

# An Expedited Care Pathway with Ambulatory Brachial Plexus Analgesia Is a Cost-effective Alternative to Standard Inpatient Care after Complex Arthroscopic Elbow Surgery

## A Randomized, Single-blinded Study

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### ABSTRACT

**Background:** Common standard practice after complex arthroscopic elbow surgery includes hospital admission for 72 h. The authors hypothesized that an expedited care pathway, with 24 h of hospital admission and ambulatory brachial plexus analgesia and continuous passive motion at home, results in equivalent elbow range of motion (ROM) 2 weeks after surgery compared with standard 72-h hospital admission.

**Methods:** A randomized, single-blinded study was conducted after obtaining approval from the research ethics board. Forty patients were randomized in a 1:1 ratio using a computer-generated list of random numbers into an expedited care pathway group (24-h admission) and a control group (72-h admission). They were treated equally aside from the predetermined hospital length of stay.

**Results:** Patients in the control (n = 19) and expedited care pathway (n = 19) groups achieved similar elbow ROM 2 weeks ( $119 \pm 18$  degrees and  $121 \pm 15$  degrees,  $P = 0.627$ ) and 3 months ( $130 \pm 18$  vs.  $130 \pm 11$  degrees,  $P = 0.897$ ) postoperatively. The mean difference in elbow ROM at 2 weeks was 2.6 degrees (95% CI, -8.3 to 13.5). There were no differences in analgesic outcomes, physical function scores, and patient satisfaction up to 3 months postoperatively. Total hospital cost of care was 15% lower in the expedited care pathway group.

**Conclusion:** The results suggest that an expedited care pathway with early hospital discharge followed by ambulatory brachial plexus analgesia and continuous passive motion at home is a cost-effective alternative to 72 h of hospital admission after complex arthroscopic elbow surgery. (*ANESTHESIOLOGY* 2015; 123:1256-66)

COMPLEX arthroscopic elbow surgery is an advanced surgical procedure indicated to improve range of motion (ROM) and decrease long-term pain for patients with symptomatic elbow arthritis that has not responded to conventional nonsurgical therapy.<sup>1,2</sup> The most common underlying etiologies are osteoarthritis and posttraumatic contractures.<sup>3</sup> Current standard practice in our institution and other tertiary care centers in North America<sup>4-6</sup> includes inpatient admission for a period of 72 h with intensive physiotherapy *via* continuous passive motion (CPM) 24-h-a-day for 3 days and continuous brachial plexus local anesthetic infusion to reduce pain and opioid requirements.<sup>7-12</sup> Outpatient management has the benefits of improved quality-of-life convalescing in the comfort of the patient's own home, a lower risk of nosocomial infection,<sup>10</sup> and lower associated hospital costs.<sup>13</sup>

#### What We Already Know about This Topic

- Complex arthroscopic elbow surgery can improve range of motion and decrease pain for patients with elbow arthritis. Current standard practice in many institutions includes inpatient admission for 72 h with intensive physiotherapy and continuous brachial plexus analgesia.

#### What This Article Tells Us That Is New

- In a randomized, single-blinded study of 40 patients, an expedited care pathway with early hospital discharge followed by ambulatory brachial plexus analgesia and physiotherapy at home was a cost-effective alternative to 72 h of hospital admission after complex arthroscopic elbow surgery.

However, the impact of outpatient management on surgical outcome and patient safety has not been fully evaluated.

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The primary aim of this study was to determine the effect of an expedited care pathway with a shorter period of hospital admission (24 h), followed by enhanced outpatient management with continuous brachial plexus analgesia and CPM at home, on surgical and functional outcome compared with standard 3-day hospital admission after complex arthroscopic elbow surgery. Our specific hypothesis was that this expedited care pathway results in equivalent arc ROM defined as maximum flexion to maximum extension (within  $\pm 10$  degrees of the control group) 2 weeks postoperatively.

## Materials and Methods

This prospective, randomized, single-blinded, equivalence study was approved by the research ethics board of the University Health Network (Toronto, Ontario, Canada). All subjects gave written informed consent. The study was registered at ClinicalTrials.gov (under the identifier NC: T01151241; initial release date: June 24, 2010; principal investigator: Dr. Perlas).

Consecutive patients undergoing elective arthroscopic elbow surgery at Toronto Western Hospital (University Health Network, Toronto, Ontario, Canada) were enrolled at the time of initial consultation with a single attending orthopedic surgeon between October 2010 and May 2014. Inclusion criteria were age 18 to 65 yr, American Society of Anesthesiologists' physical status class I to III, and elective complex elbow surgery requiring postoperative CPM use. The types of surgical procedures included synovectomy, capsulectomy, extensive debridement, contracture release, and osteocapsular arthroplasty. Exclusion criteria were cognitive impairment, significant psychiatric history, absence of social home support, allergy to ropivacaine, chronic opioid use ( $> 60$  mg oral morphine equivalents per day for at least 1 month) and severe comorbidities that may require prolonged hospitalization for medical reasons unrelated to the surgical indication. All patients in the study had standard provincial health insurance coverage (Ontario Health Insurance Plan, Ontario, Canada). No financial considerations or patient preferences had any impact on inclusion and exclusion criteria.

### Patient Randomization and Study Groups

Patients were randomized in a 1:1 ratio to one of the two groups; *control group* (72 h of hospital admission) and *expedited care pathway group* (24 h of hospital admission), using a computer-generated randomization sequence (www.random.org, accessed May 1, 2014). Group allocation was concealed in sealed opaque envelopes. Both surgical and anesthetic teams were unaware of group allocation until after completion of surgery. Investigators measuring and documenting all outcomes beyond the first 72 h postoperatively were also unaware of group allocation. Due to the nature of the intervention, it was not possible to blind the patients to group allocation.

Except for the length of hospital stay, patients in both groups received identical care. Preoperative and intraoperative management, postoperative analgesic, and CPM protocols were standardized and identical across the groups.

### Preoperative Management

Intravenous access was established and baseline heart rate, noninvasive blood pressure, and pulse oximetry were recorded. Anxiolysis was achieved with midazolam 1 to 2 mg if required. After completing a regional anesthesia time-out and correct side check, an infraclavicular brachial plexus catheter was inserted (StimuCath Arrow International, USA) as per standard institutional practice. The catheter was placed under real-time ultrasound guidance by a staff anesthesiologist or regional anesthesia fellow under staff supervision, using an in-plane approach, a linear high-frequency (6 to 13 MHz) ultrasound transducer, and a SonoSite Turbo unit (SonoSite Bothell, USA). Five to 10 ml of 5% dextrose was injected through the introducing needle and catheter to ensure the appropriate spread of the solution posterior to the axillary artery and within the brachial plexus compartment with spread to all three cords. The catheter was advanced 2 to 3 cm beyond the tip of the introducer needle. Nerve stimulation was used if necessary to confirm catheter position by eliciting a distal hand/wrist motor response with an amplitude of 0.3 to 0.5 mA (Stimuplex; B. Braun Medical, USA). The catheter was secured with a sterile adhesive tape (Epi-Guard; LiNA Medical ApS, Denmark) and covered with an occlusive dressing (Tegaderm, 3LM Corporation, USA). No local anesthetic was administered preoperatively to allow the surgeon to assess neurologic function in the immediate postoperative period.

### Intraoperative Management

General anesthesia was induced with intravenous fentanyl 2 to 3  $\mu\text{g}/\text{kg}$  and propofol 1.5 to 2.0  $\text{mg}/\text{kg}$  titrated to obtain loss of consciousness. Rocuronium 0.6  $\text{mg}/\text{kg}$  was administered for muscle relaxation. Patients were intubated and ventilated with oxygen/air 40%/60%. Anesthesia was maintained with desflurane at 0.7 to 1.0 minimum alveolar concentration. Additional fentanyl boluses of 50 to 100  $\mu\text{g}$  were administered for intraoperative analgesia at the discretion of the attending anesthesiologist. No intraarticular local anesthetics were injected. The patient was placed in the lateral decubitus position with the surgical upper extremity placed on an elbow holder. Standard arthroscopic technique and setup was employed using a safety-driven strategy.<sup>5</sup> Residual paralysis was antagonized at the end of the procedure with neostigmine (40  $\mu\text{g}/\text{kg}$ ) and glycopyrrolate (7  $\mu\text{g}/\text{kg}$ ), if necessary. After emergence from anesthesia, the patient was extubated in the operating room and then transferred to the postanesthetic care unit.

### Analgesic Protocol

On arrival in the postanesthetic care unit, the neurovascular function was evaluated by the surgical team with particular

attention to the radial, median, and ulnar nerve territories. Once nerve function was documented to be intact, a standard bolus of 30 ml of 0.25% bupivacaine with 1:400,000 epinephrine was administered through the brachial plexus catheter. The brachial plexus block was considered to be adequate if weakness ensued in the radial, median, and ulnar nerve distributions and a numeric rating scale (NRS) score of no more than 3/10 was achieved within 30 min of initial bolus administration. Subsequently, an infusion of ropivacaine 0.2% was started at a rate of 7 ml/h with a patient-controlled bolus of 5 ml and a lockout period of 30 min. The brachial plexus catheter was replaced if the initial bolus resulted in inadequate block or if it had become displaced during the surgical procedure. An electronic pump (Abbott GemStar, USA) was used overnight for all patients. The morning after surgery, the electronic pump was exchanged for a disposable elastomeric pump (Baxter Regional Analgesia Infusor System; Baxter International Inc., USA) with identical infusion and bolus settings in both groups. This infusion was discontinued 60 h postoperatively on all patients in both groups. The multimodal analgesic regimen also included the following medications: sustained-release indomethacin 75 mg orally once daily for 3 weeks, sustained-release oxycodone 10 mg twice daily, and acetaminophen 325 mg/oxycodone 5 mg combination one to two tablets every 4 to 6 h as needed. The infraclavicular catheter was removed 72 h postoperatively in all patients in both groups.

Patients in the *control group* (72-h admission) were visited daily by the acute pain service team as per standard institutional practice. Analgesic efficacy was monitored and changes in dosing regimens made as required to optimize analgesia. The goal for analgesia was compliance with CPM protocol and a "mild" level of pain NRS  $\leq 3$ ). The infusion was discontinued 60 h postoperatively (on the evening of postoperative day 2). The infraclavicular catheter was removed by the acute pain service team 72 h after surgery on the morning of hospital discharge.

Patients in the *expedited care pathway group* (24-h admission) were discharged home the morning after surgery following verbal and written instructions on portable elastomeric pump and CPM equipment use. No home care nursing was arranged. An anesthesiologist contacted each patient daily by telephone to monitor analgesic efficacy and advice on changes in dosing regimens if required. In addition, patients had access to telephone advice 24-h-a-day for questions or support regarding analgesia. The goal for analgesia was compliance with the CPM protocol and a "mild" level of pain (NRS  $\leq 3$ ). The infusion was discontinued 60 h postoperatively (on the evening of postoperative day 2). The infraclavicular catheter was removed 72 h postoperatively by the patient while on the phone with the anesthesiologist. The follow-up intervals were as follows: daily for 72 h (either in person in hospital or on the phone if at home) and in-person office visits at 2 weeks, 6 weeks, and 3 months. Any interim complications, the need for additional unscheduled

visits, or hospital admissions were recorded during the first 3 months postoperatively.

### CPM Protocol

Once analgesia was established, and within 6 h of the surgical procedure, the upper extremity was set up on the E3 Elbow CPM Device (Ottobock Canada, Canada). The CPM protocol involves elbow motion through the full arc of motion obtained at the time of surgery. Each hour is separated into the following cycles: (1) cycle terminal extension (0 to 20 degrees, 10 min), (2) cycle terminal flexion (120 to 140 degrees, 10 min), (3) cycle terminal extension (0 to 20 degrees, 10 min), (4) cycle terminal flexion (120 to 140 degrees, 10 min), (5) run full ROM (0 to 140 degrees, 15 min), and (6) break (5 min). The entire cycle is repeated for 72 h and then a weaning protocol is started. The weaning protocol involves coming out of the CPM machine for increasingly longer periods of time, 30 min on day 4, 1 h on day 5, 2 h on day 6, 4 h on day 7, increasing the off-period by 2 h a day until day 14, and after which time CPM is discontinued and patients begin a static progressive stretch program on their own. Identical CPM protocol was used for all patients in the study, regardless of group allocation.

### Primary and Secondary Outcomes

The primary outcome measure is the arc ROM (defined as maximum flexion to maximum extension) 2 weeks after surgery. All patients in this study had a preexisting limitation of elbow ROM, and improving their arc ROM was the main indication for the surgical procedure. The primary outcome was measured 2 weeks after surgery because most of the ROM recovery occurs within this time frame. Secondary outcomes include (1) elbow ROM at 6 weeks and 3 month; (2) global measures of postsurgical functional recovery assessed with the Disability of the Arm, Shoulder, and Hand (DASH) questionnaire (appendix 1)<sup>14,15</sup> and the Short-Form-12 questionnaire (SF-12, appendix 2)<sup>16</sup> at 2 weeks, 6 weeks, and 3 months; (3) quality of analgesia evaluated by pain scores (reported with an 11-point verbal NRS, where 0 is no pain at all and 10 is the worst pain imaginable) and opioid consumption; (4) patient safety outcomes (incidence of postoperative neurologic dysfunction and surgical-site infection); and (5) cost-effectiveness analysis.

Official hospital-related costs were obtained from the hospital finance unit, following year-end closure and case-costing analysis performed as per standard hospital practice. The costs reported herein are the actual costs of care for the individual patients. These are followed for each individual patient and recorded prospectively by the hospital finance department. Direct costs (*e.g.*, costs of drugs administered to the patient or imaging studies) are known shortly after the care encounter. Indirect costs, however, usually represent a portion of a larger cost item incurred by a department, which is then subdivided by the total number of patients cared for in a particular patient unit in a given time period (*e.g.*, facilities

cost, unit overhead costs). Therefore, the precise total cost to the hospital of a given patient care encounter for a given individual is only fully known after closing the “hospital books” at the financial year end. Our study includes real total costs for each individual patient calculated and reported at the hospital’s financial year end. The cost categories reported include fixed (both direct and indirect costs) as well as variable (direct and indirect) costs. Costs are also reported by department (*e.g.*, pharmacy, operating room, recovery room, or imaging).

### Statistical Analysis and Sample Size Calculation

The sample size calculation was based on the following assumptions:

- The minimum clinically significant difference in arc improvement was conventionally established at 10 degrees.
- The SD of the arc change is the same for the two treatment groups and equal to 10 degrees.<sup>17</sup>
- Power = 0.8 and type I error = 0.05, for two one-sided *t* tests (TOST).

We estimated that a minimum of 17 patients were required in each treatment group. To allow for possible early withdrawals or incomplete follow-up due to patient factors, we enrolled a total of 40 patients.

All analyses were undertaken on a per-protocol set. Analysis of equivalence for the primary outcome (ROM at 2 weeks postoperatively) was carried out using TOST. Univariate differences between the early discharge group and the control group were compared using the Wilcoxon rank sum test for

continuous variables unless otherwise stated. Data are presented as mean followed by SD for continuous variables. In addition, repeated-measures ANOVAs were conducted to assess the differences between groups in the DASH score, SF-12, pain score, oral opioid consumption, and patient satisfaction with perioperative care. Least-squares mean differences between groups were compared; their associated 95% CIs and *P* values are presented. For all analyses, *P* value less than 0.05 was considered statistically significant. SAS version 9.3 (SAS Institute, USA) was used for analysis.

### Results

Forty patients were enrolled between October 2010 and May 2014 and randomized into control (*n* = 20) and expedited care pathway (*n* = 20) groups (fig. 1). Two patients were excluded after randomization. One patient randomized to the control group was excluded due to technical difficulties with CPM equipment that resulted in CPM protocol violation. In addition, one patient randomized to the expedited care pathway group was excluded as no social support was available at home in the immediate perioperative period, precluding early discharge. Thirty-eight patients completed the study and were included in the analysis on a per-protocol basis (fig. 1). However, all patients enrolled in the study received the treatment they were allocated to, with no cross-overs. Follow-up data were complete for all patients, with the exception of hospital cost data, which were unavailable for one patient in the control group and for two patients in the expedited care pathway group. Patient demographics

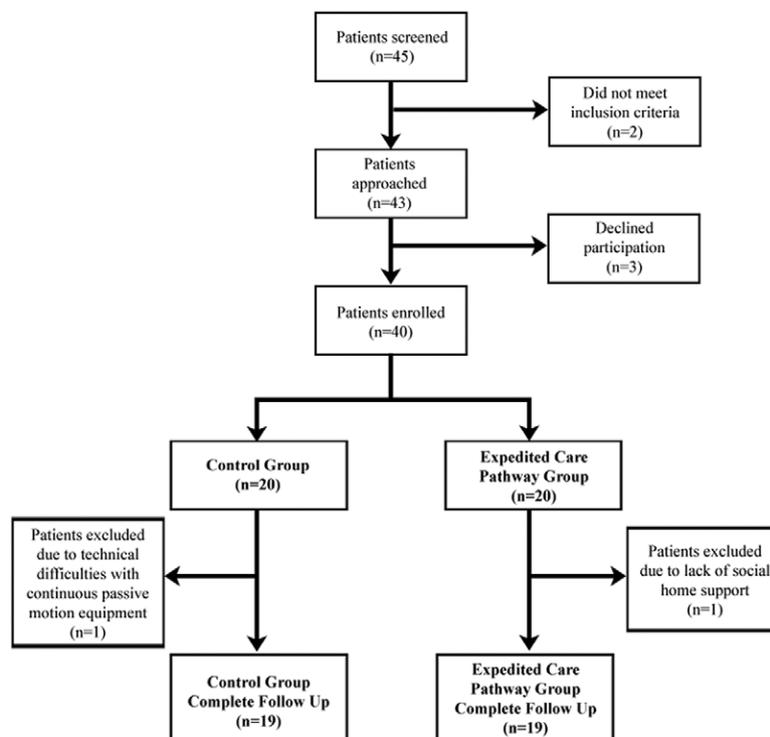


Fig. 1. Patient flow diagram.

were similar in both groups (table 1). Ten catheters needed to be resited in the immediate postoperative period (seven in the control group and three in the early discharge group).

Patients in both groups experienced a clinically significant improvement in their arc ROM from their preoperative baseline, with most of the improvement being evident by 2 weeks postoperatively (table 2). The arc ROM was similar in the control and early discharge groups at 2 weeks ( $119 \pm 18$  vs.  $121 \pm 15$  degrees,  $P = 0.627$ ) and at 3 months postoperatively ( $130 \pm 18$  vs.  $130 \pm 11$ ,  $P = 0.897$ ). The mean difference in primary outcome (arc ROM at 2 weeks postoperatively) between the expedited care pathway and control groups was 2.6 degrees (95% CI,  $-8.3$  to  $13.5$ ). With a predetermined minimally clinically significant difference of 10 degrees, we cannot conclusively state that the primary outcome was *equivalent* between groups. Rather, the TOST analysis suggests that patients in the expedited care pathway group did at least as well as (were noninferior to) the control group (lower limit of the 95% CI within 10 degrees). A superior outcome in the expedited care pathway group cannot be excluded (upper limit of 95% CI  $> 10$  degrees).

Functional outcome improved over time in both groups postoperatively. The DASH score and the mental health component of the SF-12 improved over time (repeated-measures ANOVA  $< 0.0001$  and  $0.002$ , respectively) in both groups, with no differences between the two groups ( $P = 0.1276$  and  $0.427$ , respectively) (table 3). Interestingly, the physical component of the SF-12 improved over time in both groups ( $P < 0.001$ ), but it improved to a greater extent in the expedited care pathway group ( $P = 0.0479$ ) (table 3). Pain scores, daily systemic opioid consumption, and overall patient satisfaction with perioperative care were similar between groups (tables 4 and 5). There were no major complications (including no cases of neurologic dysfunction, no surgical-site or catheter-site infections, no unplanned hospital admissions, and no reoperations) in any patient.

The total hospital cost was 14.6% lower in the expedited care pathway group (CAD\$  $5,675 \pm 1,232$  vs. CAD\$  $6,646 \pm 1,354$ ;  $P = 0.034$ ; table 6). Most of the cost saving was related to a shorter period of hospital admission, specifically in the nursing unit and pharmacy cost categories (table 7), whereas surgical equipment and operating room costs were similar in both groups, as expected.

## Discussion

The current prospective randomized study suggests that an expedited care pathway, with 24 h of hospital admission followed by continuous brachial plexus anesthesia and CPM at home, results in at least similar arc ROM 2 weeks after surgery and at least similar improvements in functional outcome compared with standard 72-h hospital admission after complex arthroscopic elbow surgery. No significant differences in pain, physical function, and patient satisfaction with perioperative care were observed for up to 3 months

**Table 1.** Patient Demographics

	Control Group (n = 19), Mean $\pm$ SD	Expedited Care Pathway Group (n = 19), Mean $\pm$ SD
Sex (male/female)	11/8	15/3
Age (yr)	43 $\pm$ 11	40 $\pm$ 14
Weight (kg)	83 $\pm$ 15	86 $\pm$ 17
Height (cm)	170 $\pm$ 10	174 $\pm$ 9
BMI (kg/cm <sup>2</sup> )	29 $\pm$ 4	28 $\pm$ 6
ASA physical status classification (I/II/III)	5/9/4	6/11/1
Intraoperative fentanyl ( $\mu$ g)	220 $\pm$ 82	233 $\pm$ 105
Tourniquet time (min)	111 $\pm$ 19	117 $\pm$ 23
Surgical time (min)	147 $\pm$ 33	151 $\pm$ 23

ASA = American Society of Anesthesiologists; BMI = body mass index.

postoperatively. In addition, associated hospital costs were 15% lower in the early discharge group.

Ambulatory continuous regional anesthesia is not new. Early practice involved the maintenance of a perineural catheter while in hospital and discontinuation of the infusion before hospital discharge.<sup>11</sup> Early attempts at ambulatory perineural infusions were associated with a number of technical problems including catheter dislodgment, imprecise infusion rates, and undesirable side effects.<sup>12</sup> More recently, several small studies suggest that ambulatory perineural infusions of local anesthetics are feasible and provide adequate analgesia for specific surgical procedures including total shoulder, hip, and knee arthroplasties.<sup>18–20</sup> However, these studies report only short-term analgesic outcomes (such as pain scores and opioid consumption) in the immediate postoperative period.<sup>18–20</sup> Previous clinical experience with ambulatory continuous brachial plexus analgesia for elbow surgery is limited. A published series of three patients suggests that early discharge 24 h after elbow arthroplasty with an ambulatory continuous infusion of local anesthetic is feasible. However, the effect of such shorter hospital stay on rehabilitation and surgical outcomes is largely unknown.<sup>21</sup>

The primary goal of complex arthroscopic elbow surgery (osteocapsular arthroplasty, debridement, synovectomy, or contracture release) is to improve ROM in patients with contractures secondary to either severe arthritis or previous trauma.<sup>19</sup> Establishing immediate postoperative ROM using CPM equipment is a standard practice in many North American centers. It is considered essential to reduce postoperative inflammation and tissue edema, enhance tissue extensibility, and ultimately ensure adequate surgical and functional outcome after major elbow surgery.<sup>3,20</sup> Continuous brachial plexus analgesia within a multimodal regimen is a common standard practice in this setting to minimize pain and enhance functional outcome.<sup>8,9</sup> These advanced interventions usually require inpatient admission for 3 to 4 days.<sup>5</sup>

The results of the current randomized controlled study suggest that an expedited care pathway with 24 h of hospital

**Table 2.** Results: Elbow Range of Motion

	Control Group	Expedited Care Pathway Group	P Value	Mean Difference (95% CI), TOST P Value*
Arc ROM (degrees)				
Baseline	76 ± 28	84 ± 19	0.3248	
2 weeks	119 ± 18	121 ± 15	0.6275	2.6 (−8.3 to 13.5)
6 weeks	121 ± 20	125 ± 19	0.4925	4.4 (−8.5 to 17.4)
3 months	130 ± 18	130 ± 11	0.8859	0.8 (−9.8 to 11.3)
Arc improvement (2 weeks – baseline)	42 ± 29	37 ± 21	0.5321	

\* The overall P value for the TOST equivalence test.

Arc ROM = elbow arc range of motion (from full extension to full flexion); TOST = two one-sided t tests.

**Table 3.** Physical Function and Health-related Quality of Life

	Control Group (n = 19), Mean ± SD	Expedited Care Pathway Group (n = 19), Mean ± SD	P Value*
DASH score			
Baseline	54 ± 19	49 ± 16	> 0.99
2 weeks	58 ± 18	53 ± 24	> 0.99
6 weeks	43 ± 14	34 ± 8	0.3892
3 months	35 ± 12	31 ± 8	> 0.99
SF-12 PCS score			
Baseline	40 ± 9	39 ± 8	> 0.99
2 weeks	39 ± 7	40 ± 8	> 0.99
6 weeks	43 ± 9	50 ± 8	0.0972
3 months	46 ± 9	53 ± 4	0.1056
SF-12 MCS score			
Baseline	54 ± 12	59 ± 7	0.6484
2 weeks	52 ± 9	52 ± 11	> 0.99
6 weeks	55 ± 10	57 ± 6	> 0.99
3 months	57 ± 8	58 ± 7	> 0.99

\* P values were adjusted using Bonferroni correction for multiple comparisons.

DASH = Disability of the Arm, Shoulder, and Hand; MCS = mental component summary; PCS = physical component summary; SF-12 = Short-Form 12.

**Table 4.** Pain and Satisfaction Scores

	Control Group (n = 19), Mean ± SD	Expedited Care Pathway Group (n = 19), Mean ± SD	P Value*
Pain scores (NRS)			
Baseline	3.9 ± 3.2	2.3 ± 2.5	0.6048
PACU	2.2 ± 2.3	2.5 ± 2.6	> 0.99
POD 1	3.2 ± 3.1	3.5 ± 2.9	> 0.99
POD 2	3.2 ± 3.4	2.4 ± 1.4	> 0.99
POD 3	2.4 ± 2.3	2.4 ± 1.5	> 0.99
POD 4	3.6 ± 2.3	2.0 ± 1.0	0.315
Patient satisfaction with perioperative care			
2 weeks	9.4 ± 0.8	9.3 ± 1.3	> 0.99
6 weeks	9.4 ± 0.8	9.3 ± 1.2	> 0.99
3 months	9.4 ± 0.9	9.6 ± 0.7	> 0.99

\* P values were adjusted using Bonferroni correction for multiple comparisons.

NRS = numeric rating scale; PACU = postanesthetic care unit; POD = postoperative day.

admission followed by ambulatory continuous brachial plexus analgesia and CPM at home results in at least similar surgical outcome (assessed by arc ROM 2 weeks postoperatively) compared with inpatient management for 72 h. The close to 40-degree improvement in elbow ROM, compared

with preoperative values, was similar in both treatment groups and consistent with previous reports of 15 to 75 degrees.<sup>17,22</sup> Although the mean difference in primary outcome between the two groups was very small (2.6 degrees) and clinically insignificant, the 95% CI of this difference

**Table 5.** Analgesic Consumption

Opioid Consumption, Daily Oral Morphine Equivalents (mg)	Control Group (n = 19), Mean ± SD	Expedited Care Pathway Group (n = 19), Mean ± SD	P Value*
Baseline	0 ± 0	0 ± 0	> 0.99
PACU	45 ± 50	32 ± 37	> 0.99
POD1	33 ± 35	28 ± 27	> 0.99
POD2	39 ± 46	33 ± 38	> 0.99
POD3	26 ± 26	18 ± 28	0.7974
POD4	13 ± 18	17 ± 31	> 0.99

\* P values have been adjusted using Bonferroni correction for multiple comparisons.

PACU = postanesthetic care unit; POD = postoperative day.

**Table 6.** Hospital Cost in Canadian Dollars

		Control Group (n = 18)	Expedited Care Pathway Group (n = 17)	P Value
Indirect cost	Variable cost	1,305 ± 274	1,124 ± 326	0.083
	Fixed cost	835 ± 252	757 ± 134	0.273
Direct cost	Variable cost	3,727 ± 745	3,088 ± 708	0.014
	Fixed cost	779 ± 197	706 ± 154	0.229
Total cost		6,646 ± 1,354	5,675 ± 1,232	0.034

Values are expressed as mean ± SD.

**Table 7.** Itemized Cost in Canadian Dollars

	Control Group (n = 18)	Expedited Care Pathway Group (n = 17)	P Value
Surgical, anesthetic, and PACU cost	4,053 ± 1,123	4,390 ± 952	0.345
Admission/nursing unit cost	2,068 ± 260	961 ± 461	0.000
Pharmacy cost	445 ± 260	210 ± 179	0.004
Other cost	80 ± 40	114 ± 72	0.091
Total cost	6,646 ± 1,354	5,675 ± 1,232	0.034

Values are expressed as mean ± SD.

PACU = postanesthetic care unit.

was -8.3 to 13.5 degrees. This implies that patients in the expedited care pathway group were at least noninferior (lower limit of the 95% CI, -8.3 degrees) than the control group, but a superior result cannot be excluded (upper limit of the 95% CI, 13.5 degrees). The minimum clinically significant difference for our sample size calculation was conventionally set at 10 degrees. Most previous studies of complex elbow surgery are retrospective or single cohort studies, and there is no widely accepted precedent as to what constitutes an acceptable or expected outcome. Therefore, our definition of minimally clinically significant difference is based on previous clinical experience.<sup>17</sup> Because previous studies report improvements between 15 and 75 degrees,

we considered a difference of less than 10 degrees between groups to be of negligible clinical consequence.

Along with elbow arc ROM, overall physical function improved and self-reported disability declined to a similar extent in both groups up to 3 months postoperatively. The previously validated DASH and SF-12 questionnaires are widely used to assess overall physical function both in the general population and in patients with orthopedic conditions.<sup>1,2</sup> The improvement in the physical component of the SF-12 is of particular clinical significance. The preoperative baseline score (approximately 40 points for both groups) is well below the mean value of 50 to 52 points reported by middle-aged North Americans.\*† Three months after the surgical procedure, patients in both groups improved their self-reported physical functionality and health-related quality of life to a level similar to that of the general population.<sup>2</sup>

Another finding of the current study is a significant reduction in total hospital cost by approximately 15% in the expedited care pathway group. The greatest savings, not surprisingly, were due to a 50% reduction in inpatient

\* Interpreting the SF-12. Utah Department of Health. Available at: [www.health.utah.gov/opha/publication/2001hss/sf12/SF12\\_interpreting.pdf](http://www.health.utah.gov/opha/publication/2001hss/sf12/SF12_interpreting.pdf). Accessed August 3, 2014.

† Johnson JA, Pickard AS: Alberta-based SF-12 Survey Scores. Working paper 98-2. Available at: [www.ihe.ca/documents/1998-02](http://www.ihe.ca/documents/1998-02). Accessed August 3, 2014.

admission and pharmacy cost. It is important to note that all costs related to patient care in the immediate perioperative period (72 h) were included in the analysis. No additional costs were incurred by the healthcare system after discharge from hospital. The costs of the ambulatory disposable infusor and the local anesthetic solution are included in the pharmacy costs for patients in both groups (table 7). Patients on the expedited care pathway group were assessed postoperatively daily on the phone by the anesthesia team, and no additional home care or home nursing visits were required. In addition, there were no surgical complications reported, no readmissions, or no additional unscheduled hospital visits within the first 3 months for any patient in the study. These additional potential sources of “hidden costs” are important to consider. Previous studies of expedited hospital discharge after orthopedic procedures report short-term cost savings but do not evaluate patient outcome, complications, or additional cost of care after discharge.<sup>23</sup> As expected, the cost of the surgical procedure, surgical equipment, and anesthetic management was similar in both groups (table 7). It is interesting to note that although a shorter hospital stay is a frequent goal of hospital cost-savings or cost-effectiveness strategies, even a significant reduction in the length of stay as is the case in this study only resulted in a total cost saving of 15%. Macario *et al.*<sup>24</sup> had previously demonstrated that inpatient admission represents about one third (33%) of the total hospital cost of surgical care. This is consistent with our findings, in which the cost of admission represented 31% of the total cost in the control group (and 17% of the total cost in the expedited care pathway group). As previously reported, operating room–related costs were the largest component of the cost of care (61 to 77% of total hospital cost).

One possible limitation of this study is the higher-than-expected incidence of intraoperative catheter dislodgement (10 in 38 or 25%) requiring replacement in the postanesthesia care unit. Because no other patient group in our practice has such high incidence of intraoperative dislodgement, we speculate that this may have been related to the degree of movement of the surgical extremity, with frequent shoulder rotation and abduction during a 3- to 4-h surgical procedure. Since this observation, we have changed our practice to place the brachial plexus catheters immediately postoperatively, rather than preoperatively. In addition, a limitation to the wide-spread application of our findings is that we studied relatively young and healthy patients who have social support at home. One might argue that this is in fact the typical profile of patients who are good candidates for complex arthroscopic elbow surgery. Nevertheless, these results may not be applicable to older patients with a higher comorbidity burden and/or limited social support.

## Conclusion

The results of this study suggest that an expedited care pathway with early hospital discharge followed by ambulatory brachial plexus analgesia and CPM at home is a cost-effective alternative to 72 h of hospital admission after complex arthroscopic elbow surgery.

This expedited care pathway results in at least noninferior elbow arc ROM 2 weeks postoperatively and similar improvements in physical function with an associated reduction in 15% of total hospital cost of care.

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## Competing Interests

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## Reproducible Science

Full protocol available at: [anahi.perlas@uhn.on.ca](mailto:anahi.perlas@uhn.on.ca). Raw data available at: [anahi.perlas@uhn.on.ca](mailto:anahi.perlas@uhn.on.ca).

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## Appendix 1. Disabilities of the Arm, Shoulder, and Hand

The Disability of the Arm, Shoulder, and Hand (DASH) is a 30-item self-report questionnaire designed to measure physical function items, six symptom items, and three social/role function items. The DASH is designed to measure physical disability and symptoms in a heterogeneous population that includes both males and females; people who place low, moderate, or high demands on their upper limbs during their daily lives (work, leisure, or self-care); and people with a variety of upper-limb disorders.

### Scoring

Patients are asked to answer all sections and respond based on their ability to perform activities over the past week; only one answer per question.

At least 27 of the 30 items *must* be completed for scoring. The assigned values are summed and divided by the number of questions answered. This value is transformed to a score out of 100 by subtracting 1 and multiplying by 25.

$$\text{DASH} = \{(\text{Sum of } n \text{ responses}) - 1\} \times 25 / n$$

Where  $n$  = total number of questions answered.

Minimum detectable change: 12.7 points; current literature holds 12.7 points to be the minimal change in score to be statistically significant at the 95% CI.

Minimum clinically important difference: 15 points; this represents the change in score needed to be considered clinically significant.

Appendix 1. Continued

	No Difficulty	Mild Difficulty	Moderate Difficulty	Severe Difficulty	Unable
1. Open a tight or new jar	1	2	3	4	5
2. Write	1	2	3	4	5
3. Turn a key	1	2	3	4	5
4. Prepare a meal	1	2	3	4	5
5. Push open a heavy door	1	2	3	4	5
6. Place an object on a shelf above your head height	1	2	3	4	5
7. Do heavy household chores (e.g., wash walls, wash floors)	1	2	3	4	5
8. Gardening or do yard work	1	2	3	4	5
9. Make a bed	1	2	3	4	5
10. Carry a shopping bag or briefcase	1	2	3	4	5
11. Carry a heavy object (over 10 lbs)	1	2	3	4	5
12. Change a lightbulb overhead	1	2	3	4	5
13. Wash or blow dry your hair	1	2	3	4	5
14. Wash your back	1	2	3	4	5
15. Put on a pullover sweater	1	2	3	4	5
16. Use a knife to cut food	1	2	3	4	5
17. Recreational activities that require little effort (e.g., cardplaying, knitting, etc.)	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder, or hand (e.g., golf, hammering, tennis, etc.)	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g., playing frisbee, badminton, etc.)	1	2	3	4	5
20. Manage transportation needs (getting from one place to another)	1	2	3	4	5
21. Sexual activities	1	2	3	4	5
	Not at All	Slightly	Moderately	Quite a Bit	Extremely
22. During the past week, to what extent has your arm, shoulder, or hand problem interfered with your normal social activities with family, friends, neighbors, or groups?	1	2	3	4	5
	Not Limited	Slightly Limited	Moderately Limited	Very Limited	Unable
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder, or hand problem?	1	2	3	4	5
	None	Mild	Moderate	Severe	Extreme
24. Arm, shoulder, or hand pain	1	2	3	4	5
25. Arm, shoulder, or hand pain when you performed any specific activity	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder, or hand	1	2	3	4	5
27. Weakness in your arm, shoulder, or hand	1	2	3	4	5
28. Stiffness in your arm, shoulder, or hand	1	2	3	4	5
	No Difficulty	Mild Difficulty	Moderate Difficulty	Severe Difficulty	I Cannot Sleep
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder, or hand?	1	2	3	4	5
	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
30. I feel less capable, less confident, or less useful because of my arm, shoulder, or hand problem	1	2	3	4	5

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**Appendix 2. Short-Form 12**

	1-Excellent	2-Very good	3-Good	4-Fair	5-Poor
1. In general, would you say your health is:	1-Yes, limited a lot	2-Yes, limited a little	3-Not limited at all		
2. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1-Yes, limited a lot	2-Yes, limited a little	3-Not limited at all		
3. Climbing several flights of stairs	1-Yes	2-No			
4. During the past 4 weeks, have you accomplished less than you would like as a result of your physical health?	1-Yes	2-No			
5. During the past 4 weeks, were you limited in the kind of work or other activities as a result of your physical health?	1-Yes	2-No			
6. During the past 4 weeks, have you accomplished less than you would like as a result of any emotional problems (such as feeling depressed or anxious)?	1-Yes	2-No			
7. During the past 4 weeks, did not do work or perform other activities as carefully as usual as a result of any emotional problems (such as feeling depressed or anxious)?	1-Yes	2-No			
8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?	1-Not at all	2-A little bit	3-Moderately	4-Quite a bit	5-Extremely
9. How much of the time during the past 4 weeks, have you felt calm and peaceful?	1-All of the time	2-Most of the time	3-A good bit of time	4-Some of the time	5-A little of the time
10. How much of the time during the past 4 weeks, did you have a lot of energy?	1-All of the time	2-Most of the time	3-A good bit of time	4-Some of the time	5-A little of the time
11. How much of the time during the past 4 weeks, have you felt downhearted and blue?	1-All of the time	2-Most of the time	3-A good bit of time	4-Some of the time	5-A little of the time
12. During the past 4 weeks, how much of the time has your physical or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?	1-All of the time	2-Most of the time	3-Some of the time	4-A little of the time	5-None of the time