Do Continuous Peripheral Nerve Blocks Decrease Home Opioid Use Following Anterior Cruciate Ligament Reconstruction in Children and Adolescents? The Envelope Please

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Background: Levels of opioid misuse and addiction among children and adolescents have reached alarming proportions. Exposure to opioids after surgery for anterior cruciate ligament reconstruction (ACLR), which is commonly performed in young athletes, increases this risk. This study was designed to evaluate whether continuous peripheral nerve block (CPNB) with placement of an elastomeric reservoir ball, compared with single-shot peripheral nerve block (SPNB), would decrease the need for home opioid analgesia and improve pain control after ACLR in children and adolescents.

Methods: Prospectively collected data from a consecutive cohort that underwent ACLR by a single surgeon were retrospectively reviewed. Patients who received ACLR with 72-hour CPNB were assigned to Group 1. Patients who received ACLR with SPNB were assigned to Group 2. Postoperative pain management included cryotherapy, oral acetaminophen, and ibuprofen. A prescription for 10 doses of hydrocodone/acetaminophen (5/325 mg) was provided in a sealed envelope with instructions that the prescription should only be used in the case of uncontrolled pain. Reports of no opioid use were corroborated by the unopened envelope and unfilled prescription.

Results: One hundred and ninety-six patients were enrolled in the study (SPNB = 114 patients, CPNB = 82 patients). Average age was 15 ± 1.5 years (115 female). A total of 138 patients (70%) did not need home opioid analgesia after surgery. Of the 58 patients (30%) that did there were 35 (30.7%) in the SPNB group and 23 (28.0%) in the CPNB group ($P = 0.659$). There were no differences between groups in demographics, operative data, or visual analog scale scores on any postoperative day.

Conclusion: The findings of this study demonstrate equivalent pain control and opioid consumption in children and adolescents undergoing ACLR treated with either a CPNB or a SPNB. At-home opioid analgesia use can be negated after ACLR in 70% of children and adolescents. For the patients in this study who required opioids, average use was only 2 pills of 5 mg hydrocodone/325 mg acetaminophen, with no child using more than 10 pills.

Level of Evidence: Level II—therapeutic.

Key Words: opioid, anterior cruciate ligament reconstruction, peripheral nerve blocks

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At his first postoperative follow-up visit for implant removal after guided growth for the correction of bilateral genu valgum, a 15-year-old patient voluntarily informed the senior author that his high school classmate had asked, "Looks like you had surgery, if you have any drugs left, can I buy some?" Such scenarios are not uncommon, as ~13% of high school seniors have reported nonmedical use of prescription opioids in their lifetimes with 8.7% to 11% reporting use within the last year.[1,2] The second most common source of opioids (36.9%) in this population is leftover medication from previous legitimate prescriptions after injury or procedures.[1] Before injury or surgery, most children and adolescents are narcotic naive. Medical use of opioids in this population increases the risk for nonmedical opioid misuse after high school by 33%.[3] As orthopaedic surgeons, we are in a powerful position to understand and affect change in the adolescent population through patient/parent education and through controlling the amount and type of pain medications we prescribe. Although the opioid crisis among adolescents in the United States has been a topic of recent research,[4–7] there is a paucity of literature on pain management following outpatient orthopaedic surgery in this population.[8] One of the most common orthopaedic surgeries performed in this population is an anterior cruciate ligament reconstruction (ACLR).[9] Regional nerve blocks are commonly used to mitigate pain after ACLR and can be placed as a single-shot peripheral nerve block (SPNB) or as a continuous peripheral

nerve block (CPNB). CPNB involve placement of an elastomeric reservoir ball that delivers medication over a prolonged duration, depending on the volume contained in the reservoir and the rate of delivery.[10,11] The purpose of this study was to evaluate whether CPNB compared with SPNB, would decrease or potentially negate the need for home opioid analgesia after ACLR in children and adolescents. Our hypothesis was that CPNB would result in lower home opioid consumption after ACLR when compared with SPNB.

METHODS

An Institutional Review Board approved the retrospective review of prospectively collected data from a consecutive cohort of patients, 10 to 19 years of age, who had undergone ACLR by a single surgeon during the period from March 2018 to April 2020. Patients who had undergone ACLR at our in-patient hospital and received CPNB as well as placement of an elastomeric reservoir ball (On-Q Pain Relief System; Avanos Medical, Alpharetta, GA) designed to last 72 hours were assigned to Group 1. Patients who had undergone ACLR at our outpatient surgery centers and received SPNB were assigned to Group 2. The decision to perform surgery at the outpatient surgery center or at the hospital was determined by several factors, including operating room/patient/surgeon availability and insurance type. Decisions regarding the type, duration, and location of the regional nerve block and the type of medication used were left to the discretion of the anesthesiologist. All blocks were placed in the operating room with the patient anesthetized.

The same anesthesiologists/anesthesia group worked at both the hospital "inpatient" OR and at the outpatient surgery center OR.

Preoperative demographic data (height, weight, body mass index, sex, insurance type government or commercial) and operative data (procedure performed, ACLR graft, block type, tourniquet time, surgery time) were collected. Surgery time was defined as the duration from procedure start time to procedure stop time. For postoperative analgesia, patients were instructed to use cryotherapy and to alternate the use of acetaminophen and ibuprofen. For cryotherapy, patients used either a commercial cold therapy unit (DONJOY Iceman Clear or a similar product); if use of a cold therapy unit was not feasible, then ice packs were used. The prescribed use of cryotherapy was 20 minutes on, then 20 minutes off, several times per day, for at least the first 3 days postoperatively. A prescription for 10 pills or liquid equivalent of hydrocodone/acetaminophen (5/325 mg) was placed in a sealed business envelope and handed to the patient. Patients and caregivers were instructed to use the opioid medication only if the pain was uncontrolled by the previously described modalities. Written and verbal education was provided on proper acetaminophen dosing.

All patients recorded their level of pain, as measured using the visual analog scale (VAS), and the amounts of ibuprofen, acetaminophen, and hydrocodone taken during the three days following surgery in a written log. Those that reported not using narcotics were asked to provide the unfilled prescription. Total and daily hydrocodone consumption was standardized through conversion to morphine milligram equivalents (MME), where 1 mg hydrocodone = 1 MME. In each case, an inquiry was run on our state Controlled Substance Utilization Review and Evaluation System (CURES) to further verify the filling of narcotic prescriptions during the perioperative period. Any patient who failed to return the written log was excluded from the study, as was any patient who reported not using narcotics but failed to provide the unfilled prescription.

Data were analyzed by an independent statistician. A power analysis was performed using pilot data. This study was adequately powered to detect a difference of 20% in the rate of narcotic consumption at 80% power and alpha ≥ 0.05. Comparisons between groups were performed with analysis of variance for continuous variables, the nonparametric Mann-Whitney U test for ordinal data, and the χ^2 test for categorical data. Assumptions of normality and homogeneity of variances were evaluated before the use of parametric statistics. All analyses were performed using SPSS v. 25 with alpha set at $P < 0.05$ to declare significance (Released 2017. IBM SPSS Statistics for Windows, Version 25.0; IBM Corp., Armonk, NY).

RESULTS

One hundred and ninety-eight patients were enrolled in the study, 2 were excluded for failure to return their postoperative log, leaving 196 patients (99%) in the final cohort (SPNB = 114 patients, CPNB = 82 patients). Average age in the study population was 15 ± 1.5 years (81 male patients, 115 female patients). Overall, 138 patients (70%) did not consume any opioids after surgery. In the SPNB group 79 patients (69.3%) did not consume opioids versus 59 patients (72.0%) in the CPNB group. Fifty-eight patients (30%) took opioids after surgery, 35 (30.7%) in the SPNB and 23 (28.0%) in the CPNB group ($P = 0.659$). In those that filled the prescription 44% in the CPNB group consumed at or above the median consumption (3 MME) compared with 71% that consumed at or above the median in the SPNB group which met significance $P = 0.033$.

There were no significant differences between groups in demographics, operative data, or VAS scores on any postoperative day (Table 1). All patients were satisfied with their postoperative pain control.

There were no differences in the characteristics of meniscal injury and treatment between groups (Table 2).

A subgroup analysis was performed on the 58 patients that used opioids after surgery. There was no statistical difference in any variable (sex, block type, timing of block, ACLR graft or type of insurance type; Table 3).

There was a statistically significant difference in ibuprofen consumption between groups however no difference in the average total and daily opioid and

TABLE 1. Demographic Characteristics, Surgical Data, and Visual Analog Scale (VAS) Scores for Children and Adolescents Who Underwent ACLR With a CPNB (Group 1) and Children and Adolescents Who Underwent ACLR With a SPNB (Group 2)

	Group 1, N = 82, n (%)	Group 2, N = 114, n (%)	*P*
Age (y)	15.1 ± 2	15.3 ± 2	0.407
Sex (male/female)	38/44	43/71	0.227
Surgery time (min)	97 ± 27	104 ± 32	0.103
Block type			0.804
Adductor canal	61 (74)	83 (73)	
Femoral nerve	21 (26)	31 (27)	
Timing of block			**0.023**
Before surgery	70 (85)	108 (95)	
End of surgery	12 (15)	6 (5)	
ACLR graft			0.586
Hamstring tendon	58 (71)	79 (69)	
Hybrid auto/allograft hamstring tendon	3 (1)	5 (5)	
Patella tendon	14 (17)	22 (19)	
Quadriceps tendon	6 (7)	7 (6)	
Iliotibial band	3 (5)	1 (1)	
Visual analog scale (median, range)			
VAS day 1	6 (0-10)	5.5 (0-10)	0.88
VAS day 2	6 (0-10)	6 (0-10)	0.26
VAS day 3	4 (0-10)	5 (0-10)	0.47

Bold value indicates statistical significance ($P < 0.05$).

ACLR indicates anterior cruciate ligament reconstruction; CPNB, continuous peripheral nerve block; SPNB, single-shot peripheral nerve block.

acetaminophen consumption over the study period (Table 4).

There is a significant difference in the distribution of private versus government insurance between the study groups ($P < 0.001$). Upon further analysis of the CPNB group, there was no significant difference in the rate of narcotic consumption between insurance types where 4/6 (25%) of commercially insured patients consumed narcotics versus 28.8% (19/66) of those with government insurance ($P = 0.99$).

Regarding complications associated with the peripheral nerve block, 2 patients in the CPNB group had issues with the reservoir ball device. Patient 1, an 11-year-old boy who underwent hamstring autograft ACLR and lateral meniscus repair, visited the outpatient clinic day 3 postsurgery because of a leak. The patient presented the unfilled prescription, and the device was removed. Patient 2 an 18-year-old girl underwent bone tendon bone autograft ACLR, and medial meniscus repair had the reservoir ball dislodge while going to the restroom on day 2 postsurgery and removed the device before 72 hours. Patient 2 reported

TABLE 2. Characteristics of Meniscal Injury and Treatment for Children and Adolescents Who Underwent ACLR With a CPNB (Group 1) and Children and Adolescents Who Underwent ACLR With a SPNB (Group 2)

	Group 1, N = 82	Group 2, N = 114	*P*
Any meniscus work performed	62	83	0.659
Lateral meniscus repair (LMR)	11	15	0.484
Medial meniscus repair (MMR)	14	21	
MMR+LMR	19	34	
Partial lateral meniscectomy (PLM)	12	8	
Partial medial meniscectomy (PMM)	0	1	
PMM+LMR	1	0	
MMR+PLM	5	4	

ACLR indicates anterior cruciate ligament reconstruction; CPNB, continuous peripheral nerve block; SPNB, single-shot peripheral nerve block.

TABLE 3. Demographic Characteristics, Surgical Data, and Insurance Type for Children and Adolescents Who Underwent ACLR With Either a CPNB (Group 1) or a SPNB (Group 2) and Took Narcotics Postoperatively, N = 58

	N = 58, n (%)	*P*
Sex (male/female)	19/39	0.127
Block type		0.211
Adductor canal	39 (67.2)	
Femoral nerve	19 (32.8)	
Timing of block		0.382
Before surgery	51 (87.9)	
End of surgery	7 (12.1)	
ACLR graft		0.248
Hamstring tendon	34(58.6)	
Hybrid auto/allograft hamstring tendon	2 (3.4)	
Patella tendon	16(27.6)	
Quadriceps tendon	4 (6.9)	
Iliotibial band	2 (3.4)	
Insurance type		0.941
Commercial	38 (65.5)	
Government	20 (34.5)	

ACLR indicates anterior cruciate ligament reconstruction; CPNB, continuous peripheral nerve block; SPNB, single-shot peripheral nerve block.

TABLE 4. Hydrocodone Reported as Morphine Milligram Equivalent (MME), Ibuprofen and Individual Acetaminophen Medication Consumption in Milligrams (mg) for Children and Adolescents Who Underwent ACLR With a CPNB (Group 1) and Children and Adolescents Who Underwent ACLR With a SPNB (Group 2) Where 1 Dose Hydrocodone 5 mg = 5 MME, 1 Dose Ibuprofen = 200 mg, and 1 Dose Acetaminophen = 500 mg

	Group 1, N = 82	Group 2, N = 114	*P*
MME ± SD POD1	1.2 ± 3	1.3 ± 3.3	0.827
MME ± SD POD2	1.5 ± 3.9	2.9 ± 5.4	0.109
MME ± SD POD3	2 ± 4.2	2.3 ± 4.9	0.931
MME ± SD total	4.7 ± 10.1	6.5 ± 11.75	0.427
Ibuprofen (mg) POD 1	674 ± 700	1010 ± 648	< 0.001
Ibuprofen (mg) POD 2	802 ± 692	1306 ± 834	< 0.001
Ibuprofen (mg) POD 3	670 ± 642	1158 ± 824	< 0.001
Ibuprofen (mg) total	2152 ± 1850	3390 ± 1998	< 0.001
Acetaminophen (mg) POD 1	1315 ± 1290	1395 ± 1275	0.572
Acetaminophen (mg) POD 2	1490 ± 1200	1765 ± 1285	0.072
Acetaminophen (mg) POD 3	1215 ± 1150	1575 ± 1370	0.07
Acetaminophen (mg) total	4020 ± 3290	4760 ± 3430	0.098

ACLR indicates anterior cruciate ligament reconstruction; CPNB, continuous peripheral nerve block; POD, postoperative day; SPNB, single-shot peripheral nerve block.

taking 1 hydrocodone/acetaminophen pill on day 2 post-surgery. There were no complications in the SPNB group.

DISCUSSION

One of the most notable findings in this study is that a CPNB compared with SPNB did not decrease or potentially negate the need for home opioid analgesia after ACLR in children and adolescents undergoing ACLR. This conclusion was surprising given that in adults, a CPNB has been shown to improve postoperative VAS and narcotic usage compared with SPNB after total knee arthroplasty and in verbal pain scores in adults after ACLR.[12–15] Williams et al[15] performed a randomized clinical trial comparing postoperative pain [numeric rating scale (NRS)] and opioid consumption in 233 adult patients that underwent ACLR treated with a continuous infusion femoral nerve block, single-shot femoral nerve block or saline placebo. The study found improved NRS pain scores in the continuous femoral nerve block group over the single-shot femoral nerve block group for the first 2 postoperative days (NRS 2 vs. 3).[15] However, the study did not show any difference between the continuous versus single-shot nerve block groups in the amount of opioid medication the patients consumed on any postoperative day or total over 4 days (132 vs. 141 MME). Similarly, our study found no difference in the opioid consumption postoperatively between the CPNB and SPNB groups on any postoperative day or total over 3 days (9 MME vs. 13 MME, $P = 0.427$). However, unlike the study by Williams and colleagues, our study did not show any statistical difference in pain scores (VAS) on any postoperative day. It is interesting to note that the average MME patients used in our study was 10-fold lower than in the study by Williams and colleagues. We would attribute this to the difference in physician directions and education before surgery. Williams and colleagues, instructed patients to preemptively take pain medication, whereas our study instructed patients to only use the medication in the event of uncontrolled breakthrough pain. This does illustrate the powerful effect the surgeon can have on reducing opioid usage postoperative. A recent metanalysis by Maheshwer et al[16] compared VAS scores from studies that had used a continuous femoral nerve block compared with different studies that had used any type of single-shot regional block. The metanalysis found improved VAS 12 hours after surgery to 24 hours after surgery. There was no difference between VAS in the first 12 hours after surgery and pain control past 24 hours was not studied. Because of the heterogeneity of data in reporting opioid consumption, the study was unable to analyze or make conclusions on usage. The results of our study contrasted with Maheshwer and colleagues in relation to VAS after surgery. One reason may be because our study recorded average VAS daily and not every 4 hours, which may account for some variation in results and may be less sensitive in picking up variations in different time periods within the first postoperative day. When comparing the VAS in our study population, the average daily value was higher than reported in the metanalysis by Maheshwer and colleagues. The VAS on POD #1 in the CPNB group was 6 in our study compared with 2.72 (range: 1.00 to 5.70) in the pooled metanalysis and 5.5 in the SPNB group compared with 4.28 (3.70 to 5.70) in the pooled metanalysis.[16] We attribute this difference to our preoperative opioid education. Since patients/parents were instructed to only use the opioids in the case of uncontrolled breakthrough pain, they likely did not use the medication unless the pain level reached a severe level (7+). This would result in a higher average VAS and a lower opioid consumption, which is consistent with our review of the literature. While this scenario may not be ideal in adults, we support this approach in the pediatric population given the opportunity to potentially mitigate future opioid misuse and decrease the number of unused opioids available in the home/society following surgery.

One of the most important findings in this study is that only 30% of pediatric patients undergoing ACLR with a regional nerve block, required opioids for postoperative pain control. Of those that required opioid, the average amount used was 2 pills of hydrocodone/acetaminophen (9 to 13 MME), with no patient requiring more than 10 pills (50 MME). In addition, most patients (70%) did not even fill the narcotic medication, which keeps the medication out of the home entirely. While this finding was not the primary purpose of this study, it gives orthopaedic surgeons a valuable reference for an appropriate amount of opioid medication to give to pediatric patients undergoing ACLR surgery. This change in prescribing practice can hopefully lead to a decrease in leftover medication, which is often the source of future nonmedical opioid misuse in this population.

Similar to other previously published programs[17–19] the physician-led program at our institution resulted in a maximum total of 50 MME prescribed, which is substantially lower than figures reported previously.[6] Beck and colleagues studied 103 patients 12 to 18 years of age scheduled to undergo primary isolated ACLR, with or without meniscal treatment. Two orthopaedic surgeons performed ACLR and determined whether to perform hamstring or bone-patellar tendon-bone autograft on a case-by-case basis. For postoperative pain management, patients were prescribed 40 tablets of hydrocodone/acetaminophen 5/325 mg (200 MME total). Patients were instructed to document daily pill consumption and side effects in a daily log for 6 weeks. The median number of postoperative opioids taken by patients in their study was 85 MME (range: 0 to 200 MME).[6]

Before embarking on the current study, the practice of prescribing narcotics at our institution was similar to the approach described above. In most cases, 30 pills of hydrocodone-acetaminophen (5/325 mg) or a maximum total of 150 MME were prescribed. Patients and caregivers were instructed to start taking the pills upon returning home from surgery to prevent a spike in pain that could occur as the regional block was wearing off. At the conclusion of the current study, it became clear that this approach to the management of postoperative pain

required revision. The amount of narcotic medication prescribed has since been decreased 3-fold to 10 pills of hydrocodone-acetaminophen (5/325), a maximum total of 50 MME. The instructions to the patient and caregiver have also been revised. Now, the patient and caregiver are instructed not to open the envelope, fill the prescription, or use the drug unless postoperative pain is severe and is not relieved by other modalities. These changes to our protocol for pain management resulted in a significant decrease in the use of opioid medication in both study groups. The hypothesis of this study, that postoperative at-home narcotic use would be lower in patients who underwent CPNB after ACLR, compared with those who underwent SPNB after ACLR, was refuted. There was no statistically significant difference between groups in terms of at-home narcotic consumption.

The current study has several limitations. Neither the type of cryotherapy used, nor the intensity of use was quantified. The study did not analyze or control the amount of analgesic medication used during the procedure or in the recovery room. Such decisions regarding perioperative analgesic medication were left to the discretion of the attending anesthesiologists in all cases. In addition, 26.5% of patients received a femoral nerve block, and it is well understood that this can cause late weakness and delayed quadriceps reactivation and has been discouraged by recent publications, limiting the applicability to general practice.[20] There was no statistical difference in the proportion of patients that received a femoral versus adductor canal nerve block between groups. While this may be a limitation of the study, it does not appear to be confounding variable.

Furthermore, the perioperative use of over-the-counter pain medicine before surgery, which was left to the discretion of the patients and their caregivers, was not recorded. This aspect of our study design reflects a reluctance to micromanage the perioperative care provided at the surgery centers and at the in-patient Children's hospital, to ensure that the results of this study were translatable and useful to other practitioners and institutions. It has been the custom and practice of the senior author and surgeon in this study to use hydrocodone/APAP. Specific verbal and written instructions are provided to patients and caregivers regarding the need to adjust acetaminophen dosage if the hydrocodone/APAP is utilized. Oxycodone is easily available in most pharmacies; however, hydrocodone alone is not as readily available in our state. This may be a regional difference. Hydrocodone has a lower MME conversion factor as compared with oxycodone 1 to 1.5, respectively. Neither anesthesia duration nor total time in the operating room was recorded. The intraoperative and postoperative MME before discharge was not recorded nor was the relationship of intraoperative and postoperative MME to block timing (before or after procedure) recorded. Surgical times and tourniquet times were recorded because surgical time was expected to have more of an effect on postoperative pain than total in-operating room or anesthesia time. Notably, the clinical experience of the researchers who contributed to this study has shown that CPNB placement requires more time than SPNB placement. Although specific time differences were not investigated in this study, future research efforts may provide valuable information.

CONCLUSIONS

The findings of this study demonstrate equivalent pain control and opioid consumption in children and adolescents undergoing ACLR treated with either a CPNB or a SPNB. At-home opioid use can be negated after ACLR in 70% of children and adolescents. For the patients in this study who required narcotics, average use was only 2 pills of 5 mg hydrocodone/325 mg acetaminophen, with no child using more than 10 pills.

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