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Reduced Opioid Use After Surgeon-Administered Genicular Nerve Block for Anterior Cruciate Ligament Reconstruction in Adults and Adolescents

George L. Caldwell Jr, MD · Michael A. Selepec, PA-C

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Abstract *Background:* Pain management after anterior cruciate ligament reconstruction (ACLR) may pose a risk of prolonged opioid use. *Questions/Purposes:* The purposes of this study in ACLR were to investigate the efficacy of a surgeon-administered local–regional block of specific genicular nerves on post-operative analgesia following ACLR and to quantify the outpatient opioid consumption and duration through the complete post-operative course. *Methods:* Prospectively, all patients undergoing primary ACLR by a single surgeon were studied over a 10-month period. Exclusion criteria consisted of history of pre-operative opioid use, revision surgery, multi-ligament surgery, allergy to oral opioids, and allergy to local anesthetic. ACLR was performed using autograft or allograft patellar tendon bone (PTB) graft under general anesthesia. At the conclusion of the procedure, all patients received a local anesthetic (bupivacaine 0.25%) injection by the surgeon including a unique circumferential genicular nerve and fat pad block performed based on anatomic landmarks without use of image guidance. Post-operatively, the quantity and duration of opioid use (hydrocodone 5 mg) and pain scores were recorded for 4 months prospectively. Statistical analysis was performed to evaluate risk factors for increased opioid use. *Results:* A single surgeon performed 75 ACLRs. After exclusions, a total of 70 patients were enrolled and followed prospectively. None were lost to follow-up. Total opioid consumption ranged from 0 to 30 tablets. The average number of opioid tablets used over the 4-month post-operative course was 5.5 (±6.7). After surgery, 84% of patients took between 0 and 10 tablets and 21% of patients took no opioids throughout their entire post-operative course. The average duration of consumption was 2.6 days (±3.1). No patients were taking opioids at the 6-week or 4-month follow-up. There were no refills required. No statistically significant differences were seen in regard to graft choice of autograft PTB ($n = 48$) vs allograft PTB ($n = 22$) in total opioid consumption or duration of use. In comparing adolescent ($n = 31$) versus adult ($n = 39$), no significant difference was seen in total opioid consumption or duration of use. All patients were satisfied with the post-operative pain management protocol. *Conclusion:* Opioid use was unexpectedly low among patients undergoing ACLR after a surgeon-administered circumferential genicular nerve block and fat pad infiltration. With this protocol, the graft choice and patient age did not correlate with increased opioid use. These results could be useful in guiding post-operative opioid prescribing after ACLR.

Keywords anterior cruciate ligament reconstruction · ACL · opioid · adolescent · genicular nerves

Introduction

Outpatient anterior cruciate ligament reconstruction (ACLR) is a common procedure and is increasing in frequency [5]. Effective post-operative pain management is especially critical in ACLR for expedited recovery, rehabilitation goals, and patient satisfaction. Previously, physicians had been encouraged to be more aggressive in treating their patients' pain with opioids [28]. However, opioid use and misuse has increased to the point that the current situation in the USA is

Level of Evidence: Therapeutic Study: Level IV

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G. L. Caldwell, Jr, MD (✉) · M. A. Selepec, PA-C
Florida Institute of Orthopaedic Surgical Specialists, 2307 West Broward Blvd. Suite 200,
Fort Lauderdale, FL 33312, USA
e-mail: glc@caldwellsportsmed.com

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considered an epidemic [11, 25]. In a recent database study of surgical patients without a history of misuse or ongoing opioid use, researchers revealed a 44% increase in misuse for every opioid refill [4].

There has been a call for evidence-based guidelines for prescribing post-operative opioids after orthopedic surgical procedures [30]. A recent review determined that a major limitation in development of such guidelines was the "lack of data on post-discharge use of opioids as well as the paucity of studies focusing directly on recording patterns in the post-operative opioid consumption" [22]. In a survey of orthopedic surgeons, Herkowitz et al. reported overwhelming surgeon support for the development of proven, effective, and safe ways to decrease reliance on opioids for post-operative pain management [13]. Current methods of regional anesthesia widely used in ACLR often involve more proximal nerves of the lower extremity (femoral nerve block, adductor canal block, and sciatic nerve block) [16, 29]. They can be effective tools for pain control, but complications can include hematoma, local anesthetic systemic toxicity, rebound pain, and vessel or nerve damage [16].

It is suggested that the ideal anesthetic for outpatient ACLR should be a sensory-only blockade that is technically simple, rapid onset of action, highly effective; have few or no side effects; and be relatively inexpensive [26]. The knee is innervated by branches from the femoral, obturator, and sciatic nerves [10, 14, 18]. However, there is no exact agreement on the relative contribution from each of these nerves. Anatomically, there are two main divisions of identified terminal sensory branches, often termed "genicular" nerves, with the anterior division innervating the anterior, medial, and lateral knee capsule, fat pad, and deeper structures [10, 15, 16]. We used this information to develop an anesthetic technique focused on these anterior genicular nerves.

The purpose of this study in anterior cruciate ligament reconstruction (ACLR) was to investigate the efficacy of a surgeon administered local–regional block of specific genicular nerves on post-operative analgesia following ACLR and to quantify the outpatient opioid consumption and duration through the complete post-operative course. We hypothesized that a new protocol of surgeon-administered local–regional anesthetic to the anterior genicular nerves could provide a desirable sensory-only blockade with sufficient post-operative pain control, facilitating lower post-operative oral opioid requirements. In this study, we aimed to answer questions about the precise long-term opioid requirements after ACLR and differences in opioid requirements between graft choice, age group, and other surgical and patient variables.

Methods

Institutional review board approval was obtained for this prospective observational study. Target enrollment was set at 60 patients based on a priori sample size calculation. Inclusion criteria consisted of all primary ACLR performed using patellar tendon bone (PTB) graft. This included both autograft and allograft PTB. Exclusion criteria were history of pre-operative opioid use, revision surgery, multi-ligament surgery, allergy to oral opioids, and allergy to local anesthetic. We defined pre-operative opioid use as patients who had filled opioid prescriptions within 3 months of ACLR or prior history of opioid dependency. An exception to this was an opioid-naive patient who was prescribed a small quantity of opioids from the emergency department after acute traumatic ACL tear. We considered these patients non-opioid users if they had not taken opioid medication within the most recent 2 weeks prior to ACLR.

A total of 75 ACLRs were performed by a single surgeon from August 2017 through June 2018. All ACLRs were considered for the study. Excluded were two revision surgeries, one patient with pre-operative opioid use, one patient with history of opioid dependence, and one multi-ligament reconstruction. A total of 70 patients (93%) were enrolled in the study. None were lost to follow-up or declined participation. Pre-operative and surgical characteristics were available in all patients (Table 1). Complete post-operative data was collected for all study patients.

Patients with ACL tears were considered candidates for reconstruction based on physical exam findings, magnetic resonance imaging results, and patient-specific factors. Graft

Table 1 Demographic and surgical characteristics

Baseline characteristics	Data
Number of patients (*n*)	70
Age (years)	27.2 (11.8)
Adolescent, age 19 years or less	31
Sex, male	29
Body mass index	24.1 (4.1)
Acute ACL tear (under 3 months post-trauma)	53
Chronic ACL tear (greater than 3 months post-injury)	17
Associated pathology	
Meniscus tear (medial or lateral)	41
Meniscus tear (medial and lateral)	26
Full-thickness articular lesion	4
Multi-ligament instability (MCL, PCL, LCL)	1
Autograft PTB, 11-mm diameter	48
Allograft PTB, 11-mm diameter	22
Partial meniscectomy (medial or lateral)	46
Partial meniscectomy (medial and lateral)	6
Meniscus repair (medial or lateral)	23
Meniscus repair (medial and lateral)	6
Microfracture chondroplasty	4
Intra-operative complications	0
Tourniquet time (min)	68.2 (14.0)
PACU time: minutes from end of surgery to discharge from facility	105.9 (49.9)
VAS score	
Pre-op	3.8(2.9)
PACU	2.3(2.3)
Day 1	2.5(2)
Day 7	1.4(1.7)
Week 6	0.1 (0.6)
Week 16	0.1 (0.3)
Location of outpatient surgery	
ASC	53
Hospital	17

ASC ambulatory surgery center, *LCL* lateral collateral ligament, *MCL* medial collateral ligament, *PACU* post-anesthesia care unit, *PCL* posterior cruciate ligament, *PTB* patellar tendon-bone, *VAS* visual analog scale

choices of autograft versus allograft were made pre-operatively on an individual basis for each patient. This practice typically uses PTB for ACLR, recommends autograft PTB grafts for younger athletes, and though not using specific age criteria for graft choice commonly recommends allograft PTB in patients over 40 years old.

All procedures were performed on an outpatient basis using standardized operative and post-operative treatment protocols (Online Resource 1). All surgeries were performed under general anesthesia with no pre-operative or post-operative regional nerve block. Procedures were performed at two facilities (one hospital and one ambulatory surgical center), with two independent anesthesia groups. Per practice protocol, intra-operative medications were left to the discretion of the anesthesiologist. Patients undergoing autograft procedures had initial graft harvest of an 11-mm central patellar tendon graft with proximal and distal bone blocks. From this point forward, both techniques were similar. Arthroscopy was performed, and then partial meniscectomy versus repair and chondroplasty were carried out as clinically indicated. Endoscopically, 11-mm tibial and femoral tunnels were drilled. The graft was passed and secured using 7-mm titanium interference screws.

The nerve block was administered at the conclusion of ACLR, with the patient still under general anesthesia. The block was performed by the surgeon with the aim of providing a complete local anesthetic block to the anterior division of the genicular nerves. There was no ultrasound or neurostimulation guidance for this local–regional block. The local anesthetic infiltration included a total of 0.25% bupivacaine 60 cc (not to exceed 2 mg/kg). We termed this block a "circumferential anterior genicular nerve block." There were approximately ten separate locales of injection about the anterior, medial, and lateral knee (Fig. 1). At each entry point, the needle was directed to a layer of tissue deep to the adipose tissue and just superficial to the deep ligaments, bone, or capsule. Starting anteromedially and distal to the joint line, the injections proceed medially and gradually superiorly to the direct superior–anterior aspect of the knee, then proceed down laterally to end inferolateral to the joint line. Finally, two injections are made directly into the anterior fat pad (Online Resource 2).

After wound closure, the dressing, cryotherapy pad, and knee brace are applied in the operating room and the patient was transferred to the post-anesthesia care unit (PACU). Additional pain medication was administered by IM, IV, or oral routes as per the anesthesia physician's discretion based on pain. While exact medication and dosage varied between anesthesia groups, adjunctive medication was limited to short-acting opioids, acetaminophen, and non-steroidal anti-inflammatory drugs. No long-acting medications, ketamine, or gabapentin were administered. No additional pain pumps, nerve blocks, or patient controlled analgesia (PCA) are used. Per our usual practice, patients were discharged with a prescription for 30 tablets of 5/325 mg hydrocodone/acetaminophen (5 oral morphine equivalents [OME] per tablet) [8]. This dosage was selected based on a retrospective review of our patients undergoing ACLR with the same opioid prescription prior to implementation of the local genicular block protocol. In this retrospectively reviewed group, 28% of patients required refills of their prescription. Due to this, we felt that 30 tablets were a reasonable quantity to provide adequate analgesia, without excessive unused medication. All patients were also given a prescription of 20 tablets of ibuprofen 600 mg. Patients were recommended to take an ibuprofen tablet twice daily with meals for pain. Then, if pain is not subjectively and adequately controlled, they may take a 5/325 mg hydrocodone/acetaminophen tablet every 4 h as needed for pain. No other medications were prescribed. Patients were counseled to discontinue opioid pain medication as soon as pain was tolerable. Patients were directed to dispose of unused opioids per the US Food and Drug Administration's medication disposal policy, so as to minimize the chances of diversion [31].

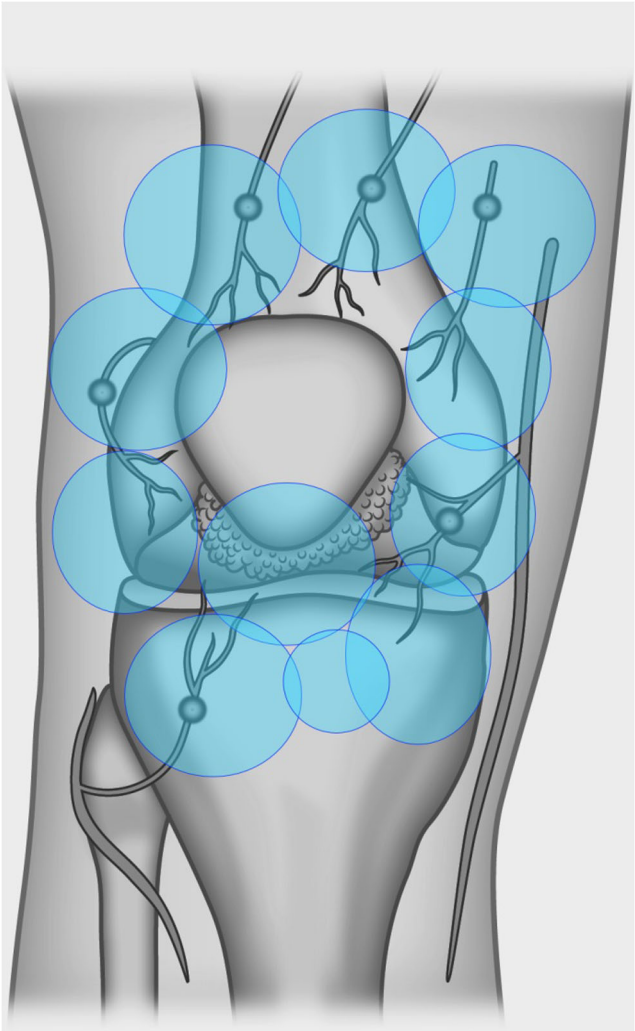

Fig. 1. Injections circumferentially about the anterior division of the genicular nerves, the fat pad, and the graft harvest site. Extension of local anesthetic injections is intended to overlap and maximize coverage of sites while done blindly, without guidance.

Post-operatively, all patients were seen by the surgeon or physician assistant (PA) in the office the day after surgery, on post-operative day 7, at 4 to 6 weeks, and at 4 months post-operatively. Patients were seen more frequently if deemed clinically necessary. Patients had initial

dressing changed on day 1 and were allowed to shower that evening. Post-operative therapy, using a standard protocol, began within 2 days after surgery, focusing on return of full range of motion and restoration of quadriceps strength. Crutches were discontinued at 4 weeks if gait was normal (Online Resource 3).

The primary study outcome measured was post-operative opioid pain medication usage after discharge. Prospectively, the quantity of opioid usage (number of tablets) and duration of opioid usage (latest post-operative day that they were taken) were documented at each visit. In addition, any prescription refill requests and visual analog scale (VAS) pain scores were recorded. Patient satisfaction with our post-operative pain management protocol was assessed using a Likert scale at the third post-operative visit. Satisfaction was rated 1 to 5, with 1 being strongly dissatisfied and 5 being strongly satisfied. Patients verbally reported their opioid use at each visit after completing self-administered at-home pill counting. Data was entered into a spreadsheet and the electronic medical record (EMR). All patients received the same post-operative dosage of opioid prescription. The dosage was also converted to OME based on standard conversion to facilitate later comparisons with other studies. At the 6-week and 4-month visit, we accessed the Florida Prescription Drug Monitoring Program (E-FORCSE) database to document if any opioids had been prescribed by other physicians.

Patients' age, sex, and body mass index (BMI) were recorded. Other operative variables documented were tourniquet time, graft choice, associated procedures, and PACU time to discharge. The range of motion was recorded at day 7 and all subsequent visits. The Lachman test for ACL stability was documented after the surgeon's physical exam at 6 weeks post-operatively. Patients' pre-operative opioid use was inquired and recorded at initial evaluation and on the day of surgery. At each post-operative visit, the surgeon or PA assessed the patients' progress with the rehabilitation protocol. Patients would be seen more frequently if there was a need to assess pain, wound complication, or delayed physical therapy progress.

Study Size

We performed a priori power analysis to determine the sample size needed to find a significant decrease in opioid consumption compared to previously published data. We utilized ACLR prescribing guidelines promoted by a recent Current Concepts Review [22]. This review established recommended dosing based on averages of currently published opioid consumption following ACLR. They made a recommendation of two to four tablets of oxycodone 5 mg per day for the first 7 days [22]. We used the mid-range value and calculated the OME for 7 days of use (3 tablets of oxycodone × 5 mg/tablet × 7 days × 1.5 OME = 157.5 OME). Unfortunately, there are no current minimal clinically important difference (MCID) values reported for opioid use in the ACLR literature as reference. Therefore, we chose a reduction of 33% opioid consumption of that 157.5 OME as our threshold for significance. Assuming a normal distribution, we utilized G*Power (Dusseldorf, Germany) to perform analysis for a difference in means for a one sample case, with an alpha of 0.05 and power of 0.80. We determined that a sample size of 60 patients was needed to detect a significant difference in opioid consumption.

Statistical Analysis

Statistical analysis was performed using R, version 3.4.2 (University of Auckland, New Zealand). Descriptive statistics and graphs were developed using Microsoft Excel (Redmond, WA, USA). First, descriptive statistics were calculated for all study variables. We then tested our outcome measures for normality using a Shapiro–Wilk test. We ran bivariate comparisons to assess potential risk factors for increased opioid consumption or duration. Due to the non-parametric nature of our outcome measures, we used Wilcoxon rank sum tests for categorical variables and Spearman's rho correlations for continuous variables. Reported pain scores were divided into four categories: none (0), mild (1–3), moderate (4–6), and severe (7–10), and compared pairwise. Statistical significance was accepted at $p < 0.05$.

Results

Over the entire 4-month post-operative course, the average number of tablets used per patient was 5.5 (± 6.7). The range was 0 to 30 tablets, and the median consumed was three tablets. Eighty-four percent of patients took 0 to 10 tablets total, with 21% of all patients taking no opioid pain medication (Fig. 2). Only one patient (1.4%) took the entire 30 tablets. The average duration of opioid consumption was 2.6 days (± 3.1). The median was 1 day. In total, 90% of our patients discontinued opioid medication by post-operative day 8 (Fig. 3). No patients took opioid medication for longer than 2 weeks. There were no prescription renewals. No patients received opioid prescriptions from outside physicians.

For the complete post-operative interval of the study, there were no readmissions, emergency department or urgent care visits, or after-hours phone calls for opioid management. There were no recurrent ACL instabilities as assessed by Lachman test at 6 weeks and 4 months post-operatively. There were no failures to achieve full range of motion in physical therapy within 6 weeks post-operatively. There were no surgical complications, infections, or re-operations. There were no complications regarding the genicular nerve block. No prolonged numbness, paresthesias, motor deficits, or prolonged quadriceps weakness were reported. Of the patient satisfaction scores, two patients were "somewhat satisfied," while all others were "strongly satisfied." No patients were "dissatisfied" with the protocol. Analysis for all categorical variables is summarized in Table 2.

Regarding age group, 39 adult patients underwent ACLR compared to 31 adolescents. Adolescents took similar amounts of opioid tablets on average (4.4 [± 4.2] vs 6.3 [±

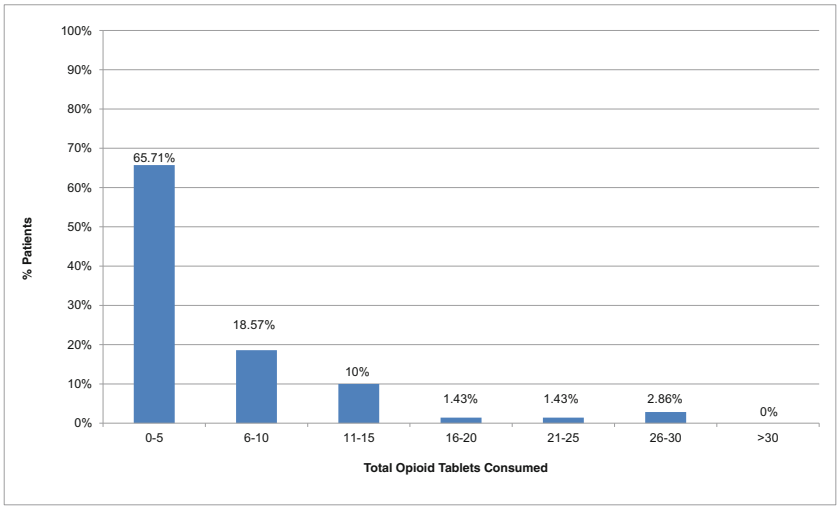

Fig. 2. Average number of opioid tablets consumed.

8.1]) ($p = 0.98$). Similarly, adolescents had similar duration of usage compared to adults (2.3 [± 2.4] days vs. 2.8 [± 3.6]) ($p = 0.87$). Controlling for graft choice (Table 3), adolescents (4.4 [± 4.2]) took similar amounts compared to adult autograft patients (8.7 tablets [± 8.7]) ($p = 0.209$). Additionally, adolescents had similar duration of use compared to adult autograft (2.3 [± 2.4] days vs. 3.3 [± 2.5]) ($p = 0.131$).

Regarding graft choice, 48 ACLR were performed with autograft and 22 with allograft. Autograft patients took more opioids on average than allograft patients (5.9 tablets [± 6.5] vs. 4.4 [± 7.3]). This approached significance ($p = 0.05$). There was no significant difference between the groups for duration of usage ($p = 0.09$). Controlling for age group (Table 4), adult autograft patients (8.7 tablets [± 8.7]) took significantly more opioids than adult allograft patients (4.4 [± 7.3]) ($p = 0.02$), and for significantly longer (3.3 days [± 2.5] vs 2.4 [± 4.3]) ($p = 0.03$).

Patient-reported pain was a poor predictor of post-operative opioid use. There was a significant positive correlation between week 1 pain and duration of use ($p = 0.03$); however, no significant correlation was found for pre-operative pain, discharge pain, day 1 pain, 6-week pain, or 4-month pain, with regard to opioid consumption or duration. No significant correlation was found for opioid use or duration with regard to BMI ($p = 0.61$; 0.67), tourniquet time ($p = 0.91$; 0.84), PACU time ($p = 0.85$; 0.65), or facility ($p = 0.13$; 0.30).

Discussion

The principal findings of this study show that adequate pain control was achieved with high patient satisfaction following outpatient arthroscopic ACLR utilizing a technique of surgeon-administered circumferential anterior genicular nerve block and a limited post-operative protocol for dispensing opioid analgesics. It was similarly effective in both autograft and allograft PTB. Additionally, post-operative opioid use was

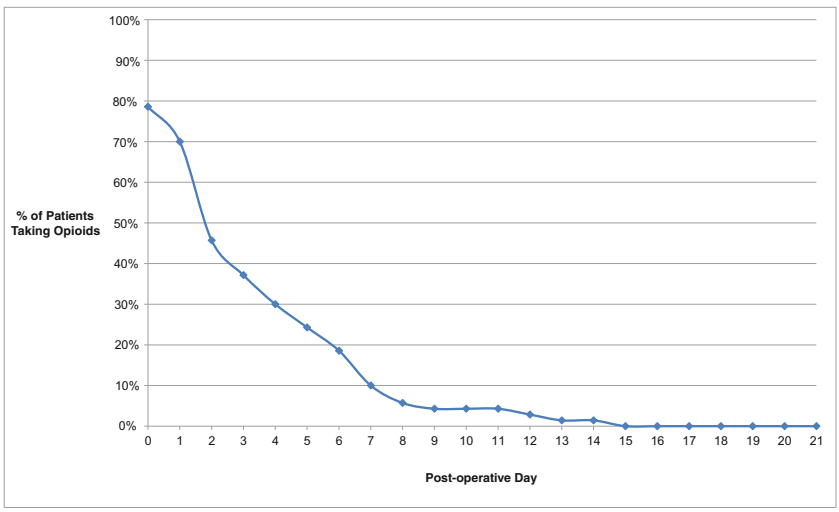

Fig. 3. Percentage of patients taking oral opioids at given post-operative day.

Table 2 Categorical variables on duration of opioid use and opioid consumption

Variable		Opioid duration mean, in days (SD)	*p* value	Mean opioid tablets consumed (SD)	*p* value
Graft choice	Autograft ($n = 48$)	2.6 (± 2.5)	0.09	5.9 (± 6.5)	0.05
	Allograft ($n = 22$)	2.4 (± 4.3)		4.4 (± 7.3)	
Age group	Adolescent ($n = 31$)	2.3 (± 2.4)	0.87	4.4 (± 4.2)	0.98
	Adult ($n = 39$)	2.8 (± 3.6)		6.3 (± 8.1)	
Chronicity	< 3 months ($n = 53$)	3.1 (± 2.6)	0.59	5.4 (± 2.6)	0.68
	> 3 months ($n = 17$)	3.3 (± 2.5)		5.7 (± 2.5)	
Associated procedure	Meniscectomy ($n = 36$)	2.7 (± 3.3)	0.88	5.3 (± 7.0)	0.47
	Meniscus repair ($n = 27$)	2.7 (± 3.0)		6.1 (± 6.9)	
Facility	Ambulatory surgery center ($n = 53$)	2.4 (± 2.9)	0.30	4.8 (± 6.4)	0.13
	Hospital ($n = 17$)	3.3 (± 3.7)		7.4 (± 7.6)	

documented with no long-term opioid usage or demand in this opioid-naive population. The protocol can be effective in adolescents as well as adults with a low complication rate.

The potential weaknesses of our study include reliance on patient reporting of opioid usage. However, we did use our state's prescription drug monitoring program (E-FORCSE) to ensure that patients were not receiving opioids from outside providers. Also, we did not track the patients' ibuprofen usage. The main objective was to document home opioid use. It was felt that ibuprofen is so readily available in most homes that it could not be reliably accounted for in usage or in prescription monitoring. We did not collect exact peri-operative medications administered by the anesthesiologist in the immediate post-operative period. Future controlled studies may be beneficial to eliminate any potential such discrepancy. Our study excluded patients with prior history of opioid use. It has been shown that pre-operative opioid use is a risk factor for increased post-operative use [2]. However, we purposely restricted our study to opioid-naive patients to gain more data on this patient population that may help form standardized guidelines. Also, we did not have a randomized, double-blinded control group. Further large sample, controlled studies may be of benefit to demonstrate the effectiveness of genicular block following ACLR.

ACLR patients can require powerful analgesics in the post-operative period while recovering at home [21, 30]. Non-steroidal anti-inflammatory drugs are a safe, low-cost alternative to oral opioids [29]. However, they may not always provide sufficient analgesia. One major challenge in ACLR is providing adequate pain control while avoiding the risks of excessive opioids that could lead to diversion, misuse, and abuse [21, 30]. Brat et al. showed that post-surgical prescriptions of opioids have been linked to overdose and misuse [4]. Remarkably, each additional week of opioid prescription was associated with an average increase in misuse of 20%.

Orthopedic surgeons have been called upon to utilize new anesthetic strategies and post-operative protocols for comprehensive post-operative pain relief [21, 22, 30]. Currently, there is no consensus on optimal pain management [29]. Regional nerve blocks proximal to the knee are performed by anesthesiologists utilizing neurostimulation or ultrasound guidance to minimize direct neural damage or anesthetic toxicity [6, 16]. The femoral nerve block (FNB) has been commonly used for acute post-operative anesthesia in ACLR [12, 29]. However, the combined motor and sensory blockade of FNB can result in a risk of falls in the immediate post-operative setting, and ongoing strength deficits have been reported as far as 6 months after ACLR [3, 24]. Alternatively, adductor canal block (ACB) and subsartorial saphenous nerve block (SSNB) have been proposed for a sensory-only block with reduced fall risk and strength deficits [1, 20]. However, these blocks generally anesthetize the saphenous nerve and may provide incomplete sensory blockade to the knee based on anatomy [10, 15, 16, 18]. A different strategy would be to focus on the specific nerves that innervate the structures responsible for post-surgical knee pain.

In a remarkable study, Dye el al. identified the various intra-articular components responsible for sensation in a non-anesthetized knee [9]. The anterior synovial tissues, fat pad, and capsule were exquisitely sensitive to mechanical stimulation (Online Resource 4). The cruciates and menisci were not. Much of the information about terminal, genicular nerve branches that innervate these structures of the knee

Table 3 Opioid usage comparing adolescent and adults while controlling for graft type

	Autograft ($n = 48$)		*p* value
	Adult ($n = 17$)	Adolescent ($n = 31$)	
Age, in years	28.8 (± 6.7)	16.8 (± 1.1)	< 0.001
Opioid tablets consumed	8.7 (± 8.7)	4.4 (± 4.2)	0.209
Duration, in days	3.3 (± 2.5)	2.3 (± 2.4)	0.131

Table 4 Opioid usage comparing allograft and autograft while controlling for age

	Adults ($n = 39$)		*p* value
	Allograft ($n = 22$)	Autograft ($n = 17$)	
Age, in years	40.6 (± 8.3)	28.8 (± 6.7)	< 0.001
Opioid tablets consumed	4.4 (± 7.3)	8.7 (± 8.7)	0.021
Duration, in days	2.5 (± 4.3)	3.3 (± 2.5)	0.032

have come from studies aimed at iatrogenic, long-term denervation of genicular nerves for chronic knee pain [10, 19]. We hypothesized that a local anesthetic technique that focused on six terminal genicular nerve branches, combined with direct fat pad infiltration, could provide adequate analgesia after general anesthesia with improved post-operative pain control in ACLR patients. What differentiates this technique is that it is tailored to anesthetize specific terminal sensory nerve pathways to the knee. It is not a local infiltration of the wounds or harvest site, and it is not direct intra-articular infiltration. The surgeon, without guidance, performs it at the conclusion of surgery, while the patient is still under general anesthesia. This strategically minimizes patient inconvenience, cost, and procedure time. We found that adequate volume of local anesthetic spread near the terminal branches of these nerves could provide sensory-only blockade, without need for adjunctive imaging or guidance. The cost of the local–regional technique was approximately $6 (for bupivacaine 60 cc) and generally took an additional 1 to 2 min to administer by the surgeon at the completion of the case.

Orthopedists lack specific information regarding complete post-discharge opioid use following ACLR in adults and adolescents [7, 21, 22]. This includes recovery from acute pain of surgery as well as the extended rehabilitation after ACLR. Joseph et al. found that autograft PTB patients were taking opioids for a mean duration of 23 days [17]. Anthony et al. reported that 50% of ACLR patients had an opioid refill after the first month and 5% were still filling opioid prescriptions at 12 months [2]. Data is necessary to identify typical duration of opioid use in order for surgeons to institute rapid cessation of post-operative opioids successfully [21]. In our study, 90% of patients had discontinued opioid medication by post-operative day 8, and no patients were taking opioids longer than 2 weeks post-operatively.

Autogenous PTB is generally considered one of the most painful graft options. Okoroha et al. found a significant increase in acute post-operative pain in ACLR using autograft PTB versus autograft hamstring tendon [27]. Within the PTB group, 76% reported breakthrough pain, 19% placed an unplanned phone call to the surgeon, and over 50% were dissatisfied with pain control on day 1. They concluded post-operative pain should be a factor when deciding on graft choice. In contrast to that study, we do not feel that post-operative pain obligates or necessitates a particular graft choice. In our practice, the younger, high-demand athletes generally receive autograft PTB, while older, lower-demand patients received allograft PTB. Although the groups did differ in age and tourniquet time, we were surprised to not see a significant difference in opioid usage between autograft and allograft ACLR. In adult patients, autograft patients did take statically significantly more opioids than allograft patients (8.7 vs. 4.4 tablets) and for a longer period of time (2.5 vs. 3.3 days). This difference would be expected based on graft type; however, we postulate that a mean difference of about four tablets may not have significant clinical importance given that both averages well below those currently in the literature. Using this protocol, we do not believe post-operative pain should be a major factor in graft choice.

The current literature is incomplete with very heterogeneous data regarding the quantity of opioid consumption, refills, and duration following ACLR [22, 23, 32]. Most surgeons do not know how many pills each patient takes [22]. In a recent review, Lovecchio et al. found that use of 105 to 210 OME (21 to 42 hydrocodone 5 mg tablets) for the first week after ACLR in opioid-naive adult patients is supported, but further guidelines for total duration were not made [22]. While no published MCID for opioid use has been identified, our study's average of 5.5 tablets is more than a fourfold reduction of the average in that comprehensive review of data (27.5 compared to 157.5 OME). Remarkably, over 20% of our study patients took no opioid medication at all during the entire post-operative course. In total, the vast majority of patients (84%) were able to complete their entire post-operative care and rehabilitation while utilizing ten tablets or less of a low-dose opioid. We had no requests for opioid prescription renewals in this prospective study group. The low usage and duration were accompanied by high patient satisfaction scores.

To date, adolescent opioid use following ACLR is not documented [7]. In our study, adolescents took less opioid medication on average than adults (4.4 to 6.3 tablets, respectively). While non-significant, this was unexpected as all of our adolescent patients received autograft tissue compared with 44% of adults. When comparing adolescent and adult autograft PTB, the difference in average use was greater at 4.3 tablets (4.4 to 8.7, respectively). This was not statistically significant ($p = 0.209$), and the difference may also have limited clinical importance. There has been a pressing need for quantitative recommendations in adolescents to understand a minimum appropriate quantity of opioids for safe pain relief, and this new information may be useful for establishing guidelines for this age group in ACLR.

One weakness in our study is the lack of a control group of ACLRs by the senior author without the genicular nerve block. We did have a retrospective sample of our patients 6 months prior to the development of the new genicular nerve block technique. This group consisted of 40 ACLRs performed by the senior author. Patients underwent reconstruction with the same graft selection criteria, opioid and ibuprofen dosage, facilities, anesthesia groups, and post-operative rehabilitation protocol. In place of the genicular nerve block, this group received local infiltration of 0.25% marcaine 30 cc around the surgical incisions. Of this group, 28% of patients required opioid refills. Unfortunately, we do not have precise opioid pill counts or duration of use in this group, making statistical comparison difficult. However, we can extrapolate that at least 28% of patients used 30 or more tablets of hydrocodone 5 mg, which is markedly different than in our prospective group. Admittedly, there may have been bias introduced between the two groups. The increased awareness of the opioid epidemic over time may have led us to perform more in-depth discussion with patients regarding opioid usage.

Our patient opioid demand is lower than prior dosages seen in the literature for such a potentially painful procedure. While opioid use is expected following a painful procedure such as ACLR, our protocol focuses on minimum necessary

usage, rapid cessation, and final disposal of unused medication. This study is the first to fully quantitate opioid usage after outpatient arthroscopic ACLR following a surgeon administered intra-operative genicular nerve block, done without imaging guidance. Importantly, it was also without using additional PCA or anesthetic blocks. Home care after discharge was simple with no infusion devices to manage. The other attributes of this study's protocol include no long-term or extended opioid usage and no readmissions or significant rebound pain crisis after discharge in both adolescents and adults.

In conclusion, opioid usage was unexpectedly low among patients undergoing ACLR after a surgeon administered genicular nerve block and fat pad infiltration. In this protocol, the graft choice and patient age may not be correlated with increased opioid usage. The results of this study could be useful in guiding post-operative opioid prescribing after ACLR.

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Compliance with Ethical Standards

Conflict of Interest: George L. Caldwell, Jr., MD, and Michael A. Selepec, PA-C, declare that they have no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

Informed Consent: Informed consent was waived from all patients for being included in this study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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