeries for excision of recurrent heterotopic bone in spite of irradiation after both the index and the repeat contracture release.

One Year Evaluation

The one year evaluation was performed at an average 15 months after the index contracture release (range, 11 to 25 months) and an average 14 months since the most recent surgery (range, 5 to 25 months). Patients made significant improvements in flexion and extension arc and the arc of forearm rotation. In addition, significant improvements were made in DASH, and SF-36 scores. Detailed results are reported in Table 2.

Table 2. Pre-Operative and Post-Operative Evaluation

	Pre-Operatively		1 Year Post-Operatively		Improvement		
	average	**range**	**average**	**range**	**average**	**range**	**p-value**
Flexion	96	50 - 135	128	65 - 140	32	5 - 90	< 0.001
Flexion Contracture	47	0 - 90	24	0 - 50	23	-10 - 50	< 0.001
Flexion and Extension Arc	50	0 - 100	105	65 - 140	55	20 - 125	< 0.001
Pronation	59	0 - 90	82	50 - 90	23	-20 - 85	< 0.01
Supination	57	0 - 90	67	10 - 90	10	-60 - 60	0.14
Arc of Forearm Rotation	117	0 - 180	149	90 - 180	30	-55 - 125	< 0.01
ASES pain score *	12	2 - 24	19	3 - 25	11	2 - 21	< 0.05
DASH score *	40	3 - 73	19	3 - 56	21	-8 - 68	< 0.001
SF-36 Physical Component Score	39	28 - 58	50	30 - 58	11	-6 - 24	< 0.001
SF-36 Mental Component Score	49	25 - 62	55	34 - 62	7	-9 - 30	< 0.05
Ulnar Nerve Dysfunction (McGowan)	7 grade 1, 2 grade 2		9 grade 1, 1 grade 2		**		
Heterotopic Ossification	21 patients (blocking motion in 17, PRUS* in 3)		1 patient (blocking extension)				
Radiographic Union	3 distal humeral nonunions (1 medial epicondyle)		radiographic union				
Arthritis (Broberg & Morrey)	7 mild, 2 moderate, 2 severe		7 mild, 3 moderate, 2 severe				

** ASES = American Shoulder and Elbow Surgeons Elbow Evaluation, DASH = Disabilities of Arm Shoulder and Hand Questionnaire, PRUS = Proximal Radio Ulnar Synostosis*

*** Ulnar nerve dysfunction at 1 year evaluation was pre-existent in 6 patients and new in 4 patients, while 3 of these 4 had transposition or release of the nerve during the index release. Four patients with pre-existent ulnar nerve dysfinction had improved function after release or transposition of the nerve during the index release and 3 of them had no more symptoms at the 1 year evaluation.*

Table 3. Bivariate Analysis

Physical Component Score

Improvement	Rho	P	Association
pain	0.49	< 0.05	
# prior surgeries	-0.41	< 0.10	
arthrosis (y/n)		< 0.05	with arthrosis more improvement

Final	Rho	P	Association
# prior surgeries	-0.41	< 0.10	
laborer occupation (y/n)		< 0.05	non-laborers better PCS
ulnar neuropathy (y/n)		< 0.10	without ulnar neuropathy better PCS
distal humerus fx (y/n)		< 0.10	with distal humerus fx worse PCS
arthrosis (y/n)		< 0.01	with arthrosis better PCS

Mental Component Score

Improvement	Rho	P	Association
none			

Final	Rho	P	Association
pain	0.71	< 0.001	
# prior surgeries	-0.54	< 0.05	
distal humerus fx (y/n)		< 0.05	with distal humerus fx worse MCS

DASH

Improvement	Rho	P	Association
ulnar neuropathy (y/n)		< 0.10	

Final	Rho	P	Association
pain	-0.68	< 0.01	
# prior surgeries	0.43	< 0.05	
ulnar neuropathy (y/n)		< 0.05	without ulnar neuropathy better DASH
gender		< 0.05	female patients better DASH
laborer occupation		< 0.05	non-laborers better DASH
distal humerus fx		< 0.10	with distal humerus fx worse DASH

Correspondence between Motion, Disability and Health Status

There was no significant correlation between improvement in the arc of flexion and extension with improvement in PCS ($p = 0.63$), MCS ($p = 0.14$) or DASH scores ($p = 0.63$). Neither was there significant correlation between final arc of flexion and extension with final PCS ($p = 0.57$), MCS ($p = 0.12$), or DASH scores ($p = 0.23$).

Bivariate and Multivariable Analysis

All explanatory variables were entered in a bivariate analysis to find associations between explanatory variables with each of the six outcome variables: improvements in the PCS, MCS, and DASH scores, and final PCS, MCS and DASH scores. Explanatory variables that had significant or near-significant association with the outcome variables (reported in Table 3) were entered in a multivariable analysis to identify those variables that explained the variation in each of the outcome variables best, while accounting for confounding between the variables. This multivariable analysis tells us about the degree to which the outcome variables are explained by the variables in the model. Overall, the models explained the final PCS, MCS and DASH scores better than improvement in PCS, MCS and DASH scores. The explanatory variable pain was included in the best multivariable models for final MCS and DASH scores. We ran additional analyses for these outcome variables with pain as the only variable entered: pain explained 48% of the final MCS and 44% of the final DASH scores. The results of the multivariable analysis are summarized in Table 4.

Discussion

Although additional surgery was often performed, operative contracture release resulted in substantial improvements in elbow motion (average 55 degrees in the arc of flexion and extension and average 30 degrees in forearm rotation). Health status improved as well: SF-36 physical and mental summary scores both increased from below United States average to better than United States average (average improvements of 11 and 7 points respectively) and the improvement in disability (DASH) averaged 21 points. However, our hypothesis was not confirmed: despite the significant improvements in all outcome measures, there was no association between improvements in motion with improvement in disability and health status. Although open elbow contracture release resulted in less disability and better health status, the degree of improvement in objectively measured motion was not associated with the degree of improvement in perceived health. Thus, none of the disability and health status measures was sensitive to changes in motion. However, the outcome measures were sensitive to other factors: particularly pain turned out to be an important predictor of disability and health status.

When possible predictors of final disability and health status and improvement in disability and health status were analyzed in multivariable regression analysis, distal humeral fracture, ulnar nerve dysfunction, and the number of surgeries prior to the release were most prevalent among objective predictors. A previous study found better results in patients without arthrosis[12]: a finding that makes sense but that was not observed in our study. A previous meta-analysis of articles reporting associations between impairment with patient-rated disability and health status[13], found only 36% of disability scores and 13% of health status

Table 4. Multivariable Analysis

Physical Component Score			**Mental Component Score**			**DASH**		
Variables	**Adjusted R2**	**P-value**	**Variables**	**Adjusted R2**	**P-value**	**Variables**	**Adjusted R2**	**P-value**
Improvement			**Improvement**			**Improvement**		
1 pain	19%	< 0.001	1 none*	na	na	1 ulnar neuropathy	12%	0.06
Final			**Final**			**Final**		
1 # prior surgeries ulnar neuropathy distal humerus fx	49%	< 0.01	1 pain # prior surgeries distal humerus fx	62%	< 0.01	1 pain ulnar neuropathy distal humeral fx # prior surgeries gender	67%	< 0.001
			2 pain	48%	< 0.001	2 pain	44%	< 0.001

* *none of the variables entered in bivariate analysis was associated with improvement in mental component score*
na = not applicable

scores to be explained by impairment. In the current study, the relationship between motion (and thus impairment) with disability and health status was limited as well. However, multivariable models that included the subjective variable pain explained up to 62% of the variation in health status and up to 67% of the variation in disability. Models that included pain alone explained more of the variability in disability and health status than the objective predictors did: pain was the best predictor of both PCS (19%), MCS (48%) and DASH scores (44%). These findings are in line with a previous study[14] that found 36% of the variation in DASH scores to be explained by pain. The perception of pain is highly variable between individuals and strongly psychosocially mediated.[15-19] Patients with low depression scores may do better in terms of disability[20], whereas good coping skills seem especially important in patients with pain resulting from unclear and vague causes[21].

Most relatively simple posttraumatic elbow contractures respond to exercises (eventually with a splinting program[22]) and patience. The majority of posttraumatic contractures for which surgery is elected in our practice are very complex: the cohort that was studied in this investigation had severely stiff elbows with an average 50 degree arc of flexion and extension prior to the release, most patients had sustained distal humerus fractures or elbow fracture-dislocations, and in many patients stiffness was complicated by nonunion or heterotopic bone. The latter has traditionally been considered a poor prognostic factor, although a recent investigation found better results of operative contracture release in patients that had excision of heterotopic bone blocking motion when compared to patients with capsular contracture alone.[23] The role of NSAIDs and irradiation as prophylaxes against the formation or recurrence of heterotopic bone in the elbow remains unclear and merits prospective investigation. In this study, none of the patients were prescribed NSAIDs as prophylaxis against formation of heterotopic bone, whereas five patients had irradiation on the morning of surgery.

Four of 23 patients had subsequent surgery for elbow stiffness prior to the one year follow-up. Including one of these four patients, there were five patients at the one year follow-up that had an arc of flexion and extension of 80 degrees or fewer. The improvement in the arc of flexion and extension that was found in this study compared well to prior reports (average improvement of 55 degrees vs. improvements ranging from 21 degrees to 66 degrees in previous studies).[24,25]

Ten of twenty-three patients (43%) had ulnar nerve dysfunction at the one-year evaluation: in six patients it was pre-existent, but the four remaining patients had no prior dysfunction of the nerve, while three of those had a transposition or release during the index contracture release. Four patients with pre-operative ulnar nerve dysfunction had improved after release or transposition of the nerve during the index release and three of them had no symptoms of ulnar neuropathy at the one-year evaluation. In two of the patients that had additional surgery to address stiffness, the ulnar nerve was transposed: at the one year evaluation, one of these patients had altered sensibility in the distribution area of the ulnar nerve. With increased flexion the ulnar nerve flattens against the medial epicondyle[26], and with full flexion the nerve elongates approximately 5mm[27,28]. A contracture release may thus increase traction on the ulnar nerve and thereby put the nerve at risk. The benefit of a release or transposition in patients without complaints of ulnar nerve dysfunction would seem questionable based upon our data. However, when interpreting our numbers, one should keep in mind that most patients had a transposition or release of the ulnar nerve because of placement of implants in the case of a nonunion, because of heterotopic bone entrapping the nerve, or because of pre-existent ulnar neuropathy. There is no conclusive evidence regarding routine decompression or transposition of the ulnar nerve during elbow contracture release in the literature.[29] The limited sample size of our study does certainly not allow definitive conclusions on this topic.

This data should be interpreted in light of its shortcomings such as the diversity of the population, including patients with complex contractures (which fitted our inclusion criteria as they reflect the true nature of post-traumatic elbow stiffness). Furthermore, we had the difficulty getting patients back at exactly one year: three patients that did not return for follow-up until approximately two years after surgery were left in the analysis. Since we did not have a one-year and two-year follow-up of all patients, we do not know whether the flexion arc remains stable over this period. Another limitation is the fact that, due to loss to follow-up and the late exclusion of a patient that underwent an interposition arthroplasty but was erroneously kept in the study, we eventually were one patient short from the 24 needed according to our power analysis. Nonetheless, the lack of correlation between improvements in motion and improvements in disability and health status was fairly convincing. Given the p-values ranging from 0.12 to 0.63, it seems unlikely that a single additional patient would have affected our findings. This lack of correlation seems counter-intuitive and brings into question the traditional surgeon and patient focus on motion as the most important measure of success. On the other hand, it might be argued that disability and health status instruments measure a much more complex construct than does a simple measure of impairment like range of motion. The failure to demonstrate a correlation may not have much to do with the relative importance of improving motion as with the fact that motion is a very simple construct and that measured by the DASH and SF-36 increasingly complex. Additional study is merited to better determine how impairments in motion affect disability and why decreases in disability are not tied to increases in motion. This will better define the role of operative release of post-traumatic elbow contracture.

References

1. Lindenhovius AL, Jupiter JB. The posttraumatic stiff elbow: a review of the literature. J Hand Surg [Am] 2007 Dec;32(10):1605-23.
2. Ring D, Adey L, Zurakowski D, Jupiter JB. Elbow capsulectomy for posttraumatic elbow stiffness. J Hand Surg [Am] 2006 Oct;31(8):1264-71.

3. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med 1996 Jun;29(6):602-8.
4. Ware JE,Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992 Jun;30(6):473-83.
5. Ware JE, Kosinski M. SF-36 Physical and Mental Health Summary Scales: A Manual for Users of Version 1. 2nd ed. Lincoln, RI.: QualityMetric; 2001.
6. King GJ, Richards RR, Zuckerman JD, Blasier R, Dillman C, Friedman RJ, et al. A standardized method for assessment of elbow function. Research Committee, American Shoulder and Elbow Surgeons. J Shoulder Elbow Surg 1999 Jul-Aug;8(4):351-4.
7. Broberg MA, Morrey BF. Results of treatment of fracture-dislocations of the elbow. Clin Orthop Relat Res 1987 Mar;(216)(216):109-19.
8. Mansat P, Morrey BF. The column procedure: a limited lateral approach for extrinsic contracture of the elbow. J Bone Joint Surg Am 1998 Nov;80(11):1603-15.
9. Cohen MS, Hastings H,2nd. Post-traumatic contracture of the elbow. Operative release using a lateral collateral ligament sparing approach. J Bone Joint Surg Br 1998 Sep;80(5):805-12.
10. Cohen MS, Hastings H,2nd. Operative release for elbow contracture: the lateral collateral ligament sparing technique. Orthop Clin North Am 1999 Jan;30(1):133-9.
11. Mezera K, Hotchkiss RN. Fractures and Dislocations of the Elbow. In: Bucholz RW, Heckman JD, editors. Rockwood and Green's Fractures in Adults. 5th ed. Philadelphia: Lippincott Williams &Wilkins; 2001. p.921-52.
12. Urbaniak JR, Hansen PE, Beissinger SF, Aitken MS. Correction of post-traumatic flexion contracture of the elbow by anterior capsulotomy. J Bone Joint Surg Am 1985 Oct;67(8):1160-4.
13. Weisscher N, de Haan RJ, Vermeulen M. The impact of disease-related impairments on disability and health-related quality of life: a systematic review. BMC Med Res Methodol 2007 Jun 19;7:24.
14. Doornberg JN, Ring D, Fabian LM, Malhotra L, Zurakowski D, Jupiter JB. Pain dominates measurements of elbow function and health status. J Bone Joint Surg Am 2005 Aug;87(8):1725-31.
15. Meredith P, Strong J, Feeney JA. Adult attachment, anxiety, and pain self-efficacy as predictors of pain intensity and disability. Pain 2006 Jul;123(1-2):146-54.
16. Meredith PJ, Strong J, Feeney JA. The relationship of adult attachment to emotion, catastrophizing, control, threshold and tolerance, in experimentally-induced pain. Pain 2006 Jan;120(1-2):44-52.
17. Severeijns R, Vlaeyen JW, van den Hout MA, Weber WE. Pain catastrophizing predicts pain intensity, disability, and psychological distress independent of the level of physical impairment. Clin J Pain 2001 Jun;17(2):165-72.
18. Elliott TE, Renier CM, Palcher JA. Chronic pain, depression, and quality of life: correlations and predictive value of the SF-36. Pain Med 2003 Dec;4(4):331-9.
19. Gonzales VA, Martelli MF, Baker JM. Psychological assessment of persons with chronic pain. NeuroRehabilitation 2000;14(2):69-83.
20. Ring D, Kadzielski J, Fabian L, Zurakowski D, Malhotra LR, Jupiter JB. Self-reported upper extremity health status correlates with depression. J Bone Joint Surg Am 2006 Sep;88(9):1983-8.
21. Ring D, Kadzielski J, Malhotra L, Lee SG, Jupiter JB. Psychological factors associated with idiopathic arm pain. J Bone Joint Surg Am 2005 Feb;87(2):374-80.
22. Doornberg JN, Ring D, Jupiter JB. Static Progressive Splinting for Posttraumatic Elbow Stiffness. J Orthop Trauma 2006 Jul;20(6):400-4.
23. Lindenhovius AL, Linzel DS, Doornberg JN, Ring DC, Jupiter JB. Comparison of elbow contracture release in elbows with and without heterotopic ossification restricting motion. J Shoulder Elbow Surg 2007 Sep-Oct;16(5):621-5.
24. Itoh Y, Saegusa K, Ishiguro T, Horiuchi Y, Sasaki T, Uchinishi K. Operation for the stiff elbow. Int Orthop 1989;13(4):263-8.
25. Morrey BF. Post-traumatic contracture of the elbow. Operative treatment, including distraction arthroplasty. J Bone Joint Surg Am 1990 Apr;72(4):601-18.
26. Patel VV, Heidenreich FP,Jr, Bindra RR, Yamaguchi K, Gelberman RH. Morphologic changes in the ulnar nerve at the elbow with flexion and extension: a magnetic resonance imaging study with 3-dimensional reconstruction. J Shoulder Elbow Surg 1998 Jul-Aug;7(4):368-74.
27. Apfelberg DB, Larson SJ. Dynamic anatomy of the ulnar nerve at the elbow. Plast Reconstr Surg 1973 Jan;51(1):79-81.

28. Schuind FA, Goldschmidt D, Bastin C, Burny F. A biomechanical study of the ulnar nerve at the elbow. J Hand Surg [Br] 1995 Oct;20(5):623-7.
29. Shin R, Ring D. The ulnar nerve in elbow trauma. J Bone Joint Surg Am 2007 May;89(5):1108-16.