Incidence of Medial and Lateral Meniscal Tears After Delayed Anterior Cruciate Ligament Reconstruction in Pediatric Patients

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Background: The treatment of pediatric anterior cruciate ligament (ACL) injuries is controversial, and no clear management guidelines have been established.

Purpose: To evaluate the association between elapsed time from ACL injury to surgery and the incidence of meniscal tears and chondral injuries in patients aged ≤16 years.

Study Design: Cohort study; Level of evidence, 3.

Methods: Between December 2012 and April 2019, a total of 207 consecutive knees in 207 patients aged ≤16 years underwent primary ACL reconstruction and were included in this study. Patients were divided into 1 of 2 groups (early group [≤150 days] and delayed group [>150 days]) based on the time between injury and surgery. Patient records, including arthroscopic findings identified by 2 experienced knee surgeons at the time of surgery, were reviewed for demographic information, incidence and types of medial and lateral meniscal tears, and chondral injuries and their locations in each group.

Results: There were 180 knees in the early group and 27 knees in the delayed group. The delayed group showed a significantly higher rate of medial meniscal tears than the early group: 16 of 27 (59.2%) and 46 of 180 (25.6%), respectively (odds ratio [OR], 4.24 [95% CI, 1.83-9.33]; $P = .0011$). The delayed group had a significantly lower rate of lateral meniscal tears than the early group: 6 of 27 (22.2%) and 90 of 180 (50.0%), respectively (OR, 0.29 [95% CI, 0.11-0.70]; $P = .007$). The delayed group had significantly higher rates of chondral injuries in the medial femoral condyle and the medial tibial plateau than the early group: 8 of 27 (29.6%) and 25 of 180 (13.9%), respectively (OR, 2.61 [95% CI, 1.03-6.62]; $P = .049$), and 2 of 27 (7.4%) and 1 of 180 (0.6%), respectively (OR, 14.32 [95% CI, 1.58-208.10]; $P = .045$).

Conclusion: Delayed ACL reconstruction was associated with an increased incidence of medial chondral injuries and medial meniscal tears but with a decreased incidence of lateral meniscal tears.

Keywords: ACL; pediatric sports medicine; delayed reconstruction; meniscal tear; children

In recent years, there has been an increase in the incidence of anterior cruciate ligament (ACL) tears and the number of ACL reconstruction procedures in children.[1,20,23] This may be the result of several factors, including increasing participation of children and adolescents in contact sports activities, a better understanding of the disease by health teams (thereby leading to more appropriate diagnoses), and the availability of better diagnostic methods.[3] However, the treatment of ACL injuries in skeletally immature patients remains controversial, and no clear management guidelines have been established.[7] In chronic ACL-deficient knees in adults, tears of the medial meniscus are common.[2,4,22] Meniscal tears and loss are also well-documented risk factors for the development of degenerative knee arthritis.[14,15,19] Therefore, in children, even those with open physes, ACL reconstruction may have to be performed as soon as possible after ACL injuries because a long delay between injury and surgery may be associated with an increased rate of meniscal and articular cartilage injuries in young, active patients. However, the validity of this assumption in children remains unclear. The primary aim of this case-controlled study was to evaluate the association between the time from ACL injury to

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surgery and the incidence of meniscal tears and chondral injuries in a cohort of patients aged ≤16 years. The secondary aim was to determine which type of meniscal tears could be affected by the elapsed time before surgery. We hypothesized that the frequency of associated meniscal and chondral injuries would increase significantly after delayed surgical reconstruction in children with ACL injuries.

METHODS

This study was approved by the ethics committee of our institution. A retrospective analysis of patients in our database was performed, focusing on the period from December 2012 to April 2019. Inclusion criteria were age ≤16 years and a history of primary ACL reconstruction. The exclusion criterion was a history of knee surgery or injuries. The diagnosis of an ACL tear was based on patient history of functional knee instability as well as knee radiography, magnetic resonance imaging, and clinical examination data, including the anterior drawer, Lachman, and pivot-shift tests in all cases. All patients were enrolled consecutively.

Patients were assigned to 1 of 2 groups (early group [≤150 days] or delayed group [>150 days]) based on the time between injury and surgery, with reference to a previous report.[6] Patient records, including arthroscopic findings that were identified by 2 experienced knee surgeons at the time of surgery, were reviewed for demographic information (age, sex, body mass index, and number of days between injury and surgery), incidence and types of medial and lateral meniscal tears, chondral injuries and their locations, anteroposterior knee laxity assessed by arthrometry before surgery, Tegner activity score before injury, and cause of injury in each group. The types, locations, and grades of meniscal tears and chondral injuries were documented with operative reports for all patients. The types of lateral and medial meniscal tears were documented in accordance with the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine criteria, and chondral injury locations and grades were examined and recorded in accordance with the International Cartilage Regeneration & Joint Preservation Society criteria. The reason for delayed surgery was not identified for each patient. However, regardless of the presence of open physes or symptoms, our strategy has been to perform ACL reconstruction in children as soon as possible after ACL injuries. With respect to the surgical procedures, male patients aged ≤12 years and female patients aged ≤11 years underwent partial physeal-sparing reconstruction with quadrupled hamstring tendon autografts. Male patients aged ≥13 years and female patients aged ≥12 years underwent transphyseal reconstruction with hamstring tendon autografts.

Data were analyzed by the Student *t* test and chi-square test to compare demographic and clinical characteristics of the 2 groups as well as the Fisher exact test to identify associations, which are reported as odds ratios (ORs) with 95% CIs. The Cochran-Armitage test was also used to analyze the association between the type of meniscal tear and the time from injury to surgery, with time as a continuous variable. $P < .05$ was considered significant. Data were analyzed with GraphPad Prism for Windows (Version 8.0; GraphPad Software).

RESULTS

A total of 207 consecutive knees of 207 patients were included in the analysis. Surgery was performed at a mean of 86.2 days after the injury, and we evaluated 180 knees in the early group and 27 knees in the delayed group. The demographic and clinical characteristics, with the exception of mean age, were similar between the 2 groups (Table 1). The cause of injury involved basketball in 91 patients, handball in 26, volleyball in 21, football in 22, rugby in 6, badminton in 6, skiing in 5, track and field in 4, wrestling in 4, gymnastics in 3, tennis in 3, judo in 2, and softball in 2 patients. There was 1 injury each for table tennis, baton twirling, baseball, and tai chi. Other factors, including accidents, caused 8 ACL tears. Overall, of the 207 patients, 62 (30.0%) had medial meniscal tears and 96 (46.4%) had lateral meniscal tears at the time of surgery. The delayed group had a significantly higher rate of medial meniscal tears than the early group: 16 of 27 (59.2%) and 46 of 180 (25.6%), respectively (OR, 4.24 [95% CI, 1.83-9.33]; $P = .0011$). On the other hand, the delayed group had a significantly lower rate of lateral meniscal tears than the early group: 6 of 27 (22.2%) and 90 of 180 (50.0%), respectively (OR, 0.29 [95% CI, 0.11-0.70]; $P = .007$).

With regard to chondral injuries, the delayed group had a significantly higher rate of chondral injuries in the medial femoral condyle compared with the early group: 8 of 27 (29.6%) and 25 of 180 (13.9%), respectively (OR, 2.61 [95% CI, 1.03-6.62]; $P = .049$). Furthermore, the delayed group had a significantly higher rate of chondral injuries in the medial tibial plateau compared with the early group: 2 of 27 (7.4%) and 1 of 180 (0.6%), respectively (OR, 14.32 [95% CI, 1.58-208.10]; $P = .045$) (Table 2).

With respect to the types of medial meniscal tears, the delayed group had a significantly higher rate of bucket-handle tears compared with the early group: 7 of

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TABLE 1
Demographic and Clinical Characteristics[a]

	All Patients (n = 207)	Early Group (n = 180)	Delayed Group (n = 27)	*P* Value
Sex, male/female, n	56/151	48/132	8/19	.628[b]
Age, y	15.1 ± 1.1	15.3 ± 1.0	14.4 ± 1.2	**<.0001**[c]
Body mass index, kg/m^2	21.4 ± 2.9	21.5 ± 2.9	21.3 ± 2.9	.725[c]
Side-to-side difference by arthrometry, mm	4.4 ± 1.9	4.4 ± 1.8	4.8 ± 2.5	.302[c]
Tegner activity score	8.4 ± 0.9	8.4 ± 1.0	8.3 ± 0.9	.613[c]
Time from injury to surgery, d	86.2 ± 88.5	59.1 ± 34.6	267.1 ± 121.3	**<.0001**[c]

[a]Data are reported as mean ± SD unless otherwise indicated. Bolded *P* values indicate a statistically significant difference between the early and delayed groups ($P < .05$).
[b]Chi-square test.
[c]Student *t* test.

TABLE 2
Meniscal and Chondral Injuries[a]

	All Patients, n (%)	Early Group, n (%)	Delayed Group, n (%)	OR (95% CI)	*P* Value[b]
Medial meniscal tear	62 (30.0)	46 (25.6)	16 (59.2)	4.24 (1.83-9.33)	**.0011**
Lateral meniscal tear	96 (46.4)	90 (50.0)	6 (22.2)	0.29 (0.11-0.70)	**.007**
Chondral injury					
Medial femoral condyle	33 (15.9)	25 (13.9)	8 (29.6)	2.61 (1.03-6.62)	**.049**
Medial tibial plateau	3 (1.4)	1 (0.6)	2 (7.4)	14.32 (1.58-208.10)	**.045**
Lateral femoral condyle	8 (3.9)	8 (4.4)	0 (0.0)	—	.264
Lateral tibial plateau	7 (2.9)	6 (3.3)	1 (3.7)	—	.921

[a]Bolded *P* values indicate a statistically significant difference between the early and delayed groups ($P < .05$). OR, odds ratio. —, not available.
[b]Fisher exact test.

27 (25.9%) and 9 of 180 (5.0%), respectively (OR, 6.65 [95% CI, 2.40-19.88]; $P = .0015$); the delayed group also had a significantly higher rate of flap tears compared with the early group: 3 of 27 (11.1%) and 1 of 180 (0.6%), respectively (OR, 22.38 [95% CI, 3.14-291.30]; $P = .007$). Regarding the types of lateral meniscal tears, the delayed group had a significantly lower rate of vertical tears compared with the early group: 2 of 27 (7.4%) and 53 of 180 (29.4%), respectively (OR, 0.19 [95% CI, 0.04-0.84]; $P = .018$) (Table 3).

When the association between the type of meniscal tear and time from injury to surgery was analyzed with time as a continuous variable, there were significant relationships between time from injury to surgery and bucket-handle medial meniscal tears, flap medial meniscal tears, and vertical lateral meniscal tears ($P < .001$, $P = .008$, and $P = .0119$, respectively) (Table 4).

DISCUSSION

An association between time from injury to surgery and the risk of medial meniscal injuries has been reported in several studies of ACL injuries in the adult population. Chhadia et al[5] and Vavken et al[21] reported a significant association between delayed surgery and the risk of medial meniscal injuries as well as between the risk of chondral injuries and delayed surgery. However, there was no association between time to surgery and the risk of secondary lateral meniscal tears.[5] Similarly, Kay et al[12] identified a significantly greater risk of medial meniscal and articular cartilage damage in children who had undergone delayed ACL reconstruction in comparison with those who had undergone early reconstruction; they found no significant difference between the groups with respect to lateral meniscal damage. With regard to vertical lateral meniscal tears, there was a significant difference between the early and delayed groups in the present study. This present study was one of the first studies to provide evidence that most vertical lateral meniscal tears associated with ACL tears would decrease without a surgical intervention in patients aged ≤16 years. Shelbourne and Heinrich[18] reported that lateral meniscal tears associated with ACL tears might be treated by being left in situ in the adult population. Moreover, Pujol and Beaufils[17] reported the outcomes of stable lateral meniscal tears left in situ during ACL surgery, and 55% to 74% of cases were completely healed. Therefore, vertical lateral meniscal tears, which do not have much instability, might heal spontaneously in ≤150 days from injury in patients in this age group who might show regenerative ability.

Conversely, the present data provide evidence that delayed ACL reconstruction in patients in this age group carried a significantly increased risk of additional chondral medial femoral condyle and medial meniscal injuries. Explanations for the increased risk of medial meniscal and cartilage injuries in children who undergo delayed ACL reconstruction relate to either repetitive micromotion during activities of

TABLE 3
Types of Meniscal Injuries[a]

	All Patients, n (%)	Early Group, n (%)	Delayed Group, n (%)	OR (95% CI)	*P* Value[b]
Medial meniscal tear					
Bucket handle	16 (7.7)	9 (5.0)	7 (25.9)	6.65 (2.40-19.88)	**.0015**
Flap	4 (1.9)	1 (0.6)	3 (11.1)	22.38 (3.14-291.30)	**.007**
Vertical	42 (20.3)	36 (20.0)	6 (22.2)	—	.789
Lateral meniscal tear					
Bucket handle	5 (2.4)	4 (2.2)	1 (3.7)	—	.640
Flap	2 (1.0)	2 (1.1)	0 (0.0)	—	.582
Vertical	55 (26.6)	53 (29.4)	2 (7.4)	0.19 (0.04-0.84)	**.018**
Radial	28 (13.5)	26 (14.4)	2 (7.4)	—	.276
Horizontal	3 (1.4)	2 (1.1)	1 (3.7)	—	.293
Discoid meniscus	3 (1.4)	3 (1.7)	0 (0.0)	—	.499

[a]Bolded *P* values indicate a statistically significant difference between the early and delayed groups ($P < .05$). OR, odds ratio. —, not available.
[b]Fisher exact test.

TABLE 4
Association Between Type of Meniscal Injury and Time From Injury to Surgery[a]

	P Value[b]
Medial meniscal tear	
Bucket handle	**<.001**
Flap	**.008**
Vertical	.11
Lateral meniscal tear	
Bucket handle	.446
Flap	.582
Vertical	**.0119**
Radial	.758
Horizontal	.393
Discoid meniscus	.995

[a]Bolded *P* values indicate a statistical significance ($P < .05$).
[b]Cochran-Armitage trend test.

daily living on the unstable knee or poor adherence with respect to sports restriction as well as denial of instability, causing repeat traumatic events.[8] Furthermore, a recent biomechanical study found that ACL-deficient knees experience higher contact forces at the posterior horn of the medial meniscus, making it more susceptible to injuries.[10]

Another important finding in the present study was the significantly increased risk of bucket-handle and flap medial meniscal injuries in children and adolescents who had undergone extremely delayed reconstruction in comparison with those who underwent early reconstruction. In the present study, a surgical delay of >150 days was not significantly associated with an increased risk of medial meniscal injuries, with the exception of bucket-handle and flap tears; however, it was significantly associated with an increased risk of overall medial meniscal injuries, including bucket-handle and flap medial meniscal injuries. This suggests that delayed surgery causes worsening of the meniscal injury itself and leads to an increased risk of overall secondary chondral injuries. Moreover, some evidence suggests that bucket-handle tears have very poor prognoses, with successful repair reported in 26% to 59% of patients, while unrepaired meniscal tears in pediatric patients are thought to precipitate the development of osteoarthritis.[9,13,16] Although meniscal repair during ACL reconstruction has a higher success rate than isolated meniscal injuries, Jackson et al[11] reported that the rate of meniscal repair for meniscal tears in pediatric patients was 53%.[16] We believe this to be an insufficient number. Therefore, severe secondary medial meniscal injuries (eg, bucket-handle or flap tears) due to delayed surgery should be avoided.

This study had several limitations. The injury dates used to calculate the patients' surgical delay were self-reported, which may have introduced errors. Time intervals from injury to surgery were selected to represent intuitive demarcations with reasonable sample sizes. Patients were not randomly assigned to treatment delay; therefore, there may have been some selection bias. Finally, anthropometric variables other than those examined might affect the rates of meniscal and cartilage injuries. Further investigations might include the evaluation of lower extremity alignment as a risk factor.

CONCLUSION

This study showed that a delay in ACL reconstruction was associated with an increased risk of chondral injuries of the medial compartment and medial meniscal injuries, although it was associated with a decreased risk of vertical lateral meniscal tears. Furthermore, delayed surgery may lead to worsened medial meniscal injuries, such as bucket-handle or flap tears. These results suggest that early reconstruction may be beneficial for ACL tears in patients aged ≤16 years.

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