Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology 32 (2023) 12–17

Contents lists available at ScienceDirect

Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology

journal homepage: www.ap-smart.com

Original Article

Analyses of associated factors with concomitant meniscal injury and irreparable meniscal tear at primary anterior cruciate ligament reconstruction in young patients

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ARTICLE INFO

Article history:
Received 11 February 2022
Received in revised form
19 March 2023
Accepted 6 April 2023

Keywords:
Anterior cruciate ligament
Irreparable meniscal tear
Meniscus
Timeline
Young patients

ABSTRACT

Purpose:: Although several factors related to the concomitant meniscal injury at anterior cruciate ligament reconstruction (ACL-R) have been investigated in a general population, few studies have identified the risk factors of meniscal tear severity in young patients in which the majority of ACL tears occur. The purpose of this study was to analyze the associated factors with meniscal injury and irreparable meniscal tear and the timeline for medial meniscal injury at ACL-R in young patients.
Methods:: A retrospective analysis of young patients (13 to 29 years of age) who underwent ACL-R by a single surgeon from 2005 to 2017 was conducted. Predictor variables (age, sex,body mass index [BMI], time from injury to surgery [TS], and pre-injury Tegner activity level) for meniscal injury and irreparable meniscal tear were analyzed with multivariate logistic
Results:: Four hundred and seventy-three consecutive patients with an average of 31.2 months post-operative follow-up were enrolled in this study. The risk factors for medial meniscus injury were TS (<= 3 months) (odds ratio [OR], 3.915; 95% CI, 2.630-5.827; P < .0001) and higher BMI (OR, 1.062; 95% CI, 1.002-1.125; P = 0.0439). The presence of irreparable medial meniscal tears correlated with higher BMI (OR, 1.104; 95% CI, 1.011-1.205; P = 0.0281)
Conclusion: An increased time from ACL tear to surgery of 3 months was strongly associated with an increased risk of medial meniscus injury, but not related to irreparable medial meniscal tear at primary ACL reconstruction in young patients.
Level of Evidence: Level IV.

1. Introduction

Anterior cruciate ligament (ACL) tear is one of the most common knee injuries and commonly associated with meniscal injury.[1] Chronic ACL deficiency increased the incidence of meniscus pathology[2] and required partial meniscectomy in the setting of irreparable meniscal tear due to meniscal tear severity, location, and pattern at ACL reconstruction.[3] As a consequence, the increased articular contact stresses associated with meniscal injury could develop osteoarthritis, especially in young active patients.[4] Additionally, although strategies to preserve the meniscus will decrease articular cartilage degeneration in the longer term, meniscal repair at the time of initial ACL reconstruction has been a strong predictor of future subsequent surgery such as meniscectomy.[5]

With respect to the age-distribution of ACL injury, the majority of ACL tears occur between 15 and 25 years of age.[6] A recent study advocated that there were age-specific peaks of ACL injury in males aged 19–25 years and in females aged 14–18 years.[7] These college-age males and high school females are highly motivated to return to higher-risk athletic participation after surgery, whereas older recreational athletes may be satisfied with playing sports at a lower level than before surgery.[8,9] Thus, the importance of the menisci in maintaining stability after ACL reconstruction and preventing

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https://doi.org/10.1016/j.asmart.2023.04.001

degenerative changes of the knee has been documented in young patients more extensively than in older patients.[10] However, most of the previous studies have examined the association of meniscal injury with ACL injury in a general population.[11–13] Therefore, the results of them could be potentially affected by age-related existing meniscal degenerative changes in older patients.[14] Moreover, few previous studies have identified the risk factors of meniscal tear severity (irreparable meniscal tear) and the timeline for meniscal tear at ACL reconstruction in young patients[3] while a recent general population study showed that increased time from ACL injury to ACL surgery (TS) reduced the likelihood of medial meniscus repair.[15]

The purpose of the current study is to analyze the associated factors with meniscal injury and irreparable meniscal tear and the timeline for medial meniscal injury at primary ACL reconstruction in young patients (13–29 years of age).

The hypotheses are (1) that high pre-injury activity level and longer TS would be the risk factors for meniscal injury at primary ACL reconstruction in young patients while longer TS might not be associated with irreparable meniscal tear, and (2) that the timeline for medial meniscal injury might be three months from ACL injury.

2. Materials and methods

2.1. Patient selection

After institutional review board approval was received, a retrospective chart and surgical record review was performed for the patients who underwent primary ACL reconstruction by a single surgeon at our institution between 2005 and 2017. Inclusion criteria were the young skeletally mature patients (without open physis) who were between 13 and 29 years old at primary ACL reconstruction. Exclusion criteria were (1) multiple ligament injury, (2) revision ACL reconstruction, (3) previous knee injury or surgery in the ipsilateral and/or contralateral knees, and (4) less than 12 months follow-up in person. Informed consent was obtained from all subjects.

2.2. Data collection

Demographic variables of interest included age at ACL reconstruction, sex, body mass index (BMI), TS, pre-injury Tegner activity level, and post-operative follow-up (in person).

Surgical details were obtained from the surgical records, including ACL graft and meniscal pathology.

Meniscal injuries were classified into simple, bucket-handle, and complex tears (multiple plane combinations with 2 or more tear components) according to a previous study.[16] The severity of meniscal tears was graded as nonsurgical tear, tear requiring debridement only, reparable tear, and irreparable tear according to methods described by Newman et al.[17] Irreparable meniscal tears were defined as those unable to retain the entire normal (medial/lateral) meniscal shape at ACL reconstruction.

Post-operative the side-to-side difference of anteroposterior laxity measured by the KT-1000 arthrometer (MEDmetric Corp., San Diego, CA, USA) with manual maximum pull.

(KT measurement), returning to preinjury levels of sports (RTS), subsequent ACL injury, and the incidence of subsequent meniscal surgery after ACL reconstruction were assessed. Comparing the pre-injury and post-operative Tegner activity scores, RTS was defined as a return to the pre-injury-defined sport and performing at or above the pre-injury level at some time during follow-up or final follow-up. Meniscal repair failure after ACL reconstruction was defined as the need for the subsequent meniscal surgery at the same location of the reparable tear, and the meniscal repair failure rate after ACL reconstruction was calculated to verify whether our treatment decisions and surgical treatments for meniscal tears were appropriate.

2.3. Surgical procedure

ACL reconstruction was performed using bone patellar-tendon bone (BPTB)[18] or hamstring autograft by a single surgeon. When hamstring autograft was used, double bundle ACL reconstruction was performed.[19]

Management of meniscal injury was dictated by the location and morphology of the tear.[20] Indication for meniscal repair was unstable tear (>15 mm in length) in the vascular zone. Meniscal repair was basically performed with inside-out technique. For relatively small longitudinal tear (10–15 mm in length), all-inside device (FasT-Fix, Smith and Nephew) was used. Stable longitudinal tear (<10 mm in length) was left in situ.

2.4. Post-operative clinical evaluation

The postoperative clinical evaluation was carried out at 6-month intervals until 24 months postoperatively or at the last follow-up (in patients with >24 months of follow-up).

2.5. Statistical analysis

2.5.1. Univariate analyses

Predictor variables included age, male sex, BMI, TS (≥3 months), and pre-injury Tegner activity level (≥7). In univariate analyses, the chi-squared test was used for categorical variables and the Wilcoxon rank sum test was used for continuous variables. The Chi-square test was used to compare categorical variables. Each *P*-value for comparing 'type of meniscal tears' and 'severity of meniscal tears' between medial and lateral meniscus was calculated using the McNemar test.

2.5.2. Multivariate logistic regression analyses

Predictors of meniscal injury and irreparable meniscal tear were identified with multivariate logistic regression for binary outcomes. The demographic data and potential confounding factors, which were chosen on the basis of a previous study,[21] were included in the multivariate analysis as follows: age, sex, BMI, TS, and pre-injury Tegner activity level. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each predictor variable.

2.5.3. ROC curve analysis

For the evaluation of the optimal value of TS for medial meniscal injury, receiver

Operating characteristic (ROC) curve analysis was performed.

For all statistical tests, a significance threshold of $P < 0.05$ was used. All P values were 2-sided. All analyses were performed using SAS Version 9.4 (SAS Institute).

3. Results

3.1. Patients' characteristic

There were 712 young patients (13–29 years of age) who underwent ACL-R by a single surgeon from 2005 to 2017. Thirty-six patients who underwent revision ACL-R, 46 patients with multiple ligament injuries, 65 patients with a previous knee injury or surgery in the affected and contralateral knees, and 92 patients with less than 12 months of follow-up were excluded. Finally, the remaining 473 patients were enrolled in the retrospective current study (Fig. 1). Of these 473 patients, there were 440 athlete patients

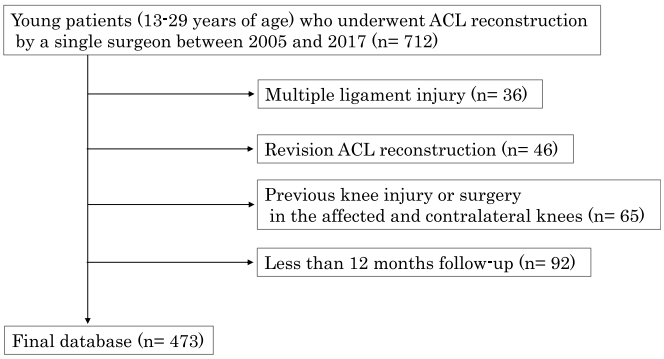

Fig. 1. Summary of subject enrollment.

Table 1
Patient demographics.

Age at ACL surgery (y.o.)	19.3 (13–29)
Sex	
male	250 (52.9)
female	223 (47.1)
Body mass index (kg/m2)	22.7 (15.8–41.7)
Pre-injury Tegner activity level	7.6 (3–9)
Time from injury to surgery (mo)	4.8 (1–24)
Post-operative follow-up (mo)	31.2 (12–151)
ACL graft	
BPTB autograft	180 (38.1)
Hamstring autograft	293 (61.9)

Values are provided as average (range) or n (%).
BPTB, bone patellar-tendon bone.

Table 2
Meniscal injury characteristics.

Meniscal injury characteristics	MM	LM	P value
Meniscal injury classification[16]			
Intact	294	294	
Total of meniscal tears	179	179	
Simple tear	120	86	0.004
Bucket handle tear	29	12	0.005
Complex tear	30	81	<0.001
Severity of meniscal tears[17]			
nonsurgical tear	14	23	0.117
tear debridement only	0	13	.
reparable tear	112	56	<0.001
irreparable tear	53	87	0.001

Data are reported as n.
MM, medial meniscus; LM, lateral meniscus.

who sustained ACL injuries while playing sports. The overall average age at ACL reconstruction was 19.3 years old (Table 1). There were 204 patients in age of 13–17, 141 patients in age of 18–21, and 128 patients in age of 22–29, respectively. The average TS and post-operative follow-up were 4.8 months and 31.2 months, respectively. BPTB and hamstring autograft were used for ACL graft in 180 patients and in 293 patients, respectively.

There were 179 meniscal injuries in both medial and lateral meniscus at ACL reconstruction (Table 2). In terms of the type of meniscal tears, simple tear (P = 0.004) and bucket handle tear (P = 0.005) were significantly more common in medial meniscus than in lateral meniscus whereas complex tear (P < 0.001) was significantly more common in lateral meniscus. Regarding the severity of meniscal tears, 53 medial and 87 lateral meniscal tears were irreparable (P = 0.001).

Table 3
Post-operative KT measurement and RTS.

KT measurement (mm)[a]	1.1 (−2 to 6)		P value
RTS	irreparable meniscal tear		
	no	yes	
yes	245	75	0.015
no	78	42	

Data are reported as n.
KT measurement: the side-to-side difference of anteroposterior laxity measured by the KT-1000 arthrometer.
RTS: returning to preinjury levels of sports.
[a] Values are provided as average (range).

3.2. KT measurement, RTS, and subsequent ACL injury and meniscal surgery

The average KT measurement was 1.1 mm (Table 3). Regarding RTS in 440 athlete patients, 320 patients (72.7%) were able to RTS. Patients who were able to RTS had fewer irreparable meniscal tears than those who were not able to RTS (23.4% vs 35.0%, P = 0.015). In terms of subsequent ACL injury after primary ACL surgery, there were 33 patients with ACL graft rupture and 38 patients with a contralateral ACL injury, respectively (Table 4). Regarding subsequent meniscal surgery, 12 patients had medial meniscectomy at an average of 25.8 months after ACL reconstruction whereas one patient had lateral meniscectomy at 27 months post-operatively. Of 13 patients who underwent subsequent meniscal surgery, two patients had ACL graft rupture and eight patients had medial meniscal repair using inside-out technique at primary ACL reconstruction. Thus, the meniscal repair failure rate after ACL reconstruction was 4.8% (8/168 patients).

3.3. ROC curve analysis

The cutoff value of TS for medial meniscal injury was determined as 3 months (Fig. 2). The area under the curve with 95% confidence interval (CI) was 0.698 (0.649–0.747).

3.4. Univariate analyses

The results of univariate analyses for association with the presence of meniscal injuries and irreparable meniscal tears were shown in Table 5. Patients with medial meniscal injury showed a high frequency of TS ≥ 3 months than those without MM injury (61.5% vs. 29.9%, P < 0.001). While patients with irreparable medial meniscal tear had higher BMI than those without irreparable medial meniscal tear (23.5 vs. 21.7, P = 0.042), these average BMI values were within normal weight. Univariate analysis in lateral meniscal injury and irreparable lateral meniscal tear showed no significant differences in terms of age, sex, BMI, TS, and Pre-injury Tegner activity level.

3.5. Multivariate logistic regression analyses

TS (≥3 months) (OR, 3.915; 95% CI, 2.630–5.827; P < 0.0001) and high BMI (OR, 1.062; 95% CI, 1.002–1.125; P = 0.0439) were the risk factors for medial meniscus injury while there were no associated factors for lateral meniscal injury (Table 6).

In terms of meniscal tear severity, high BMI (OR, 1.104; 95% CI, 1.011–1.205; P = 0.0281) was also the risk factor for irreparable medial meniscal tear (Table 7).

Table 4
Subsequent ACL injury and meniscal surgery (meniscectomy) after ACL reconstruction.

Subsequent ACL injury		Time after primary ACL surgery (mo)[a]
ACL graft rupture	33	25.1 (4–115)
ACL graft used at primary surgery		
BPTB autograft	4	
Hamstring autograft	29	
Contralateral ACL injury	38	28.1 (6–123)
ACL graft used at primary surgery		
BPTB autograft	16	
Hamstring autograft	22	
Subsequent meniscal surgery (meniscectomy)		
Total	13	
MM	12[b]	25.8 (11–77)
after meniscal repair	8	
LM	1[b]	27
after meniscal repair	0	

Data are reported as n.
BPTB, bone patellar-tendon bone; MM, medial meniscus; LM, lateral meniscus.
[a] Values are provided as average (range).
[b] There was one patient who underwent subsequent meniscal surgery after ACL graft rupture.

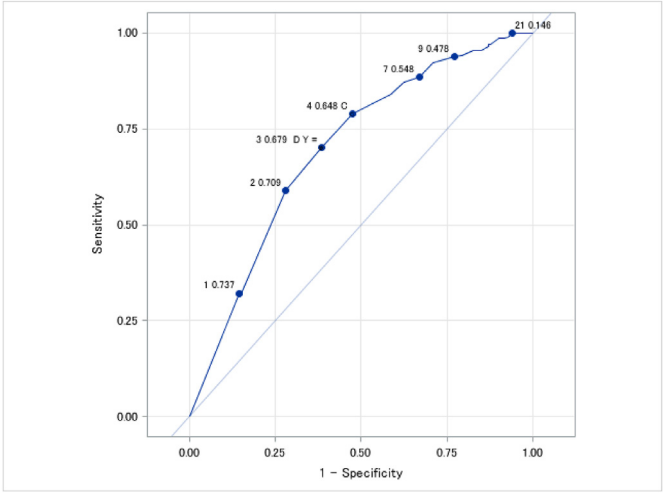

Fig. 2. ROC curve analysis for the evaluation of the optimal value of the time to surgery for medial meniscal injury.

4. Discussion

The most important finding was that TS (≥3 months) was strongly associated with medial meniscus injury while TS (≥3 months) was not the risk factor of irreparable medial meniscal tear in young ACL-injured patients. Additionally, higher BMI was the risk factor of medial meniscus injury and irreparable medial meniscal tear.

TS (≥3 months) was strongly related to medial meniscus injury in the current study. Similar to those seen in adults,[11–13] previous studies in the young population showed a significant association of increasing medial meniscal injury with increased time from injury[1,3] while the rate of lateral meniscal tears remained stable across the studied time intervals.[1] Recent studies among adolescent patients that undergo ACL reconstruction also illustrated similar findings where the incidence of new meniscal injuries was relatively high and the rate of medial meniscal injury increases with delay in surgery.[1] With respect to irreparable tear, TS (≥3 months) was not the risk factor of medial meniscal irreparable tear in this study. Abrams et al.[22] investigated the annual number of meniscus repairs and meniscectomies in the United States and found that a majority of meniscus repairs were performed in young patients (less than 25 years of age). They indicated that a majority of meniscus repairs that occurred in the younger age population was possibly related to the fact that younger patients typically have traumatic tears in the vascular zone whereas older age groups more commonly have degenerative tears. Likewise, medial meniscal tear with less degenerative change could be reparable in young patients (13–29 years of age) in the current study while TS (≥3 months) was strongly associated with medial meniscus injury.

Sex (male) was not the risk factor for meniscal injury and irreparable meniscal tear in this study. Similarly, in a previous young population study (<19 years of age),[1] sex was not found to be associated with an increased rate of meniscal or chondral injury. In adult literature, the male gender has been cited as an associated risk factor for meniscal and chondral injury findings at the time of ACL surgery.[11,20] It was suggested that a higher activity level or higher energy injury may be present in men. Our patients might experience transitions between several life stages: high school to college education, single to married life, full-time student to full-time or part-time work.[23] In these life stages, it has been considered that women are more likely to peak in sports participation during their younger years, whereas men tend to participate in sports across a longer age span.[4] Additionally, women participating in high school or college sports may be equally as active as men.[24] Therefore, the difference in sex could not affect the prevalence of meniscal injury and the meniscal severity in our study population.

Increased BMI was a risk factor of both medial meniscal injury and irreparable medial meniscal tear in this study. Due to the mechanical stress on the knee joint surfaces, morbid obesity (high BMI) causes early lesions of knee arthrosis, even in young patients.[25] With regard to irreparable meniscal tear, Patel et al.[8] advocated that children (≤20 years of age) with elevated BMI were more likely to have a meniscus tear at the time of surgery than those with normal BMI and had 1.6 times higher odds of requiring a partial meniscectomy for an irreparable tear. Whereas the average BMI value (23.5) in patients with irreparable medial meniscal tear was within a normal range in this study, surgeons should take into

Table 5
Univariate analyses for association with the presence of meniscal injuries and irreparable meniscal tears.

Variable	LM injury			Irreparable LM Tear		
	Yes (n = 179)	No (n = 294)	*P*-value[a]	Yes (n = 53)	No (n = 126)	*P*-value[a]
Age	18 (13–29)	18 (13–29)	0.660	20 (14–28)	18 (13–29)	0.024
Male sex	96 (53.6%)	154 (52.4%)	0.792	34 (64.2%)	62 (49.2%)	0.067
BMI	21.9 (15.8–40.3)	21.9 (16.6–41.7)	0.141	23.5 (18.6–40.3)	21.7 (15.8–35.2)	**0.042**
TS ≥ 3 months	110 (61.5%)	88 (29.9%)	**<0.001**	36 (67.9%)	74 (58.7%)	0.249
Pre-injury Tegner activity level ≥7	147 (82.1%)	233 (79.3%)	0.446	44 (83.0%)	103 (81.8%)	0.839

	LM injury			Irreparable LM Tear		
	Yes (n = 179)	No (n = 294)	*P*-value[a]	Yes (n = 87)	No (n = 92)	*P*-value[a]
Age	18 (13–29)	18 (13–29)	0.194	18 (13–29)	17 (14–28)	0.255
Male sex	97 (54.2%)	153 (52.0%)	0.650	37 (42.5%)	45 (48.9%)	0.392
BMI	22.2 (17.0–41.7)	21.6 (15.8–40.3)	0.269	22.4 (17.7–35.2)	22.0 (17.0–41.7)	0.329
TS ≥ 3 months	78 (43.6%)	120 (40.8%)	0.555	37 (42.5%)	41 (44.6%)	0.784
Pre-injury Tegner activity level ≥7	149 (83.2%)	231 (78.6%)	0.215	74 (85.1%)	75 (81.5%)	0.527

Data are presented as n (range or %).
MM, medial meniscus; LM, lateral meniscus; BMI, body mass index; TS, time to surgery.
[a] Determined using the chi-squared test or the Wilcoxon rank sum test.

Table 6
Multivariate logistic regression analyses for association with the presence of meniscal injuries.

Variable	Medial Meniscus, OR (95% CI)	P value	Lateral Meniscus, OR (95% CI)	P value
Age per 1-year increase	0.976 (0.924–1.030)	0.370	0.957 (0.909–1.008)	0.099
Male sex	1.067 (0.675–1.688)	0.781	0.874 (0.566–1.349)	0.543
BMI per 1-unit increase	1.062 (1.002–1.125)	**0.044**	1.024 (0.969–1.082)	0.401
TS ≥ 3 months	3.915 (2.630–5.827)	**<0.001**	1.150 (0.787–1.680)	0.471
Pre-injury Tegner activity level ≥7	1.353 (0.797–2.297)	0.263	1.232 (0.743–2.041)	0.419

OR, odds ratio; BMI, body mass index; TS, time to surgery.

Table 7
Multivariate logistic regression analyses for association with the presence of irreparable meniscal tears.

Variable	Medial Meniscus, OR (95% CI)	P value	Lateral Meniscus, OR (95% CI)	P value
Age per 1-year increase	1.066 (0.971–1.170)	0.181	1.044 (0.956–1.139)	0.339
Male sex	0.837 (0.390–1.798)	0.649	0.914 (0.459–1.821)	0.798
BMI per 1-unit increase	1.104 (1.011–1.205)	**0.028**	1.005 (0.919–1.099)	0.911
TS ≥ 3 months	1.595 (0.789–3.221)	0.193	0.910 (0.501–1.652)	0.756
Pre-injury Tegner activity level ≥7	1.416 (0.552–3.633)	0.470	1.402 (0.607–3.237)	0.429

OR, odds ratio; BMI, body mass index; TS, time to surgery.

account the possibility of an earlier ACL reconstruction in overweight patients.

The timeline for medial meniscal injury which was calculated by ROC curve analysis in this study was three months and similar to those (ranged from 3 to 6 months) in previous young population studies,[1,3,17] and seemed to be earlier than those (ranged from 6 to 12 months) in general population studies.[11–13] The difference of the timelines between the young and general population could be due to a higher level of physical activity while awaiting surgery or to a higher number of sprains in the young population.[11]

4.1. Limitations

There were several limitations in the current study. First, this study was a retrospective review and was vulnerable to the bias associated with such reviews. Second, as a single surgeon series, there was inherent bias in both the classification of meniscal tears and the selection of patients in general. Third, second-look arthroscopy was not performed on asymptomatic patients. There should be some patients with clinically silent failures after meniscal repairs as the definition of meniscal repair failure in the current study was that subsequent meniscal surgery was required. Fourth, the follow-up period after ACL reconstruction was short in the current study. However, all patients were followed in person at the last follow-up. Finally, the development of ACL reconstruction and meniscal repair would change the strategies for meniscal injury at ACL reconstruction in the future.

5. Conclusions

An increased time from ACL tear to surgery of three months was strongly associated with an increased risk of medial meniscus injury, but not related to irreparable medial meniscal tear at primary ACL reconstruction in young patients (13–29 years of age).

Levels of evidence

Cohort study; Level of evidence, 4.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical approval

This study, and all protocols, was approved by our Institutional Ethics Review Board.

Consent to participate

All patients provided informed consent to participate in this study.

Consent for publication

All participants provided informed consent for the publication of this study.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgment

The authors would like to thank Yoshihide Kanaoka, MD, PhD. and Mr. Alan Gibson for English language editing.

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