The Efficacy of Intra-Articular Injections for Pain Control Following the Closed Reduction and Percutaneous Pinning of Pediatric Supracondylar Humeral Fractures

A Randomized Controlled Trial

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Background: The purpose of this single-blinded, randomized, controlled trial was to compare the analgesic efficacy of intra-articular injections of bupivacaine or ropivacaine with that of no injection for postoperative pain control after the operative treatment of supracondylar humeral fractures in a pediatric population.

Methods: Subjects (n = 124) were randomized to treatment with 0.25% bupivacaine (Group B) (n = 42), 0.20% ropivacaine (Group R) (n = 39), or no injection (Group C) (n = 43). The opioid doses and the times of administration as well as child-reported pain severity (Faces Pain Scale-Revised) and parent-reported pain severity (Total Quality Pain Management survey) were recorded.

Results: The proportion of subjects who required morphine and/or fentanyl injections was significantly ($p = 0.004$) lower in Group B (10%) as compared with Group R (36%) and Group C (44%). On the basis of the log-rank test, the opioid-free survival rates were significantly greater in Group B as compared to Groups C and R. Total opioid consumption (morphine equivalent mg/kg) in the first seventy-two hours postoperatively was significantly less in Group B as compared with Group C (mean difference, 0.225; [95% confidence interval (CI), 0.0152 to 0.435]; $p = 0.036$). Parent-reported pain scores were also significantly lower in Group B as compared with both Group C (mean difference, 1.81 [95% CI, 0.38 to 3.25]; $p = 0.014$) and Group R (mean difference, 1.66; 95% CI, 0.20 to 3.12; $p = 0.027$). There were no significant differences across the three groups in terms of self-reported pain. Differences between Groups R and C were not significant for any of the outcome variables.

Conclusions: The intra-articular injection of 0.25% bupivacaine significantly improves postoperative pain control following the closed reduction and percutaneous pinning of supracondylar humeral fractures in pediatric patients.

Level of Evidence: Therapeutic Level I. See Instructions for Authors for a complete description of levels of evidence.

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Pediatric supracondylar humeral fractures are characterized by a break in the thin area of bone between the olecranon and the coronoid fossae¹. With an incidence that peaks around five to seven years of age, supracondylar humeral fractures are the most common pediatric elbow fracture^{2,3}. Closed reduction and percutaneous pinning is the accepted treatment for displaced, closed injuries without vascular compromise¹. Despite the frequency of this injury and subsequent surgery, little attention has been devoted to the improvement of perioperative pain control.

The use of intra-articular injections during outpatient orthopaedic surgery is a popular strategy for reducing postoperative pain. Intra-articular injections are simple and inexpensive and are associated with minimal systemic side effects^{4,5}. Intra-articular injections have been used in adults during a multitude of diagnostic and therapeutic procedures such as knee, hip, shoulder, wrist, and ankle arthroscopy; relocation of anterior shoulder dislocations; total knee arthroplasty; and total hip arthroplasty. Although the adult literature has been inconsistent^{6,7}, intra-articular injections have demonstrated an analgesic benefit during orthopaedic-related procedures⁸⁻¹⁹.

The efficacy of intra-articular injections in children has not been well studied. Current pediatric research is limited to the use of local infiltration injections during fracture reductions. Herrera et al.²⁰ retrospectively studied pain control among patients who did or did not receive a hematoma block of 0.25% bupivacaine during the elastic nailing of femoral fractures. The time to first opioid administration was significantly greater in the hematoma block group. Although this difference was not significant, the

total morphine equivalent dose in the first six postoperative hours was also less in the hematoma injection group.

On the basis of the perceived benefit of intra-articular injections, we designed a randomized, blinded (child and parent), single-center, prospective study to evaluate the effectiveness of intra-articular injection of local anesthesia following the closed reduction and percutaneous pinning of pediatric supracondylar humeral fractures.

Materials and Methods

This randomized, single-blinded trial was conducted at a large tertiary pediatric hospital from June 2008 to August 2010 (clinicaltrials.gov NCT01328782) (Fig. 1). Following institutional review board approval, potential subjects were identified among patients with Gartland type-II and III fractures. Preoperative exclusion criteria included open injuries, confirmed neurologic injury, vascular deficit, and/or the presence of any additional injuries causing local and/or global pain. The purpose of the exclusion criteria was to eliminate patients who were affected by concomitant sources of pain that may have confounded the measurement of postoperative pain. Patients with vascular deficits and/or definitive neurologic injuries were also excluded because of concerns that the intra-articular injection might affect the postoperative neurovascular examination. Per an institutional review board request, in order to limit the intra-articular dose given, subjects weighing <14 kg (representing the fifth percentile for a four-year-old female) were also excluded. As this was an investigator-initiated, nonfunded study, the availability of resources limited the enrollment of study subjects to weekdays only. Informed consent was obtained from all subjects and parents prior to surgery.

With use of a block randomization scheme stratified by age (four to seven years or eight to twelve years), subjects were randomized to treatment with no injection (Group C), ropivacaine injection (Group R), or bupivacaine injection (Group B). Presealed, sequentially numbered randomization envelopes containing each subject's group designation were delivered to the attending surgeon prior to surgery. Per institutional practices, general anesthesia was induced intravenously

*Other category includes following reasons: operating surgeon was not a co-investigator (n = 3), study materials were not available in subjects' primary language (n = 10), revision pinning (n = 1), legal guardian was not present for consent (n = 1) and injury occurred > 7 days prior to surgery (n = 1).

Fig. 1

Summary of enrollment. SCH Fx = supracondylar humeral fracture.

Fig. 2

Intra-articular injection of local anesthesia was given once the joint had been successfully aspirated. The intra-articular injections were performed with a 20-gauge needle through either an olecranon fossa or lateral approach.

with propofol and fentanyl or by means of a face mask with sevoflurane and nitrous oxide. The surgical procedures were performed by one of eight fellowship-trained pediatric orthopaedic surgeons. Tourniquets were not utilized during the reduction and pinning of the fractures. Intra-articular injections (4 mL for subjects four to seven years old and 5 mL for subjects eight to twelve years old) of 0.20% ropivacaine or 0.25% bupivacaine were then given to the subjects in Groups R and B, respectively. The intra-articular injections were performed with a 20-gauge needle through either an olecranon fossa or a lateral approach. Confirmation of appropriate needle placement was based on the presence of joint blood in the aspirate (Fig. 2). The subjects were managed with a bivalved long-arm cast and were taken to the post-anesthesia care unit for standard postoperative care.

Analgesics that were administered preoperatively (four hours before surgery), intraoperatively, and postoperatively were recorded for all periods of interest and were converted into morphine equivalents (morphine equivalent mg/kg). Pain control following discharge consisted of oxycodone (0.1 to 0.15 mg/kg) with acetaminophen. Consumption of all prescription and over-the-counter analgesics in the first seventy-two hours after discharge was recorded by the subjects' parents with use of a take-home medication log.

The Faces Pain Scale-Revised (FPS-R)²¹ and the parent Total Quality Pain Management survey (TQPM)²² were used to assess pain. The FPS-R features six faces depicting levels of pain ranging from 0 (no pain) to 10 (worst pain imaginable). This scale was chosen for its simplicity, applicability to children across a very broad range of ages²¹, and reported psychometric accuracy in school-aged children²³. Subjects were screened (preoperatively) with a seriation task (arrangement of an incremental series of six triangles in order from smallest to largest)²⁴ to verify their capacity to understand the FPS-R. Pain was assessed in the post-anesthesia care unit (within thirty to sixty minutes after arrival in the post-anesthesia care unit) and again in an observation unit (within sixty to 120 minutes after arrival in the post-anesthesia care unit) by a research assistant. During the second pain assessment, the parent or parents of the subject completed a modified version of the TQPM; the modification was done with the permission of the original authors²². The questionnaire was given to the parent or parents by the research assistant, who answered any immediate questions and then left the room for approximately ten minutes. On returning, the research assistant collected the TQPM and then administered the FPS-R. The parent or parents, the subject, and the research assistants obtaining the pain assessments were blinded during all study procedures.

Statistical Methods

Because of the lack of previous data, it was conservatively estimated that a sample size of sixty-seven patients per group would ensure 80% power to detect a minimum effect size of 0.538 on the basis of FPS-R pain scores at a 2.5% significance level. As per the study protocol, after sixty patients were enrolled, an interim unblinded conditional power analysis was performed. With an alpha of 0.05 and 80% power, it

was determined that a total of 120 subjects would be needed across all groups in order to detect a minimum difference of 2.31 on the basis of the FPS-R (effect size, 0.634).

An intent-to-treat analysis of all randomized subjects with at least one postoperative FPS-R score was performed. Baseline demographic data and clinical characteristics were summarized with use of descriptive statistics (Table I). Analysis of variance (ANOVA) or the chi-square test, when appropriate, was used to compare group differences in demographic and clinical characteristics and the primary outcome variables (FPS-R scores, parent TQPM scores, postoperative opioid consumption during all time periods of interest, and the proportion of subjects who required morphine or fentanyl injections postoperatively). A Kaplan-Meier survival analysis of the time to the first opioid administration during the first 120 minutes after arrival in the post-anesthesia care unit was performed, and the log-rank test was used to compare differences in opioid-free survival rates between the groups. Repeated-measures Poisson regression analysis was used to compare total medication dose count (the total number of times that a subject received a dose of an over-the-counter analgesic and/or opioid). A generalized estimating equation was used to account for correlation between consecutive days. T tests and/or chi-square tests were used to compare demographic characteristics of eligible subjects who were and were not approached for consent. The level of significance was set at $p \leq 0.05$.

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Results

Between June 2008 and August 2010, 512 patients underwent operative treatment of supracondylar fractures at our institution. In this cohort, 211 subjects were excluded (Fig. 1). Four subjects were discharged before the TQPM and a second FPS-R score could be obtained and thus, an additional four subjects were enrolled. The 124 patients who were enrolled in the study were randomized into three groups: the ropivacaine group (Group R) ($n = 39$), the bupivacaine group (Group B) ($n = 42$), and the control group (Group C) ($n = 43$). There were no significant differences across these three groups in terms of age, sex, fracture type, preoperative and/or intraoperative opioid dose, operative time, preoperative pain level, time from injury to surgery, or pin configuration (Table I). Because of the lack of significant differences in potential confounding variables, statistical analyses were performed without adjusting for any covariates.

There were no adverse events such as compartment syndrome and/or persistent weakness. Nerve injuries were noted, postoperatively, in 7.26% of the population. The proportion of subjects affected by nerve injuries in the bupivacaine, control, and ropivacaine groups was 9.52%, 6.98%, and 5.13%, respectively. There was no difference in the distribution of nerve injuries across the study groups ($p = 0.835$), and there were no documented cases in which the intra-articular injection confounded the postoperative neurovascular examination. Because of the intent-to-treat nature of the analysis, all subjects who were enrolled in the study were included in the analysis.

Comparison of Subjects Who Were Excluded Because of the Timing of Surgery

Among the 301 eligible subjects, 132 were not approached for consent either because the patient was not recognized in

TABLE I Demographic Data and Clinical Characteristics

	Control (N = 43)	Ropivacaine (N = 39)	Bupivacaine (N = 42)	P Value
Age* (yr)	6.92 ± 1.99	6.73 ± 2.21	6.86 yr ± 1.74	0.6719
Sex (percentage of patients)				0.9614
M	58.1%	53.8%	57.1%	
F	41.9%	46.2%	42.9%	
Fracture type (percentage of patients)				0.3705
Flexion	0.0%	0.0%	2.4%	
II	62.8%	46.2%	54.8%	
III	37.2%	53.8%	42.9%	
Time from initial injury to surgery (percentage of patients)				0.8315
<24 hr	83.72%	76.92%	78.57%	
24 to 48 hr	9.30%	10.26%	14.29%	
>48 hr	6.98%	12.82%	7.14%	
No. of pins* (percentage of patients)	2.40 ± 0.54	2.49 ± 0.56	2.63 ± 0.58	0.1483
Pin configuration (percentage of patients)				0.8346
Lateral or medial only	93.02%	94.87%	90.24%	
Lateral and medial	6.98%	5.13%	9.76%	
Preop. pain score* (points)	2.72 ± 2.75	2.84 ± 2.85	2.93 ± 3.03	0.9523
Preop. opioids* (morphine equivalent mg/kg)	0.02 ± 0.04	0.02 ± 0.04	0.04 ± 0.06	0.3130
Operative time* (min)	29.16 ± 10.07	30.85 ± 12.28	28.19 ± 8.68	0.6969
Intraop. opioids* (morphine equivalent mg/kg)	0.13 ± 0.07	0.15 ± 0.09	0.13 ± 0.07	0.5024

*The values are given as the mean and the standard deviation.

sufficient time to obtain consent or because the surgery occurred either late in the evening or on the weekend. Among subjects who were (n = 169) and were not (n = 132) approached for consent, there were no significant differences in sex, age, operative time, or fracture type (see Appendix).

Opioid Consumption

Postoperatively, morphine and/or fentanyl injections were administered to 44%, 36%, and 10% of the subjects in Groups C, R, and B, respectively. The proportion of subjects who required morphine and/or fentanyl injections was significantly different between Groups B and C (p = 0.004) and between Groups B and R (p = 0.004). Differences between Groups C and R were not significant (p = 0.499). Kaplan-Meier analysis of the time to first opioid administration demonstrated that subjects in Group B were significantly less likely to require opioids in the first 120 minutes after arrival to the post-anesthesia care unit as compared with subjects in Groups C (p = 0.005) and R (p = 0.039) (Fig. 3) (see Appendix). There was no difference in the timing of opioid administration between Groups R and C.

Prior to discharge, opioid consumption (morphine equivalent mg/kg) (Fig. 4) was significantly less in Group B as compared with Group C (mean difference, 0.042 [95% confidence interval (CI), 0.008 to 0.076]; p = 0.008). There was a nonsignificant decrease in opioid consumption in Group B as compared with Group R (mean difference, 0.031 [95% CI, -0.004 to 0.066];

p = 0.078). Although nonsignificant, opioid consumption prior to discharge was less in Group R compared with Group C (mean difference, 0.011 [95% CI, -0.024 to 0.045]; p = 0.5321).

There were no significant differences in the medication log return rates across Groups C (57%), R (57%), and B (64%). On the basis of the medication log, the mean opioid dose (morphine equivalent mg/kg) in the first seventy-two hours after discharge was 0.627 (95% CI, 0.480 to 0.775) in Group C, 0.445 (95% CI, 0.301 to 0.590) in Group R, and 0.43 (95% CI, 0.278 to 0.573) in Group B. Differences in opioid consumption were not significantly different across the groups.

Total opioid consumption (postoperative and post-discharge consumption combined) was significantly less in Group B compared with Group C (mean difference, 0.225 [95% CI, 0.0152 to 0.435]; p = 0.036). There was a nonsignificant difference in opioid consumption between Groups R and C (mean difference, 0.199 [95% CI, -0.008 to 0.407]; p = 0.0597). Although nonsignificant, opioid consumption was less in Group B than in Group R (mean difference, 0.026 [95% CI, -0.0182 to 0.233]; p = 0.806).

Analgesic Count

The total number of times that the subjects received an analgesic (the number of over-the-counter doses plus the number of opioid doses) per day is displayed in Figure 5. Differences in analgesic counts between Groups B and R and between Groups R and C groups were not significant (p > 0.05) during any of the

Fig. 3

Kaplan-Meier plot of opioid-free survival in the first 120 postoperative minutes after arrival in the post-anesthesia care unit (PACU). The vertical tick marks indicate that a subject was censored (discharged before an opioid dose was administered).

postoperative days (Fig. 5). Analgesic counts were significantly different between Groups B and C during Postoperative Days 1 and 3. On the average, subjects in Group C received 34.78% (95% CI, 9.37% to 66.08%; $p = 0.005$) more analgesic doses than

subjects in Group B on Postoperative Day 1 and 43.96% (95% CI, 8.88% to 90.34%) more analgesic doses on Postoperative Day 3. Analgesic counts in Groups B and C were not significantly different ($p = 0.133$) on Postoperative Day 2.

Fig. 4

Bar graph summarizing opioid consumption during the study period. Pre-Op = opioid dose administered four hours prior to surgery. Intra-Op = opioid dose administered during surgery. Post-Op = opioid dose administered after surgery, prior to discharge. Post-Discharge = opioid dose administered in first seventy-two hours following discharge (based on the medication log). Post-Op Total = total opioid dose administered after surgery (postoperative plus post-discharge). *Significant difference between Groups B and C ($p < 0.05$).

Fig. 5
Line graph illustrating the total analgesic count during the first three days after surgery. *Significantly different from the control group ($p < 0.05$).

Self-Reported (FPS-R) Pain Scores

At the first pain assessment (within thirty to sixty minutes after arrival in the post-anesthesia care unit), there was a nonsignificant decrease in pain scores in Group B compared with Group C (mean difference, 1.40 [95% CI, -0.14 to 2.94]; $p = 0.074$). Although nonsignificant, pain scores were lower in Group B compared with Group R (mean difference, 0.48 [95%

CI, -1.12 to 2.08]; $p = 0.556$) and were lower in Group R compared with Group C (mean difference, 0.93 [95% CI, -0.64 to 2.49]; $p = 0.244$). At the second pain assessment (within sixty to 120 minutes after arrival in the post-anesthesia care unit), pain scores were not significantly different across any of the groups (Fig. 6).

Parent-Reported Pain Scores

The TQPM survey was completed by the parents of 120 of the 124 subjects (Fig. 7). In relation to the question about the child's current level of pain (on the survey administered within sixty to 120 minutes after arrival in the post-anesthesia care unit), parent-reported pain scores in Group B were significantly lower than those in Group C (mean difference, 1.37 [95% CI, 0.43 to 2.31]; $p = 0.005$). Pain scores were lower in Group R than in Group C (mean difference, 0.47 [95% CI, -1.43 to 0.49]; $p = 0.337$) and were lower in Group B than in Group R (mean difference, 0.90 [95% CI, -1.86 to 0.07]; $p = 0.070$), but these differences did not reach significance.

With respect to the question about the child's worst level of pain while resting, parent-reported pain scores were significantly lower in Group B compared with Group C (mean difference, 1.81 [95% CI, 0.38 to 3.25]; $p = 0.014$) and Group R (mean difference, 1.66 [95% CI, 0.20 to 3.12]; $p = 0.027$). Pain scores in Groups R and C were not significantly different (mean difference, 0.16 [95% CI, -1.30 to 1.61]; $p = 0.832$). With respect to the question about child's worst level of pain while moving around, pain scores in Group B group were significantly lower than those in Group C (mean difference, 1.856 [95% CI, 0.43 to 3.26]; $p = 0.011$) and Group R (mean difference, 1.59 [95% CI, 0.17 to 3.02]; $p = 0.029$). Pain

Fig. 6
Line graph illustrating self-reported pain severity. Pre-Surgery = pain score obtained prior to surgery. Post-Op 1 = pain score obtained within thirty to sixty minutes after arrival in the post-anesthesia care unit. Post-Op 2 = pain score obtained within sixty to 120 minutes after arrival in the post-anesthesia care unit.

Fig. 7

Bar graph illustrating parent-reported pain severity. Current = level of pain within sixty to 120 minutes after arrival in the post-anesthesia care unit, Moving = worst level of postoperative pain while moving around in bed, and Resting = worst level of postoperative pain while lying quietly and resting in bed. *Significant difference between bupivacaine and control groups ($p < 0.05$). **Significant difference between bupivacaine and ropivacaine groups and between bupivacaine and control groups ($p < 0.05$).

scores were not significantly different between Groups R and C ($p = 0.722$). In relation to the question about how much pain the parents expected their child to have following surgery, expected pain level scores were not significant across Groups C (mean, 5.69 [95% CI, 4.89 to 6.49]), R (mean, 5.49 [95% CI, 4.64 to 6.34]), and B (mean, 4.68 [95% CI, 3.98 to 5.39]).

Discussion

The closed reduction and percutaneous pinning of pediatric supracondylar humeral fractures is often performed as an outpatient procedure. Research has suggested that nearly half of children experience clinically important pain following outpatient surgery²⁵. This finding is consistent with the current study, in which 40% of the parents in the control group reported that their child had clinically severe pain (pain score, ≥ 7) following surgery. As cost savings for outpatient surgery may be negated by poor pain control and subsequent unanticipated hospital admissions, there is a need for improved postoperative pain control.

Pain management for patients with pediatric supracondylar humeral fractures typically consists of intravenous opioids in combination with oral analgesics. These drugs and mechanisms of delivery may be associated with unwanted side effects such as nausea, vomiting, sedation, and/or respiratory depression^{26,27}. The use of intra-articular injections is an appealing analgesic strategy based on the premise that, by in-

jecting the anesthetic at the source of pain, there may be a decreased need for systemic analgesics¹². In a systematic review of intra-articular injections during arthroscopic knee surgery, intra-articular injections resulted in a weighted mean difference in visual analog scale (VAS) pain scores of 11 mm (95% CI, 7 to 17 mm; $p < 0.05$) as well as a 10% to 40% reduction in supplemental analgesic requests⁵. There is also evidence that, when administered alone, single-shot intra-articular local anesthetic injections are significantly more effective for managing procedure-related pain than saline solution injections or no injections during anterior cruciate ligament (ACL) reconstruction²⁸, total knee arthroplasty⁸, and arthroscopic knee⁹⁻¹⁶, hip¹⁷, wrist¹⁸, and ankle¹⁹ surgery.

Our subjects who received intra-articular bupivacaine required a significantly lower opioid dose postoperatively (from arrival in the post-anesthesia care unit to discharge) than did patients in the control group. Differences in the proportion of patients requiring fentanyl and/or morphine injections, the time to first opioid administration, total analgesic count, and parent-reported pain were also significantly improved in Group B relative to Group C. Patients in Group B reported the lowest pain scores of any of the groups at all time points; however, differences between Groups B and C did not reach significance.

Ropivacaine was not as effective as bupivacaine for controlling postoperative pain in our study population. Ropivacaine is a long-acting amide-type local anesthetic that is reported to possess similar pharmacodynamics²⁹ to bupivacaine but is associated with decreased risk of central nervous system and cardiac toxicity³⁰. Inconsistent findings have been reported in studies comparing the clinical effectiveness of ropivacaine and bupivacaine. Studies of local analgesic concentration have concluded that epidural ropivacaine may be 60% less potent than bupivacaine during early labor^{31,32}. During orthopaedic procedures involving the lower limb, however, both bupivacaine and ropivacaine regional blocks have been demonstrated to be equally effective for controlling postoperative pain³³⁻³⁵. Some authors have reported that, during pediatric tonsillectomies, peritonsillar infiltration of bupivacaine and ropivacaine are equally effective³⁶, whereas others have reported that bupivacaine provides superior pain relief³⁷. When used caudally in children, ropivacaine and bupivacaine have been reported to be equally effective³⁸⁻⁴⁰. Comparisons of the two drugs as intra-articular injections either have shown no difference in effectiveness⁴¹ or have shown ropivacaine to be more effective than bupivacaine¹⁴. Therefore, as suggested by Whiteside and Wildsmith⁴², the efficacy of both local anesthetics appear to be related to the site and clinical application of the injection.

There is some evidence to suggest that the efficacy of ropivacaine compared with bupivacaine may be related to the concentration and dose of the intra-articular injection. When epidural bupivacaine and ropivacaine were compared at differing concentrations in the study by Wang et al., the authors reported no difference in analgesic efficacy between the two drugs⁴³. On the basis of significant analgesic differences between the concentrations used, the authors concluded that the

efficacy of local anesthetics is related more to the concentration of the anesthetic than it is to the type of anesthetic used⁴³. In a meta-analysis of the analgesic efficacy of intra-articular injections, there was a nonsignificant difference ($p = 0.196$) in the dose of local anesthetics given in the studies that demonstrated a significant positive effect of intra-articular injection on postoperative pain as compared with studies that demonstrated no effect. Furthermore, Luz et al. reported that single shot of caudal anesthesia with 0.1% ropivacaine was significantly less effective than 0.2% bupivacaine in children, but when an equi-potent concentration (0.2%) was used, ropivacaine was found to be equally as effective⁴⁰.

Because of differences in the concentrations of the local in the present study anesthetics (0.20% compared with 0.25%), the mean difference in the dose of the local anesthetic administered in the ropivacaine and bupivacaine groups was 0.04 mg/kg. Given the current data, it is impossible to determine whether differences in the dose of the drugs administered or differences in the efficacy of drugs affected our findings.

Mechanism of Effect

As supracondylar fractures do not directly affect the articular surface of the elbow joint, the mechanism of analgesic effect of intra-articular injection is not fully understood. However, when performing intra-articular injections, we have consis-

tently noted the presence of blood in the joint aspirate and we believe that the source or sources of this hemarthrosis may potentially explain the mechanism of effect. Even non-displaced supracondylar humeral fractures are consistently associated with hemarthrosis. When we reviewed the arthrograms for patients with supracondylar fractures who underwent arthrography prior to fracture reduction and pinning, the fracture lines were often contained within the joint capsule (Fig. 8). However, it is not possible on the basis of this study to confirm the exact mechanism or mechanisms by which the intra-articular injection reduced postoperative pain.

Local Anesthetics and Joint Chondrolysis

Joint chondrolysis is a devastating complication that has been associated with the use of intra-articular infusion devices that utilize high volumes and/or concentrations of local anesthetics to achieve sustained localized pain control after shoulder, knee, and ankle arthroscopic surgery⁴⁴⁻⁴⁶. Reports of chondrolysis following single-shot injections, however, are very rare, and reports to date have been limited to the shoulder joint⁴⁷. Studies involving animal models have demonstrated conflicting results about the effects of single-shot intra-articular injections. An in vivo rabbit knee model demonstrated a significant ($p < 0.005$) increase in inflammation among cartilage samples exposed to 0.50% bupivacaine relative to control samples three days after a single injection⁴⁸. In

Fig. 8

Arthrograms of the elbow of a three-year-old child with a supracondylar humeral fracture. This patient underwent an intraoperative arthrogram to rule out possible joint involvement. The presence of a true supracondylar humeral fracture, without joint involvement, was confirmed, and the patient subsequently underwent closed reduction and percutaneous pinning. The arthrogram provides information about location of the joint capsule relative to the fracture line.

contrast, a pig and dog knee model revealed no significant differences in histological findings and/or cartilage anabolism between saline solution-treated and bupivacaine-treated samples three days after injection⁴⁹. In a rat knee model, there was no difference in superficial chondrocyte viability between joint samples exposed to a single injection of 0.50% bupivacaine compared with saline solution up to six months after exposure⁵⁰.

We are not aware of any reported cases of chondrolysis of the elbow joint associated with the use of intra-articular injections of local anesthetics in the current literature, despite the frequency of their use during elbow arthroscopy. In review of complications associated with elbow arthroscopy over an eighteen-year period, Kelly et al.⁵¹ reported no cases of chondrolysis following 252 procedures in which an intra-articular injection of Marcaine (bupivacaine) was delivered at the end of the procedure.

Local anesthetics are not currently labeled for intra-articular use. Because of evidence of a dose and time-dependent relationship between intra-articular injections and chondrocyte viability⁵²⁻⁵⁴ as well as the potential exacerbatory effects of epinephrine⁵⁴⁻⁵⁶, we conservatively recommend against the use of continuous infusion devices, epinephrine as an adjuvant, and/or concentrations of $\geq 0.50\%$. However, on the basis of our experience, the intra-articular injection of 0.25% bupivacaine in small volumes (<5 mL) is a very effective and safe method for controlling postoperative pain.

Limitations

We were unable to approach subjects for consent if the surgical procedure was performed late in the evening (during the week) or on the weekends, although patients who consented did not differ in terms of demographic or clinical characteristics from those who were not approached for consent. The surgeon administering the injection was not blinded. In children, the injection of a placebo (saline solution) is unethical and, consequently, we determined that it would be impossible to blind the surgeon when subjects were assigned to the control group. As the injection was given when the child was asleep and because pain was assessed by a member of the research team who was blinded, we do not believe this to be a methodological limitation. As per hospital procedures, the administration of the intra-articular injection was

recorded in the subject's chart, and, as such, the providers administering postoperative pain medication may have been made aware of the subject's study group assignment. However, we do not believe that this was a confounding factor given that differences in parent-reported pain scores (with the parents blinded) were also significantly different.

The percentage of subjects who returned the take-home medication logs (59%) was less than ideal but was similar to that in previous studies⁵⁷. Overall, these limitations are considered to be inherent to conducting unfunded research within the confines of clinical care at a large, tertiary, pediatric hospital.

In conclusion, the intra-articular injection of 0.25% bupivacaine was an effective and safe method of significantly reducing postoperative pain following the operative treatment of pediatric supracondylar humeral fractures. Given the higher cost profile of ropivacaine⁵⁸ and the lack of evidence supporting its efficacy in the current study, we recommend the use of intra-articular bupivacaine. The closed reduction and percutaneous pinning of supracondylar humeral fractures can be safely performed with excellent pain control when intra-articular injections are added to existing analgesic practices.

Appendix

Tables showing a summary of eligible subjects and opioid-free survival rates are available with the online version of this article as a data supplement at jbjs.org. ■

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