

Pain Assessment After Anterior Cruciate Ligament Reconstruction

Bone–Patellar Tendon–Bone Versus Hamstring Tendon Autograft

Kelechi R. Okoroha,^{*†} MD, Robert A. Keller,[†] MD, Edward K. Jung,[†] MD, Lafi Khalil,[‡] BS, Nathan Marshall,[†] MD, Patricia A. Kolowich,[†] MD, and Vasilios Moutzouros,[†] MD

Investigation performed at Henry Ford Hospital, Detroit, Michigan, USA

Background: Anterior cruciate ligament (ACL) reconstruction is a common outpatient procedure that is accompanied by significant postoperative pain.

Purpose: To determine differences in acute pain levels between patients undergoing ACL reconstruction with bone–patellar tendon–bone (BTB) versus hamstring tendon (HS) autograft.

Study Design: Cohort study; Level of evidence, 2.

Methods: A total of 70 patients who underwent primary ACL reconstruction using either BTB or HS autografts consented to participate. The primary outcome of the study was postoperative pain levels (visual analog scale), which were collected immediately after surgery and for 3 days postoperatively. Secondary outcome measures included opioid consumption (intravenous morphine equivalents), hours slept, patient satisfaction, reported breakthrough pain, and calls to the physician.

Results: Patients treated with BTB had increased pain when compared with those treated with HS in the acute postoperative period (mean \pm SD: day 0, 6.0 ± 1.7 vs 5.2 ± 2.0 [$P = .066$]; day 1, 5.9 ± 1.7 vs 4.9 ± 1.7 [$P = .024$]; day 2, 5.2 ± 1.9 vs 4.1 ± 2.0 [$P = .032$]; day 3, 4.8 ± 2.1 vs 3.9 ± 2.3 [$P = .151$]). There were also significant increases in reported breakthrough pain (day 0, 76% vs 43% [$P = .009$]; day 1, 64% vs 35% [$P = .003$]) and calls to the physician due to pain (day 1, 19% vs 0% [$P = .041$]) in the BTB group. There were no significant differences in narcotic requirements or sleep disturbances. Overall, the BTB group reported significantly less satisfaction with pain management on days 0 and 1 ($P = .024$ and $.027$, respectively).

Conclusion: A significant increase in acute postoperative pain was found when performing ACL reconstruction with BTB compared with HS. Patients treated with BTB were more likely to have breakthrough pain, decreased satisfaction with their pain management, and to contact their physician due to pain. These findings suggest a difference in early postoperative pain between the 2 most common graft options for ACL reconstruction. Patients should be informed of the differences in acute postoperative pain when deciding on graft choice with their physician.

Keywords: anterior cruciate ligament; pain control; knee arthroscopy; anterior cruciate ligament reconstruction; bone–patellar tendon–bone; hamstring tendon; autograft

*Address correspondence to Kelechi R. Okoroha, MD, Department of Orthopaedic Surgery, Henry Ford Hospital, 2799 West Grand Boulevard (CFP-6), Detroit, MI 48202, USA (email: krokoroha@gmail.com).

[†]Department of Orthopaedic Surgery, Henry Ford Hospital, Detroit, Michigan, USA.

[‡]School of Medicine, Wayne State University, Detroit, Michigan, USA.

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Anterior cruciate ligament (ACL) tears remain a common orthopaedic injury, with an incidence of 68.6 per 100,000 person-years.¹⁹ Surgical reconstruction of the ACL occurs nearly 135,000 times annually in the United States.² Informed decision making for the procedure includes providing the patient with information about available options for treatment, which include graft choice for ligament reconstruction.

Graft choice is a highly debated topic, with multiple factors contributing to the decision process, such as patient age, occupation, athletic activity, and preference. Most commonly, either hamstring tendon (HS) or bone–patellar tendon–bone (BTB) autografts are used by surgeons to

reconstruct the ACL.²⁰ The current literature is mixed and does not reflect absolute superiority of either graft. Benefits suggested for BTB autograft include bone-to-bone healing, increased knee stability (KT-1000 arthrometer testing), negative pivot shift, and decreased risk for revision.^{1,3,6,10,16} Advantages of HS autograft include increased extension strength, less anterior knee pain, and decreased donor site morbidity.^{5,12,13} Furthermore, it has been suggested that those who cannot tolerate anterior knee pain due to lifestyle or work involving kneeling should have an HS autograft.¹⁸ The controversy surrounding which graft type to use makes the selection of a graft an individualized process that involves the patient and their specific circumstances.

The multiple patient factors that contribute to selecting a graft include preoperative examination, age, activity level, comorbidities, and patient/surgeon preferences.²¹ Patients should be briefed on the potential benefits and disadvantages of each option. In ACL surgery, discussion of postsurgical pain is usually focused on long-term outcomes. Previous literature has elucidated that BTB autograft has a substantially greater risk for chronic anterior knee pain and kneeling pain compared with HS.^{17,23} However, studies are lacking that evaluate acute postsurgical pain between BTB and HS autografts.

This study aimed to determine whether there are differences in acute pain levels between patients undergoing ACL reconstruction with BTB compared with HS autografts. Our hypothesis was that patients treated with BTB autograft would have increased pain levels compared with patients treated with HS autografts after ACL reconstruction.

METHODS

We performed a prospective analysis of patients undergoing ACL reconstruction surgery to determine differences in early postoperative pain when comparing BTB with HS autografts. From August 2014 to April 2015, a total of 70 patients treated surgically by the senior author (V.M.) for ACL tears were consented for participation. Inclusion criteria included skeletally mature patients older than 16 years and patients undergoing primary ACL reconstructions. Exclusion criteria were documented alcohol or drug abuse, revision ACL tear, and concurrent ligamentous injuries requiring repair. Concomitant procedures were recorded for each group.

Patients consented for inclusion in the study underwent arthroscopically assisted ACL reconstructions using BTB or HS autografts through anatomic tunnels. Patients chose their graft option after a detailed discussion on the risks and benefits of each graft with the surgeon. The tibial tunnel was drilled in the typical fashion using a tibia drill guide and the femoral tunnel was drilled using an anteromedial portal technique in both graft types. The senior author (V.M.) treated all patients to increase the consistency of each procedure. According to institutional protocol at the time of the surgery, half of the patients in each group received intraoperative local infiltration of liposomal

bupivacaine (266 mg/20 mL) for primary pain control. The remaining patients in each group received a preoperative femoral nerve block by a senior anesthesiologist 1 hour prior to surgical intervention. Blocks were performed under ultrasound guidance using 40 mL of 0.5% ropivacaine with a 22-gauge needle.

Data Collection

After surgery, patients were taken to the postoperative care unit where initial opioid consumption and visual analog scale (VAS) pain scores were recorded every hour by nursing staff, who were blinded to the graft type used. Patients were then discharged home the day of surgery and were weightbearing as tolerated in a hinged knee brace locked in extension for the first 10 days. Instructions were provided on icing and elevation to reduce swelling. Physical therapy was begun at 10 days postoperatively with a goal of 0° to 90° range of motion. Patients were provided with a prescription for 60 tablets of 5 mg hydrocodone–325 mg acetaminophen and instructed to take 1 to 2 tablets every 4 hours as needed for pain. Patients were instructed to not take nonsteroidal anti-inflammatory drugs (NSAIDs) during the study period. They were given a pain diary binder to fill out for the day of surgery and 3 days postoperatively, starting with the day of surgery. The pain diary allowed patients to maintain a record of their pain and opioid consumption every 4 hours. The diary also asked patients to document any side effects from the medication and to note whether they were awoken from sleep due to pain overnight, and if so, how many times. Breakthrough pain was recorded if the patient had pain uncontrolled by the prescribed pain medications. Finally, patients were asked whether they had to contact their doctor's office due to pain and whether they were satisfied with their pain management. Pain diaries were collected at the 2-week postoperative visit, and a blinded observer recorded outcome measures. Before statistical analysis, opioid consumption between the 2 groups was converted to intravenous morphine equivalents.

Statistical Analysis

The primary endpoint of this project was to determine whether there was a difference in the average postoperative pain (visual analog scale [VAS] scale) between those undergoing BTB and HS graft ACL reconstruction. A previous study reported that the minimal clinically important difference in VAS pain scale is 1.3 points, based on data demonstrating that a difference of 1.3 points on a VAS scale represents on average the minimum change in acute pain that is clinically significant.⁷ A power analysis was performed prior to the study to assess the null hypothesis that a significant difference in mean daily pain of 1.3 points on VAS will not be found between the BTB and HS groups. With a power of 80% (beta level, 0.80; alpha level, 0.05), a sample size of 25 patients per group was needed and sought. A sample size of 70 (35 patients per group) was selected to allow for

TABLE 1
Demographic Data^a

	Graft Type			Pain Control Method		
	BTB	HS	<i>P</i> Value	FNB	LB	<i>P</i> Value
No. of patients	47	23	.130	24 BTB, 12 HS	23 BTB, 11 HS	.930
Age, y, mean (range)	19.7 (16-31)	33.4 (17-53)	.001 ^b	27.0 (16-53)	27.6 (16-53)	.736
Sex, n			.191			.936
Female	22	7		15	14	
Male	25	16		21	20	
BMI, kg/m ² , mean ± SD	25.2 ± 4.9	26.9 ± 4.3	.105	26.0 ± 6.0	26.5 ± 4.6	.582
Concomitant procedure, n						
Meniscectomy	8	5				
Meniscal repair	5	2				
Chondroplasty	0	0				
Combination	3	3				
Total	16	10	.245			

^aBMI, body mass index; BTB, bone–patellar tendon–bone; FNB, femoral nerve block; HS, hamstring tendon; LB, liposomal bupivacaine.

^bStatistically significant difference between groups ($P < .05$).

incomplete data collection. Secondary outcomes assessed include mean intravenous morphine equivalents used, hours of sleep per night, satisfaction with pain management, and calls to the physician due to pain. All data were collected and analyzed using SAS 9.4 (SAS Institute). All continuous data were analyzed using independent 2-group *t* tests and are reported as means ± standard deviations. Categorical data were compared between the 2 groups using chi-square tests and are reported as counts and percentages. A preliminary test to confirm the quality of variances was conducted prior to utilizing the *t* test to confirm the appropriate statistical analysis. Nonparametric equivalents Wilcoxon rank-sum and Fisher exact tests were used as needed for nonnormal distributions and low variable numbers, respectively. A subset analysis was performed in a similar manner based on patients treated with liposomal bupivacaine compared with a femoral nerve block. Concomitant procedures between the 2 groups were compared using the Fisher exact test. A multivariable regression analysis was performed to assess for potential confounding demographic variables. In all analyses, $P < .05$ was considered statistically significant.

RESULTS

Group Demographics

Of the 70 patients surgically treated for ACL rupture, no patients declined participation and all patients were included for further analysis. Forty-seven patients had ACL reconstruction performed with BTB autograft, while 23 had HS autograft. All patients were followed up at 2 weeks. Demographic differences between the 2 groups are presented in Table 1. The mean age of patients undergoing ACL reconstruction was 33.4 years (range, 17-53 years) in the HS group and 19.7 years (range, 16-31 years) in the

TABLE 2
Mean Pain Score^a

POD	VAS Score		<i>P</i> Value
	BTB (n = 47)	HS (n = 23)	
0	6.0 ± 1.7	5.2 ± 2.0	.066
1	5.9 ± 1.7	4.9 ± 1.7	.024 ^b
2	5.2 ± 1.9	4.1 ± 2.0	.032 ^b
3	4.8 ± 2.1	3.9 ± 2.3	0.151

^aData are presented as mean ± SD. BTB, bone–patellar tendon–bone; HS, hamstring tendon; POD, postoperative day; VAS, visual analog scale.

^bStatistically significant difference between groups ($P < .05$).

BTB group ($P = .001$). There were no other significant differences in cohort demographics. BTB autograft was the most common graft utilized ($P = .130$). However, there were no differences in the primary pain control method used between groups, with 36 patients receiving a femoral nerve block (51% BTB vs 52% HS) and 34 receiving local infiltration of liposomal bupivacaine (49% BTB vs 48% HS; $P = .930$) (Table 1). A multivariable regression analysis did not find any demographic variables to be significant confounders.

BTB Versus HS Autografts

There was an increase in pain in the BTB group compared with the HS group in the acute postoperative period, with statistically significant differences on postoperative day (POD) 1 and 2 (Table 2). However, these differences did not reach the minimal clinically important difference. Although there was a significant increase in pain, we found no significant differences in mean daily morphine equivalents used between the groups on POD 0 to 3 (Table 3).

TABLE 3
Mean Opioid Usage^a

Opioid Usage, Daily IV Morphine Equivalent			
POD	BTB (n = 47)	HS (n = 23)	P Value
0	14.4 ± 7.7	13.5 ± 8.8	.654
1	16.3 ± 10.2	15.6 ± 9.1	.767
2	14.1 ± 11.0	12.3 ± 8.8	.490
3	8.2 ± 7.1	7.9 ± 7.2	.878

^aData are presented as mean ± SD. BTB, bone–patellar tendon–bone; HS, hamstring tendon; IV, intravenous; POD, postoperative day.

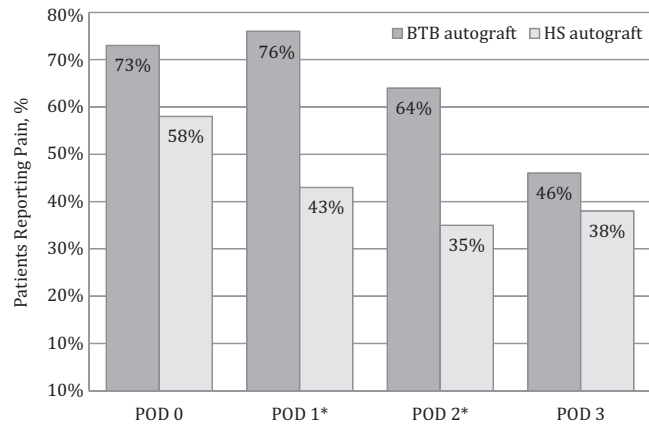


Figure 1. Percentage of patients reporting breakthrough pain. *Statistically significant difference between groups ($P < .05$). BTB, bone–patellar tendon–bone; HS, hamstring tendon; POD, postoperative day.

More patients reported having breakthrough pain in the BTB group compared with the HS group on POD 1 (76% vs 43%; $P = .009$) and POD 2 (64% vs 35%; $P = .033$) (Figure 1). Subset analysis comparing those who received liposomal bupivacaine (LB) compared with a femoral nerve block (FNB) demonstrated no differences between groups on POD 0 ($P = .097$), POD 1 ($P = .968$), POD 2 ($P = .516$), or POD 3 ($P = .469$).

Evaluation of sleep patterns showed no significant differences in sleep disturbances between the groups at each POD (POD 0–3; $P = .736, .488, .323, \text{ and } .316$, respectively) (Figure 2). Patients in the BTB group were significantly more likely to call their doctor on POD 1 due to pain (19% vs 0%; $P = .041$). This value did not reach significance on POD 2 or 3 ($P = .549$ and $.315$, respectively) (Figure 3). Patients who called in due to pain were contacted to assure no postoperative complications had occurred; however, no changes were made to the standardized pain regimen. Satisfaction with pain management was lower in the BTB group compared with the HS group on the day of surgery and the 2 days after surgery (POD 0: 49% vs 72% satisfied [$P = .095$]; POD 1: 50% vs 80% satisfied [$P = .024$]; POD 2: 69% vs 95% satisfied [$P = .027$]; POD 3: 86% vs 94% [$P = .358$]) (Figure 4).

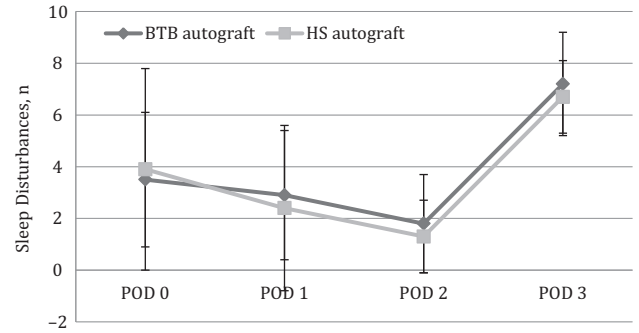


Figure 2. Number of sleep disturbances. BTB, bone–patellar tendon–bone; HS, hamstring tendon; POD, postoperative day.

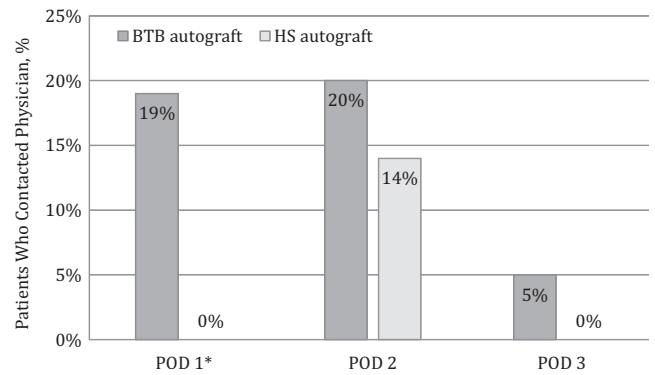


Figure 3. Percentage of patients who contacted their physician due to pain. *Statistically significant difference between groups ($P < .05$). BTB, bone–patellar tendon–bone; HS, hamstring tendon; POD, postoperative day.

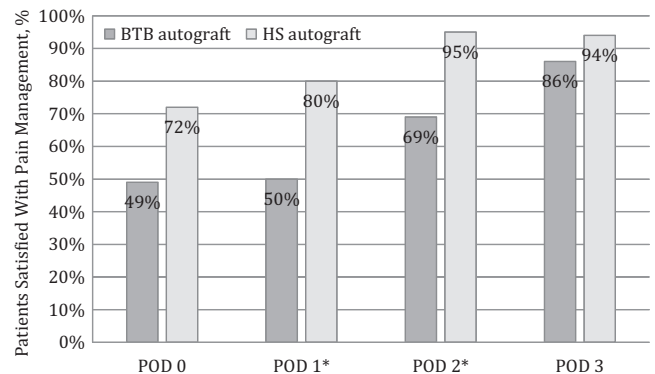


Figure 4. Percentage of patients who were satisfied with their pain management. *Statistically significant difference between groups ($P < .05$). BTB, bone–patellar tendon–bone; HS, hamstring tendon; POD, postoperative day.

DISCUSSION

Postoperative pain after ACL reconstruction is an individualized patient experience that contributes significantly to patient-perceived outcome. Postdischarge pain after any outpatient surgery is known to delay return to normal daily activities and thus rehabilitation.²² Differences in postoperative pain between various surgical options should be discussed with patients before a treatment plan is made. Our results suggest that patients treated with BTB autografts experience a significant increase in pain scores in the acute postoperative period when compared with those treated with HS autografts. In addition, patients treated with BTB autografts reported an increased incidence of breakthrough pain, were more likely to call their physician due to pain, and had less satisfaction with pain management.

Although the literature is sparse in comparing acute postoperative pain between BTB and HS autografts, differences between these grafts have been studied extensively with regard to long-term pain outcomes. Specifically, long-term outcomes have generally found increased anterior knee pain and patellofemoral symptoms associated with BTB autografts. Xie et al²³ conducted a meta-analysis of 22 studies with a total of 1930 patients undergoing ACL reconstruction. Their study found patients treated with BTB autograft had more significant long-term anterior knee and kneeling pain when compared with those treated with HS autografts.²³ Additionally, Li et al⁹ evaluated outcomes after ACL reconstruction across 9 randomized controlled trials totaling 738 patients. Their study also concluded BTB autografts produced significant anterior knee pain and kneeling pain.⁹ This current study provides additional knowledge in the form of acute rather than long-term pain differences. Our results suggest that those treated with BTB autograft have increased pain acutely when compared with HS autograft. This result is most likely multifactorial but may be attributed to more extensive dissection in the anterior knee and bone cuts made during BTB grafting while HS grafting entails only soft tissue resection of the graft.

Other studies have investigated pain in the acute postoperative period after ACL reconstruction. Macdonald et al¹¹ compared VAS pain scores and medication consumption in patients undergoing ACL reconstruction with either a single- or double-bundle technique and found that there was no difference in VAS scores but a statistically significant increase in opioid and analgesic medications consumed in the double-bundle group. Similarly, Joseph et al⁴ demonstrated significantly fewer days of opiate medication usage with employment of quadriceps tendon graft compared with BTB or HS over the entire rehabilitation period. Although these studies did not compare acute postoperative pain between BTB and HS autografts, they illustrate a difference in pain levels between various autograft techniques and donor sites in the acute postoperative period. They differ from our study in that they found significant differences in pain medication consumption whereas our results showed no differences in pain medication consumption despite significantly increased VAS pain scores in the BTB group.

Previous studies have attempted to evaluate sleep disturbance after ACL reconstruction. Lefevre et al⁸ evaluated 133 patients undergoing ACL reconstruction utilizing HS autograft and analyzed rates of sleep disturbance after the procedure. They found that 50% of their patients experienced at least 1 awakening during the first postoperative night. Although the current study did not find differences in sleep disturbance between graft types, we did find high rates of sleep disturbance after ACL surgery, regardless of the graft type used. Both groups had an increased number of sleep disturbances on POD 3, this is possibly due to the resolution of LB effects on pain control in each group.

Orthopaedic literature has evaluated factors that lead to patient satisfaction and unplanned physician contact. Mattila et al¹⁴ evaluated unplanned healthcare professional contact rates after ambulatory orthopaedic surgery and reported that 6% of patients made unplanned emergency calls or appointments in the acute postoperative period. In our cohort, we found that the BTB group was more likely to contact their physician due to pain on POD 1, and similar to the study by Mattila et al,¹⁴ most physician contacts, regardless of graft type, were made during POD 2. The potential for pain levels postoperatively to affect patient satisfaction, and thus affect surgical outcomes, have been demonstrated by various studies. O'Toole et al¹⁵ demonstrated that patient satisfaction after lower extremity injury is more dependent on pain levels rather than on the actual characteristics of the patient or injury. Kocher et al⁷ reported similar findings in that patient satisfaction after ACL reconstruction was associated strongly with subjective symptoms. Our study confirmed the previous results in that the patients in the BTB group who experienced more pain acutely were less satisfied with their pain management. Although patients in the BTB group were less satisfied acutely, there were a significant percentage of patients in both groups who were not satisfied with their pain management in the early postoperative period. This demonstrates the potential for additional modalities to be used to supplement pain relief.

This study does have potential limitations. One limitation is the use of the VAS, which is a simple 1-dimensional analog rating scale to assess the patient's subjective pain level. A well-recognized limitation of such a simple 1-dimensional scale is that patients tend to report high scores and their ability to detect subtle changes is limited. Given this, we utilized morphine equivalent requirements as an objective measure to complement subjective pain profiles. Although we found a statistical difference in VAS scores between the 2 groups acutely, this difference did not reach the minimal clinically important difference. The non-randomized nature of the study induces potential bias due to patients being allowed to choose their graft type. Therefore, we did expect some selection bias, which can be seen as 39% of males were treated with HS while 24% of females were treated with HS. This could not be controlled due to the observational cohort nature of the study; however, the percentage of males and females in each group was not found to be statistically significant. Additionally, patient compliance is a limitation. The majority of patients did not complete the section on side effects from medications. This

could be due to patients not having side effects or patients not filling out this portion; we therefore excluded analysis on side effects due to low counts. However, while patients were in the hospital, the nursing staff kept strict logs and patients were educated and encouraged to maintain their diaries. There was an age difference between the cohorts, with a greater number of younger patients in the BTB group. This is likely due to the higher activity level in the younger group, who tended to choose BTB due to a slight decreased rate of rerupture reported in some studies.^{3,16} Younger patients may have greater pain ratings, which may have led to a bias in our results. However, a multivariable regression analysis did not identify age as a factor altering pain levels. Finally, alternate methods of anesthesia were used in the study. However, statistical analysis found no significant differences between the cohort groups, with each group having an equal number of patients treated with femoral nerve block and liposomal bupivacaine. Despite these limitations, this study's strengths include the prospective analysis of a cohort of patients from a single surgeon.

CONCLUSION

This study evaluated the differences in acute postoperative pain control in patients undergoing ACL reconstruction with BTB versus HS autograft. A significant increase in acute postoperative pain was found when performing ACL reconstruction with BTB autograft compared with HS. Patients treated with BTB autograft were also more likely to have breakthrough pain, have decreased satisfaction with their pain management, and contact their physician due to pain. These findings suggest a difference in early postoperative pain between the 2 most common graft options for ACL reconstruction. Patients should be informed of the differences in acute postoperative pain in addition to other factors when deciding on graft choice with their physician. Surgeons should continue to look for additional ways to reduce early postoperative pain in patients undergoing ACL reconstruction.

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