Posttraumatic Elbow Stiffness

Lindenhovius, A.L.C.

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CHAPTER 10

POSTOPERATIVE MANAGEMENT

Open Elbow Contracture Release: Postoperative Management with and without Continuous Passive Motion
Abstract

Purpose: Operative contracture release can restore motion to stiff elbows. Some authors suggest that use of continuous passive motion (CPM) in postoperative management can increase ultimate mobility. This study tests the null hypothesis that there is no difference in the arc of flexion and extension between patients who used CPM and those who did not use CPM (no CPM; NCPM) after open elbow contracture release.

Methods: Sixteen patients who had an arc of flexion and extension of less than 80° and used CPM after open contracture release were matched based on age, gender, diagnosis, preoperative arc of flexion and extension, and radiographic appearance (joint congruity, heterotopic bone, and arthritis) to 16 control patients who did not use CPM. Stiffness was of posttraumatic origin in 24 patients, related to primary osteoarthrosis in 4 patients, and related to heterotopic ossification after central nervous system injury or burns in 4 patients. The preoperative arc of flexion and extension averaged 38° in the CPM cohort and 42° in the NCPM cohort.

Results: Subsequent surgeries included procedures to address residual stiffness in 1 patient in the CPM cohort and in 3 patients among the NCPM cohort. At an average 6 months follow-up, there was no difference in improvement in the arc of flexion and extension (58° vs 61°) between the CPM and NCPM cohorts. At the final evaluation, the improvement in arc of flexion and extension (59° in both cohorts) and the final arc of flexion and extension (96° vs 101°) were comparable between cohorts.

Conclusions: These matched retrospective data do not demonstrate a benefit of CPM in the postoperative management of elbow contracture release.

Type of study/level of evidence: Therapeutic III.

Background

Open contracture release can often restore motion to the stiff elbow. Although continuous passive motion (CPM) after operative contracture release is recommended by many authors as a way to improve ultimate elbow motion by facilitating postoperative exercises during the painful immediate postoperative period, there is only limited and low-level scientific evidence supporting use of CPM. Disadvantages of CPM include the risks associated with regional anesthesia (often used in conjunction with CPM), the cumbersome nature of the CPM device, prolonged hospital stay and increased costs.

In this study, we test the null hypothesis that there is no difference in the arc of flexion and extension between matched retrospective patient cohorts treated with or without CPM at least 4 months after operative elbow release.
Materials and Methods

The conception, design, and data collection and analysis of this investigation were performed entirely by researchers who were not involved in the care of the patients. Between June 2001 and March 2006, 29 of 113 patients who were treated by a single surgeon for operative release of severe elbow stiffness (arc of flexion and extension less than 80°) had postoperative CPM. The senior author’s interest in CPM waxed and waned over the study period. There were also availability, planning, and practicality issues creating a use of CPM that was relatively random. To further reduce the potential for bias, each patient who used CPM was matched (by an independent investigator not involved in the care of the patients and prior to examining the results of treatment) to a control patient who did not use CPM (no CPM; NCPM) after surgery according to (1) presurgery arc of flexion and extension (within 20°), (2) diagnosis, and (3) radiographic appearance (joint congruity and extent and location of heterotopic ossification and arthritis). An attempt was also made to match for age (within 15 years; possible for 14 pairs) and gender (possible for 14 pairs). A suitable match was found for 23 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. Seven patients who had fewer than 4 months follow-up since the most recent surgery and either could not be located (2 patients) or declined participation (5 patients) were excluded, leaving 16 matched pairs (32 patients) available for the study (Table 1). Among these 32 patients, 25 patients with an average follow-up of 20 months (range, 10–45 months) were evaluated based on data from the medical or research record, and 7 patients who had fewer than 10 months follow-up returned to our outpatient clinic for a comprehensive examination and interview, resulting in 2 cohorts of 16 patients each. In addition, we evaluated short-term results (4–10 months) in a subset of 22 patients who had early follow-up information available from the medical record.

Patients who used CPM

The CPM cohort consisted of 11 men and 5 women with an average age of 42 years (range, 18–63 years). Twelve patients were employed in desk-based work, 3 were laborers, and 1 was unemployed. The right arm was involved in 8 patients (6 dominant) and the left in 8 patients (5 dominant).

Twelve patients had posttraumatic elbow stiffness. The initial injury was a distal humerus fracture in 6 patients (with a persistent nonunion in 1), an elbow fracture-dislocation in 4, and a radial head fracture in another 2. In 3 patients, the fracture was associated with a wound: in 1 patient, a type 1 wound according to Gustilo and Anderson14; for the other 2 patients, the type of wound could not be determined retrospectively. Nine patients were injured in a fall from standing height, 1 in a fall from greater height, 1 in a motor vehicle crash, and 1 was
injured during an explosion. Two patients had ipsilateral injuries of the upper extremity: one had an open distal radius fracture and a closed ulnar midshaft fracture, and the other had associated forearm injury. One patient had sustained an ipsilateral distal humerus fracture in the past with an eventually healed nonunion.

Ten of the 12 patients with a fracture had initial operative treatment: open reduction and internal fixation in 8 patients, a radial head replacement in 2 patients, and an intramedullary nail and external fixation in 1 patient. Four patients had a total of 9 additional surgical procedures prior to the index contracture release (average, 1 surgery; range, 1–5 surgeries): 5 were procedures for revision of failed fixation and an infected nonunion in 1 patient, 2 were procedures for implant removal (2 patients) followed by a release in one of them, and 1 more patient had a contracture release.

Two patients had elbow stiffness related to primary osteoarthritis. They had radiographic evidence of arthritis and loose bodies, progressive loss of motion over the years with increasing pain, and no history of trauma. One patient with a hemiparesis, C1 and C2 fractures, and brachial plexopathy after a car accident, and 1 patient who had severe body burns (40% of total body surface area) and who was comatose (Glasgow Coma Scale score of 3) after a car accident and fire had stiffness resulting from heterotopic bone blocking motion. The average arc of flexion and extension prior to the index procedure was 38° (range, 0° to 75°) with an average flexion of 97° (range, 85° to 120°) and an average flexion contracture of 60° (range, 20° to 100°). The mean arc of forearm rotation was 122° (range, 0° to 180°) with an average pronation of 65° (range, 0° to 90°) and an average supination of 57° (range, 0° to 90°). Heterotopic bone contributed to the elbow contracture in 12 patients. Ten patients had preoperative signs of ulnar nerve dysfunction.

Excluding the 2 patients with primary osteoarthritis, the interval between the injury and index surgery for elbow contracture release averaged 14 months (range, 5–33 months). The contracture release was performed using a combined medial and lateral interval through a single dorsal incision in 13 patients, a lateral interval in 2 patients, and a medial and lateral interval through separate incisions in 1 patient. In all but 1 patient who had a medial muscle interval, the ulnar nerve was released or transposed anteriorly. The radial head was excised in 1 patient. Implants were removed in 1 patient.

Four patients received preoperative radiation (a single 7-Gy dose) as prophylaxis against recurrence of heterotopic bone. None of the patients was prescribed nonsteroidal inflammatory drugs (NSAIDs) postoperatively. Patients were started on the CPM machine immediately after surgery. The CPM machine was set at the maximum level of flexion and extension that had been achieved in the operating room. Patients took the machine home and were instructed to use it for 2 weeks for as many hours per day as tolerated. If pain allowed, they could increase the angle slightly during the first few days. Active and gravity-assisted motion exercises were initiated the morning after surgery. The total duration of hospitalization
in this cohort was 42 days. Pain was managed with a plexus catheter in 6 patients, and the remaining patients used oral narcotics during the postoperative period. Twelve patients that had difficulty regaining motion began using a static progressive turnbuckle (10 patients) or a dynamic (2 patients) splint between 3 and 6 weeks after surgery.

In both cohorts, active and gravity-assisted exercises were initiated on the first postoperative day or after discontinuing CPM. Patients who reached a plateau or decreased in motion were instructed in use of static progressive splints.

**Patients who did not use CPM**

There were 10 men and 6 women with an average age of 50 years (range, 33 to 67 years) in the control NCPM cohort of patients. Nine patients were employed in desk-based work, 3 were laborers, 3 were retired, and 1 was unemployed. The right arm was involved in 8 patients (7 dominant) and the left arm in 8 patients (2 dominant).

Thirteen patients had posttraumatic elbow stiffness. The initial injury was a distal humerus fracture in 6 patients (complicated by a persistent nonunion in 1 patient and concomitant head trauma with subsequent heterotopic ossification in 1 patient), an elbow fracture-dislocation in 4, and a radial head fracture in 3. Eight patients were injured in a fall from standing height, 4 in a fall from greater height, and 1 in a motor vehicle accident. Twelve of the 13 patients had operative treatment of the fracture: 10 patients had open reduction and internal fixation, 1 had a radial head replacement, and 1 had open reduction after failed closed reduction. The patient with closed head injury and a concomitant distal humerus fracture was treated nonoperatively.

Five patients had 9 additional surgical procedures of the same upper extremity prior to the index contracture release: 7 procedures in 3 patients for the treatment of a nonunion or revision of hardware (1 patient also had a subsequent carpal tunnel release), 1 patient had manipulation under anesthesia to address stiffness, and 1 patient had a prior ulnar nerve transposition.

Of the 3 remaining patients, stiffness was related to primary osteoarthritis in 2 patients; in 1 patient, stiffness was related to heterotopic bone due to a 30% total body surface area flame burn. The 2 patients with primary osteoarthritis had no prior trauma, presented with progressive loss of motion and pain, and had radiographic evidence of arthritis and loose bodies. One of them had a previous operative procedure to address stiffness.

The average arc of flexion and extension prior to the index contracture release was 42° (range, 0° to 75°) with an average flexion of 90° (range, 30° to 125°) and an average flexion contracture of 48° (range, 25° to 80°). The arc of forearm rotation averaged 126° (range, 0° to 180°) with an average 65° of pronation (range, 0° to 90°) and an average 61° of supination (range, 0° to 90°). Heterotopic bone was blocking motion in 8 patients. Nine patients had signs of ulnar neuropathy prior to the index release.
Excluding the 2 patients who had primary osteoarthritis, the interval between the original injury and the index contracture release was 12 months (range, 2–66 months). In 9 patients, the contracture release was performed using a combined medial and lateral interval through a single dorsal incision; in 3 patients a lateral interval was used; in 3 patients a medial interval was used; and in 1 patient medial and lateral intervals through separate incisions were used. The ulnar nerve was released and/or transposed anteriorly in the 13 patients who had a medial interval. An attempt to replace the radial head was made in 3 patients but failed in 1 because of deficient bone at the capitellum, and in 1 patient the radial head was excised. Implants were removed in 5 patients.

Six patients received preoperative radiation (a single dose of 7 Gy) as a prophylaxis against the recurrence of heterotopic bone. None of the patients was prescribed NSAIDs. Active and gravity-assisted motion exercises were begun on the first postoperative day. The total duration of hospitalization was 20 days. All patients used oral narcotic medications for pain control. None of the patients in this cohort had a brachial plexus catheter. Eight patients who had difficulty regaining the motion that was obtained during surgery, in spite of active exercises, began using a static progressive turnbuckle (7 patients) or a dynamic (1 patient) splint between 3 and 6 weeks postoperatively.

### Table 1. Comparison of Cohorts

<table>
<thead>
<tr>
<th></th>
<th>CPM Cohort</th>
<th>None CPM Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td>5 women, 11 men</td>
<td>6 women, 10 men</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>42 years (range, 18 to 63 years)</td>
<td>50 years (range, 33 to 67 years)</td>
</tr>
<tr>
<td><strong>Occupation</strong></td>
<td>13 deskbased</td>
<td>9 deskbased</td>
</tr>
<tr>
<td></td>
<td>5 laborer</td>
<td>3 laborer</td>
</tr>
<tr>
<td></td>
<td>1 unemployed</td>
<td></td>
</tr>
<tr>
<td><strong>Diagnosis</strong></td>
<td>5 distal humerus fracture</td>
<td>4 distal humerus fracture</td>
</tr>
<tr>
<td></td>
<td>1 distal humerus nonunion</td>
<td>1 distal humerus nonunion</td>
</tr>
<tr>
<td></td>
<td>4 elbow fracture-dislocation</td>
<td>4 elbow fracture-dislocation</td>
</tr>
<tr>
<td></td>
<td>2 radial head fracture</td>
<td>3 radial head fracture</td>
</tr>
<tr>
<td></td>
<td>2 primary osteoarthritis</td>
<td>2 primary osteoarthritis</td>
</tr>
<tr>
<td></td>
<td>1 CNS injury</td>
<td>1 head trauma + distal humerus fracture</td>
</tr>
<tr>
<td></td>
<td>1 coma + flame burns</td>
<td>1 flame burns</td>
</tr>
<tr>
<td><strong>Dominant Arm</strong></td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>Pre-Surgery FE Arc</strong></td>
<td>38 degrees (range, 0 to 75 degrees)</td>
<td>42 degrees (range, 0 to 75 degrees)</td>
</tr>
</tbody>
</table>

*CPM = continuous passive motion, CNS = central nervous system, FE = flexion and extension*
Complications and subsequent surgeries

Prior to the early evaluation

Prior to the 6-month evaluation (2 months after the index release and 3 months prior to the early follow-up), 1 patient in the CPM cohort had a subsequent elbow surgery for release of residual stiffness and a previously transposed ulnar nerve. In the NCPM cohort, 4 patients had 7 subsequent procedures prior to the early evaluation. Three of these patients had 6 procedures for residual stiffness: manipulation (2 months after the index release) and subsequent release with application and removal of a hinged external fixator (4 months after the index release and 2 months prior to the early evaluation) in 1 patient, interposition arthroplasty with application and removal of an external fixation in 1 patient (6 months after the index release and 4 months prior to the early evaluation), and a release with radial head replacement (4 months after the index release and 2 months prior to the early evaluation) in 1 patient. One patient had a release of the previously transposed ulnar nerve at an outside institution 2 months after the index release and 11 months prior to the final evaluation (this patient did not have an early follow-up in the medical record). In addition, 2 patients had surgery on the contralateral arm: 1 patient had a release of a congenital syndactyly with skin grafting (completely unrelated to the elbow problem), and 1 patient with burns had release of a flexion contracture of the contralateral index finger.

Between the early and final evaluation

In the CPM cohort, 1 patient had a release of a previously transposed ulnar nerve 1 year after the index release and 4 months prior to the final evaluation. One patient with primary osteoarthritis had a release of the contralateral elbow 10 months after the index release of the other elbow. In the NCPM cohort, the patient who had a radial head replacement after the index release had a revision of the implant 16 months after the index release and 15 months prior to the final evaluation.

Comparison of cohorts

There were no significant differences between the cohorts in terms of age (p = 0.07), gender (p = 1.00), occupation (p = 1.00), dominant limbs involved (p = 0.46), injury (fracture vs no fracture [head trauma, burns, primary osteoarthritis]; p = 1.00), distal humerus fractures (p = 1.00), ipsilateral upper extremity injuries (p = 0.48), number of surgeries subsequent to the initial treatment and prior to the index release (p = 1.00), presence of heterotopic bone prior to surgery (p = 0.27), preoperative arc of flexion and extension (p = 0.60), preoperative arc of forearm rotation (p = 0.91), and the number of additional surgeries after the index release (p = 0.22). The total duration of hospitalization differed significantly between cohorts (total of 37 days in the CPM cohort vs 20 days in the NCPM cohort; p < 0.01).
Evaluation

Early evaluation
Twelve patients in the CPM cohort and 10 patients in the NCPM cohort had early results (4 to 10 months) available from the medical record.

Final evaluation
All patients were evaluated according to the Broberg and Morrey Evaluation System (B&M).\textsuperscript{17} Twenty-three patients were evaluated by an investigator who was not involved in the care of the patients during a research-specific visit for the purpose of the current or a previous study. These patients (10 in the CPM cohort and 13 in the NCPM cohort) were evaluated according to 2 physician-based elbow scoring systems (the Mayo Elbow Performance Index [MEPI]\textsuperscript{18} and the American Shoulder and Elbow Surgeons Elbow Evaluation [ASES]\textsuperscript{19}) and completed an upper-extremity–specific health status questionnaire: the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire\textsuperscript{20}. As a quantitative measure of pain, we calculated the ASES pain score from 5 patient-rated pain subscales. This pain score ranges from 0 to 25 points with 25 points indicating no pain. Arthritis was rated according to the system of Broberg and Morrey\textsuperscript{17} by an independent observer who was blinded to use of CPM.

Statistical analysis
Continuous data are presented in terms of mean, standard deviation, and range. The 2 cohorts were compared using Student’s t-test for continuous variables and Fisher’s exact test for dichotomous variables (SPSS version 10.0; SPSS Inc, Chicago, IL). A power analysis indicated that a sample size of 17 patients in each cohort would provide 80% power to detect a difference of 10% in the arc of flexion and extension between cohorts ($\alpha = 0.05$; $\beta = 0.20$). P-values of less than 0.05 were considered statistically significant. In univariate analysis, relationships between the arc of flexion and extension with continuous variables (age, number of surgeries prior to the index release, number of additional surgeries after the index release, and time between the index release and follow-up) were evaluated using Pearson correlation ($r$), and relationships with dichotomous variables (gender, occupation [laborer vs non-laborer], limb dominance, initial injury type [fracture vs no fracture], distal humerus fracture, ipsilateral injury, ulnar neuropathy, arthritis, and use of CPM) were evaluated using Student’s t-test. All factors that had significant or near-significant ($p < 0.10$) correlation with the final arc of flexion and extension were included in a multivariate analysis to determine the strongest predictors of arc of flexion and extension.
Results

Early evaluation

Early results (4–10 months) were available for 12 patients in the CPM cohort and for 10 patients in the NCPM cohort. The time since surgery averaged 6 months ± 2 (range, 4–10 months) in the CPM cohort and 7 months ± 2 (range, 4–10 months) in the NCPM cohort. The early results are reported in Table 2.

There were no significant differences between the 2 cohorts in terms of arc of flexion and extension (p = 0.86) and improvement in the arc of flexion and extension (p = 0.83) (Fig. 1). The difference in forearm rotation was statistically significant (p < 0.01), but the average improvement in forearm rotation was comparable between cohorts (p = 0.90).

<table>
<thead>
<tr>
<th></th>
<th>CPM Cohort</th>
<th>None CPM Cohort</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>avg</td>
<td>SD</td>
<td>range</td>
</tr>
<tr>
<td>Flexion</td>
<td>118</td>
<td>10</td>
<td>100 - 135</td>
</tr>
<tr>
<td>Extension</td>
<td>25</td>
<td>6</td>
<td>15 - 135</td>
</tr>
<tr>
<td>FE arc</td>
<td>94</td>
<td>12</td>
<td>70 - 115</td>
</tr>
<tr>
<td>Improvement in FE arc</td>
<td>58</td>
<td>16</td>
<td>30 - 80</td>
</tr>
<tr>
<td>Pronation</td>
<td>87</td>
<td>10</td>
<td>60 - 90</td>
</tr>
<tr>
<td>Supination</td>
<td>81</td>
<td>17</td>
<td>45 - 90</td>
</tr>
<tr>
<td>PS arc</td>
<td>168</td>
<td>26</td>
<td>105 - 180</td>
</tr>
<tr>
<td>Improvement in PS arc</td>
<td>26</td>
<td>56</td>
<td>0 - 150</td>
</tr>
</tbody>
</table>

CPM = continuous passive motion, avg = average, SD = standard deviation, FE = flexion and extension, PS = pronation and supination

Final evaluation

The results at the final evaluation are summarized in Table 3. In the CPM cohort, the final follow-up was performed an average of 19 months ± 10 (range, 10–52 months) after the index release and 18 months ± 10 (range, 10–52 months) after the most recent surgery. Four patients with preexistent ulnar neuropathy and who had a release or transposition during the index release had signs of ulnar nerve dysfunction at follow-up. In 2 of these 4 patients, the ulnar nerve had also been addressed in an additional procedure. One patient without preexistent ulnar nerve dysfunction reported in the medical record, but in whom the nerve was freed up during the index surgery, developed new symptoms of ulnar nerve dysfunction.

In the NCPM cohort, the final evaluation occurred at an average 31 months ± 15 (range, 12–56 months) after the index release and 28 months ± 15 (range, 7–56 months) after the most recent surgery. Five patients with preexistent ulnar nerve dysfunction had residual signs of ulnar neuropathy at follow-up in spite of release or transposition of the nerve during the index contracture release. In 2 of these 5 patients, the ulnar nerve had been addressed in a
subsequent procedure. Two patients without preexistent ulnar neuropathy in the medical record developed new symptoms of ulnar nerve dysfunction; in 1 of these 2 patients, the nerve had been transposed during the index surgery.

There was no significant difference between cohorts in terms of the final arc of flexion and extension (p = 0.56; Fig. 1), the final arc of forearm rotation (p = 0.71), improvement in the arc of flexion and extension (p = 0.95), and ulnar nerve dysfunction (p = 0.72). In univariate analysis, there was near-significant association between fracture of the distal humerus with worse final flexion and extension (p = 0.06). There was no significant or near-significant relation between the final arc of flexion and extension with age (p = 0.78), gender (p = 0.87), occupation (p = 0.65), limb dominance (p = 0.14), initial injury type (p = 0.90), ipsilateral injury (p = 0.50), number of subsequent surgeries prior to the index release (p = 0.48), number of additional surgeries after the index release (p = 0.38), time between the index release and follow-up (p = 0.65), use of CPM (p = 0.46), ulnar neuropathy (p = 0.74), and arthritis (p = 0.15). A linear regression model with distal humerus fracture explained 9% of the variation in final arc of flexion and extension but was not statistically significant (p = 0.06).

![Figure 1. Comparison flexion and extension arc between cohorts](image_url)

**Figure 1.** Comparison flexion and extension arc between cohorts

**Questionnaires**

All patients were evaluated according to the B&M evaluation system, and 10 patients in the CPM cohort and 13 patients in the NCPM cohort were also evaluated with the MEPI, ASES,
and the DASH questionnaire. There were no differences between cohorts in B&M, MEPI, ASES and DASH scores (Table 3).

Radiographic assessment
Radiographs were available for 15 of the 16 patients in both cohorts. There was a statistically significant difference in the number of patients with arthritis between cohorts (\(p = 0.16\); Table 3).

<table>
<thead>
<tr>
<th>Table 3. Final evaluation</th>
<th>CPM Cohort</th>
<th>None CPM Cohort</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>avg SD</td>
<td></td>
<td>avg SD</td>
</tr>
<tr>
<td>Flexion</td>
<td>123 13 90 140</td>
<td>120 19 65 145</td>
<td>0.60</td>
</tr>
<tr>
<td>Extension</td>
<td>26 13 5 50</td>
<td>19 12 0 35</td>
<td>0.08</td>
</tr>
<tr>
<td>FE arc</td>
<td>96 22 60 130</td>
<td>101 26 35 135</td>
<td>0.56</td>
</tr>
<tr>
<td>Improvement in FE arc</td>
<td>59 27 25 110</td>
<td>59 26 20 110</td>
<td>0.95</td>
</tr>
<tr>
<td>Pronation</td>
<td>83 10 60 90</td>
<td>87 9 60 90</td>
<td>0.23</td>
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<tr>
<td>Supination</td>
<td>75 22 25 90</td>
<td>74 18 40 90</td>
<td>0.93</td>
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<tr>
<td>PS arc</td>
<td>158 30 105 180</td>
<td>161 20 130 180</td>
<td>0.71</td>
</tr>
<tr>
<td>Improvement in PS arc</td>
<td>28 50 -30 130</td>
<td>36 60 -20 150</td>
<td>0.73</td>
</tr>
<tr>
<td>B &amp; M score</td>
<td>84 13 52 98</td>
<td>83 11 60 100</td>
<td>0.35</td>
</tr>
<tr>
<td>MEPI score</td>
<td>85 11 70 100</td>
<td>78 16 50 100</td>
<td>0.29</td>
</tr>
<tr>
<td>ASES score</td>
<td>90 11 62 100</td>
<td>85 11 57 97</td>
<td>0.35</td>
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<tr>
<td>ASES pain score</td>
<td>22 5 9 25</td>
<td>18 6 6 24</td>
<td>0.11</td>
</tr>
<tr>
<td>DASH score</td>
<td>16 18 1 56</td>
<td>16 10 2 32</td>
<td>0.99</td>
</tr>
<tr>
<td>B &amp; M categorical rating</td>
<td>3 exc, 10 good, 2 fair, 1 poor</td>
<td>2 exc, 7 good, 7 fair</td>
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</tr>
<tr>
<td>MEPI categorical rating</td>
<td>3 exc, 5 good, 2 fair</td>
<td>3 exc, 5 good, 3 fair, 2 poor</td>
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</tr>
<tr>
<td>B &amp; M arthritis</td>
<td>4 grade 1, 2 grade 2</td>
<td>4 grade 1, 4 grade 2, 2 grade 3</td>
<td></td>
</tr>
</tbody>
</table>

\(CPM = \text{continuous passive motion, avg = average, SD = standard deviation, FE = flexion and extension, PS = pronation and supination, B & M = Broberg and Morrey, MEPI = Mayo Elbow Performance Index, ASES = American Shoulder and Elbow Surgeons Elbow Evaluation, DASH = Disabilities of Arm Shoulder and Hand questionnaire, exc = excellent}\)

Discussion
Many studies have documented satisfactory results after operative contracture release of the stiff elbow.\(^1\) The popular use of CPM after a contracture release is primarily based on anecdotal support\(^2\)\(^-\)\(^12\) rather than scientific evidence. In the current retrospective comparison of cohorts of patients that were put on a CPM device after an elbow contracture release versus those that did not use CPM (control NCPM cohort), no differences in elbow arc of flexion and extension or in improvement in arc of flexion and extension were found. CPM either provided no benefit or such a small or specific benefit that it was not detected in this retrospective study. Given these results, and in light of the costs of the device, risks related to
regional anesthesia, and the prolonged hospitalization associated with use of CPM (p < 0.01 in this study), the onus is on advocates of CPM to demonstrate that the risk, costs, and inconveniences are merited.

Two retrospective investigations by Urbaniak’s group\textsuperscript{6,10} suggested an advantageous effect of CPM on restoration of ulnohumeral motion after operative release of flexion contractures—thus, loss of extension. It is notable that one of these studies\textsuperscript{10} found a significant greater improvement in flexion instead of extension with use of CPM. Furthermore, when interpreting these studies, it is important to be aware that NCPM patients were immobilized with an extension splint postoperatively (in one study for a total of 10 days; in the other study the number of days was not reported) rather than beginning immediate active-assisted exercises. Patients that used CPM had a greater improvement in the arc of flexion and extension than that of NCPM patients; however, the differences in improvement must be interpreted in light of the fact that—prior to the contracture release—patients using CPM had substantially stiffer elbows than those of NCPM patients (an average difference of 21° in each of the studies), potentially jeopardizing the validity of their comparisons. The results in our study (average improvements of 59° in both cohorts) compared favorably with the results reported in these two studies (average improvements of 47° and 45° with CPM and 25° and 26° without CPM)\textsuperscript{6,10}, as well as with results documented in other retrospective studies that reported on contracture release without specifically addressing the effect of CPM (average improvements ranging from 21° to 66°).\textsuperscript{1}

There were no statistically significant differences between the cohorts in terms of ulnar neuropathy and the number of additional surgeries. The incidence of arthritis was somewhat lower in the CPM cohort than that in the NCPM cohort (38% vs 63%; p =0.16). In spite of the apparently better joints in the CPM cohort, CPM did not show a benefit in terms of gains in motion. There was no significant correlation between arthritis and the arc of flexion and extension.

We do realize that this study has several shortcomings, for instance the short duration of follow-up in some patients, the lack of recorded data on patients’ use of and compliance with the CPM device, variation in the type of exercises and supervision, and those inherent to a retrospective study, including the potential for selection bias. As mentioned in the “Materials and Methods” section, we believe that the bias in this study is limited because of the inconsistent use of CPM for reasons that were believed to be inconsequential and is further limited by the study design with matched control patients. Another limitation of our study is the difference in follow-up time between the CPM cohort and the NCPM cohort (average, 19 vs 30 months) potentially influencing the arc of flexion and extension. However, when the subgroup of patients who had early follow-up available was analyzed, there was no difference in improvement in the arc of flexion and extension between cohorts at any time point. Furthermore, in univariate analysis, there was no association between follow-up time and the
arc of flexion and extension. Therefore, it would seem unlikely that the difference in follow-
up time between cohorts affected the results of this study. Of course, the effectiveness of CPM
would be best investigated in a prospective randomized trial. On the other hand, such a study
is very difficult to execute because of the relative infrequency of the problem, as well as
inconsistent coverage of CPM by insurance companies. Even retrospective data are difficult to
come by as reflected in the paucity of studies investigating CPM.

With the limitations of this retrospective study in mind, and while encouraging others to
repeat our work, we believe that it is safe to assume that there is no advantage of CPM on the
arc of flexion and extension after open elbow contracture release. Postoperative management
with early active and gravity-assisted exercises, and perhaps static progressive or dynamic
splinting for residual stiffness, is indicated after operative elbow contracture release. If our
current line of research into the importance of selfefficacy, mindfulness, and confidence with
painful postrelease stretching exercises confirms our gut feeling that these psychological
aspects of rehabilitation are associated with a better arc of flexion and extension, passive
treatments like CPM may even turn out to be counterproductive.

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PART V

General Discussion