Which Factors Increase the Risk of Reoperation After Meniscal Surgery in Children?

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Background: Meniscal injuries in children can pose treatment challenges, as the meniscus must maintain its biomechanical function over a long lifetime while withstanding a high activity level. While the adult literature contains a plethora of studies regarding risk factors for failure of meniscal surgery, such reports are scarcer in children.

Purpose: To determine the rate at which children undergoing meniscal surgery require subsequent reoperation as well as to define risk factors for reoperation in this population.

Study Design: Case-control study; Level of evidence, 3.

Methods: A retrospective institutional database of 907 first-time meniscal surgical procedures performed between 2000 and 2015 was reviewed. All patients were <18 years old. Demographic and intraoperative information was recorded, as were concurrent injuries or operations and subsequent procedures. Univariate analysis consisted of chi-square and independent-samples *t* tests. Multivariate logistic regression with purposeful selection was then performed to adjust for confounding factors.

Results: The mean ± SD patient age was 13.2 ± 2.1 years, and 567 (63%) were male. The mean postoperative follow-up duration was 20.1 ± 10.1 months. Overall, 83 patients (9%) required repeat surgery at a mean of 23.2 months after the index operation. After adjustment for confounders in a multivariate model, meniscal repair resulted in 3.1-times higher odds of reoperation when compared with meniscectomy (95% CI, 1.2-8.3; $P = .02$), while white-white zone tears had 2.8-times lower odds of reoperation (95% CI, 1.01-7.7; $P = .04$) versus red-red and red-white zone tears.

Conclusion: Approximately 9% of children undergoing meniscal surgery will require reoperation at a mean 23.2 months after the index operation. Repair carried approximately 3-times higher odds of reoperation than meniscectomy, while white-white zone tears had nearly 3-times lower odds of requiring repeat surgery when compared with tears in other zones.

Keywords: knee; meniscus; pediatric sports medicine

A number of recent reports describe an increase in pediatric and adolescent sports injuries.[4,12,18,21] Among the proposed reasons behind this trend are a higher overall rate of youth sports participation, increased training time and intensity, and earlier single-sport specialization.[2,5,8,19,22,23] Regarding meniscal tears, these issues combine with improved magnetic resonance imaging technology and earlier physician diagnosis to bring new focus on pediatric meniscal injuries.[3,10]

The role of the meniscus as a secondary stabilizer, partial load bearer, and impact absorber are well described.[9,13,16,24] Previous authors have also reported the consequences of meniscectomy, of which early degenerative changes are the most significant, possibly occurring in up to 60% of patients in long-term follow-up.[7,25,27,29] These issues are especially important for children, who tend to have a higher activity level than that of adults and whose menisci must maintain their biomechanical function for a longer length of time. Meniscal tears in the pediatric population can present complex treatment challenges and have significant long-term implications. Therefore, an analysis of factors influencing the outcomes of pediatric meniscal surgery is prudent.

While the literature on this subject is growing, there remains a relative paucity of large, well-powered studies. The purpose of the present investigation was 2-fold: (1) to assess the rate at which children undergoing meniscal surgery require a return to the operating room and (2) to identify pre- and intraoperative factors that affect the risk of reoperation in a large cohort of pediatric meniscal surgical procedures.

METHODS

After institutional review board approval was obtained, all meniscal tears seen at our institution between 2000 and

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2015 were queried retrospectively with the following codes per the International Classification of Diseases, 9th Revision: 717.0, 717.1, 717.2, 717.3, 717.40, 717.41, 717.42, 717.43, 717.49, 717.5, 836.0, 836.1, and 836.2. From this cohort, the search was then further narrowed via chart review to those undergoing first-time meniscal surgery. Patients were excluded if they were >18 years of age, had previous surgery or pathology in the affected knee, or were missing relevant documentation (demographic information, operative notes, etc). Of note, those with a concomitant injury or discoid meniscus were not excluded.

Patients were typically indicated for surgery if they had a meniscal tear associated with a mechanical block to motion or with loose or unstable intra-articular fragments. Surgery was also discussed if patients had persistent pain or mechanical symptoms after at least 6 weeks of nonoperative treatment. All operations were performed by fellowship-trained surgeons at a single institution. The decision for repair or meniscectomy was dictated by the location and morphology of the tear, as was the decision for all-inside, inside-out, or outside-in repair. Patients typically returned for additional appointments on an as-needed basis if a satisfactory outcome was achieved 12 months after surgery.

Data were collected by research staff who were uninvolved in the clinical care of the patients. Demographic variables of interest included age, body mass index, and sex. Clinical data included concurrent injuries and intraoperative findings and procedures. Specifically, detailed information regarding the tear pattern, location, and morphology was recorded. Postoperative data collection consisted of complications and repeat operations. Patients were considered as having returned for a revision operation if subsequent procedures were performed on the same meniscus that was treated during the index procedure. An operation on the contralateral knee or in the opposite meniscus in the ipsilateral knee was therefore not considered a reoperation for the purposes of this study. Complications, reinjuries, and reoperations were identified via chart review.

Statistical analysis was completed with SPSS Statistics for Macintosh (v 24.0; IBM Corp). Standard descriptive statistics were calculated for demographic variables. Specifically, mean ± SD values are reported. Categorical variables were analyzed with chi-square or Fisher exact tests, as appropriate. Means were compared with independent-samples *t* tests. A Kolmogorov-Smirnov test was used to evaluate normality of continuous variables. Univariate analysis was followed by multivariate logistic regressions to adjust for confounders. Purposeful entry was used for regression modeling to best recognize clinical relevance while respecting statistical significance. To adjust for any historical treatment biases or changes in technology over the 15-year span of the study, the year of the index surgery was included in multivariate analysis. Coefficients are reported with 95% CIs. For all statistical tests, a significance threshold of $P < .05$ was employed.

TABLE 1
Patient Demographics and Tear Details

	Mean ± SD or n (%)
Age, y	13.2 ± 2.1
Sex	
Male	567 (62.5)
Female	340 (37.5)
Body mass index	22.2 ± 5.1
Tear pattern	
Vertical cleavage	211 (23.2)
Degenerative	200 (22.1)
Bucket-handle	169 (18.6)
Horizontal cleavage	93 (10.3)
Other	234 (25.8)
Tear zone	
Red-red	284 (31.3)
Red-white	354 (39.0)
White-white	269 (29.7)
Tear location	
Anterior horn	148 (16.3)
Body	239 (26.4)
Posterior horn	520 (57.3)

RESULTS

The initial query returned 1341 respondents, of which 201 had prior surgery or pathology in the affected knee, 128 did not have all of the required data in their medical records, 86 were aged >18 years, and 19 were miscoded (did not have a meniscal tear). A total of 907 children who underwent meniscal surgery were included in the study; the mean follow-up period was 20.1 ± 10.1 months (median, 16.2 months). The lateral meniscus was torn in 659 (73%), the medial meniscus in 171 (19%), and both in 77 (8%). A discoid meniscus was found in 239 patients (26%). Detailed descriptions of patient demographics, tear locations, and tear patterns are displayed in Table 1.

Overall, 525 (58%) patients underwent repair, while the remainder required partial resection. Of those undergoing repair, 452 (86%) were all-inside, 40 (8%) inside-out, and 33

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Ethical approval for this study was obtained from the Children's Hospital of Philadelphia Institutional Review Board (No. 15-012614).

TABLE 2
Procedures Performed at Time of Reoperation[a]

Procedure Performed	n (%)
Meniscectomy	40 (48.2)
Meniscus repair	29 (34.9)
Meniscus repair + revision ACL reconstruction	10 (12)
Meniscectomy + OCD drilling	3 (3.6)
Meniscectomy + osteochondral allografting	1 (1.2)

[a]ACL, anterior cruciate ligament; OCD, osteochondritis dissecans.

(6%) outside-in. Concurrent operations included anterior cruciate ligament (ACL) reconstruction in 429 patients (47%), osteochondritis dissecans drilling or fixation in 51 (6%), and tibial eminence fracture fixation in 28 (3%).

A total of 83 patients (9%) required reoperation on the ipsilateral meniscus at a mean of 23.2 ± 17.2 months after the index operation. Subsequently, 9 patients (1%) returned for a third operation at a mean of 37.1 ± 20.8 months, and 1 (0.001%) required a fourth operation at 86.7 months after the first operation. The specific procedures performed at the first reoperation are shown in Table 2.

In univariate analysis, 13% of meniscal repairs underwent repeat surgery versus 5% of meniscectomies ($P < .001$). When the subgroup of meniscal repairs was analyzed, there was no significant difference in the rate of subsequent surgical procedures based on repair technique (all-inside vs inside-out vs outside-in). Regardless of treatment methods, 17% of bucket-handle tears required reoperation, as opposed to 7% of other tear patterns ($P < .001$). However, the rate of reoperation was lower for degenerative tears as compared with other patterns (6% vs 11%; $P = .02$) and for white-white zone tears versus other locations (4% vs 13%; $P = .002$). Of note, 74% of degenerative tears and 65% of white-white zone tears in the cohort underwent meniscectomy rather than repair. There was no significant difference in the risk of repeat surgery if patients underwent concurrent ACL reconstruction (8.9% vs 9.6%; $P = .69$), osteochondritis dissecans drilling (7.8% vs 9.3%; $P = .72$), or tibial eminence fracture fixation (10.7% vs 9.2%; $P = .79$) when compared with patients who did not undergo these concomitant procedures, respectively.

When discoid menisci were evaluated separately, 155 of 239 (65%) underwent resection or saucerization rather than repair. Of these patients, 22 (9%) required additional surgery. This was not different from the overall rate in nondiscoids (9%; $P = .97$). There was no significant difference in the rate of reoperation between discoids that underwent repair and those that underwent saucerization or resection (13% vs 7%, respectively; $P = .13$). Further subgroup analysis of only repaired discoids did not yield a significantly different rate of reoperation when compared with nondiscoids that were repaired (13% vs 12; $P = .86$) or with all other menisci in the cohort (13% vs 9; $P = .23$).

After adjustment for patient age, body mass index, sex, year during which surgery was performed, and tear pattern in multivariate regression, meniscal repair resulted in 3.1-times higher odds of repeat surgery as compared with meniscectomy (95% CI, 1.2-8.3; $P = .02$). White-white zone tears retained their "protective" effect against reoperation, with these tears at 0.36 times the odds of requiring subsequent surgical procedures versus other tear locations (95% CI, 0.13-0.99; $P = .04$). In other words, white-white zone tears were 2.8 times less likely to require reoperation (95% CI, 1.01-7.7; $P = .04$). The details of the multivariate model are displayed in Table 3.

TABLE 3
Multivariate Analysis of Risk Factors for Reoperation[a]

	Odds of Reoperation	95% CI	*P* Value
Repair	3.1	1.2-8.3	**.02**
White-white zone	0.36	0.13-0.99	**.04**
Bucket-handle	2.1	0.96-4.6	.06
Degenerative	1.6	0.54-4.5	.41
Age	0.98	0.78-1.2	.88
Sex	0.65	0.30-1.4	.28
Body mass index	1.0	0.94-1.1	.73
Year of index surgery	1.0	0.99-1.1	.99

[a]Bolded *P* values indicate statistical significance ($P < .05$).

DISCUSSION

In this study of 907 pediatric meniscal surgical procedures, 9.2% of all patients required at least 1 subsequent reoperation, and 1% required 2 repeat procedures. The initial reoperation occurred at a mean of 23.2 months after the index surgery. Just over half these patients underwent partial meniscectomy at the time of the repeat procedure. After adjustment for confounding factors in a multivariate model, meniscal repair increased the odds of returning to the operating room approximately 3-fold when compared with meniscectomy, while white-white zone tears conferred lower odds of reoperation versus other tear locations. To our knowledge, the present study includes the largest cohort of pediatric meniscal surgical procedures to date.

Given the role of the meniscus as an impact absorber, load bearer, and joint stabilizer, we favor repair whenever the tear morphology and location allow, even if there is a higher rate of reoperation when compared with meniscectomy. The success rate of meniscal repair in adults varies widely in the literature depending on the criteria used.[1] Lyman et al[17] reported that 8.9% of adult patients undergoing meniscal repair required subsequent meniscectomy in New York State, with older age lowering the risk of reoperation. The reoperation rate for children undergoing meniscal repair in the present study was 13%, suggesting that younger age is likely a risk factor for repair failure. Since the meniscus must withstand a higher level of activity for a longer lifetime in children than in adults, an identification of risk factors for treatment failure in this younger population is important.

As the incidence and awareness of pediatric sports injuries continue to grow, so does the literature on pediatric meniscal tears. Most of these reports consist of small series. However, in a study of 324 meniscal operations among 293 children, Shieh et al[26] reported a failure rate of 13% at a mean of 14 months after the index procedure. The authors found that meniscal repair increased the odds of reoperation approximately 2-fold and that skeletally immature patients with bucket-handle tears had the highest overall retear rate. These results are similar to those of the present study, although we found that the first revision operation occurred at a mean of 23 months rather than 14. We found bucket-handle tears to increase the risk of reoperation in univariate analysis, but statistical significance was lost in multivariate regression. While both the present study and that of Shieh et al[26] report meniscal repair to confer a higher risk of reoperation than meniscectomy, this finding must be balanced against the potential risk of arthritis that may develop among patients undergoing meniscectomy. These patients should be informed that while their reoperation risk is lower, their risk of eventual osteoarthritis is likely higher. We generally agree with the conclusions of Vanderhave et al,[30] who recommend attempting repair of the pediatric meniscus whenever possible.

Interestingly, degenerative and white-white zone tears were found to confer a "protective" effect against reoperation in univariate analysis, with white-white tears retaining significance in our multivariate model. While these results may not be intuitive at first glance, they are clarified by a deeper analysis of the data. The aforementioned tears were more likely to undergo resection than repair. Meniscectomy was an independent protective factor against return to the operating room, probably because a meniscus that was sufficiently resected to a stable rim was less likely to retear than a repaired meniscus that did not fully heal. Therefore, it is reasonable that degenerative and white-white zone tears were also less likely to require repeat surgery, because the majority of these underwent a meniscectomy.

A similar trend was noted in discoid menisci, which one may initially hypothesize would be at increased risk of revision surgery. The majority of our patients with a discoid meniscus underwent resection or saucerization rather than repair, perhaps explaining why discoid meniscus was not a predictor of reoperation in our analysis. Further subgroup analyses of repaired discoids did not find any difference in reoperation rates when compared with non-discoids that were repaired or with all other menisci in the cohort. These are potentially encouraging findings, suggesting that while the underlying pathology and tear patterns are often different in discoids versus normal menisci, the reoperation rates may not be higher for these patients.

A number of adult studies describe improved success of meniscal repair when performed with concurrent ACL reconstruction.[6,11,28,31] Krych et al[14,15] evaluated the same phenomenon in a series of 99 children, with a historical control group for comparison. The authors found that complex and bucket-handle tears were at increased risk for repair failure, but complex tears had better odds of healing when repaired in the setting of ACL reconstruction than as an isolated injury.[15] In the present study, concomitant ACL reconstruction did not improve the overall reoperation rate as compared with that of isolated tears. These results are similar to those of a meta-analysis by Nepple et al[20] and the previously discussed study by Shieh et al.[26] In the latter publication, the authors hypothesized that a larger sample size may have detected a statistical difference in their cohort, with a post hoc power analysis suggesting that 924 patients would be required. No difference in reoperation rate was detected in the present study of 907 children. The exact reasons for this are beyond the scope of the data, but one can postulate that because children may carry a higher baseline ability for meniscal healing than adults, the effect of concurrent ACL reconstruction might not add any additional physiologic advantage.

This study is not without limitations, including those inherent to a retrospective design. Along these lines, follow-up duration was variable, so there remains the possibility that the true reoperation rate could be higher, especially if care was sought elsewhere. A longer follow-up period would have strengthened the study. There was no available information on subsequent degenerative changes and osteoarthritis. Finally, patient-reported outcome scores and reliable clinical assessments were not available at baseline or follow-up but would have added additional depth to our results.

Despite these limitations, this analysis of the largest reported cohort of pediatric meniscal surgical procedures suggests that 9.2% of these children require reoperation 23 months after their index surgery. Over half of these repeat procedures included a partial meniscectomy. When adjusting for other factors in a multivariate model, white-white zone tears had 2.8-times lower odds of requiring reoperation, while meniscal repair had 3.1-times higher odds of requiring repeat surgery. However, the risk of reoperation after repair must be weighed against the risk of degenerative changes after meniscectomy. These results can be used to counsel patients undergoing meniscal surgery and help guide treatment in these children.

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