Epidemiology, Injury Patterns, and Treatment of Meniscal Tears in Pediatric Patients

A 16-Year Experience of a Single Center

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Background: Meniscal injuries in children continue to increase, which may be attributable to increasing levels of athletic participation and may be associated with additional injuries or need for additional surgeries.

Purpose: To better understand the patterns of pediatric meniscal injuries by analyzing tear location, morphologic features, and associated injury patterns over a 16-year period.

Study Design: Case series; Level of evidence, 4.

Methods: Pediatric patients were identified and were included in the study if age at the time of initial surgery for meniscal tear was between 5 and 14 years for female patients and 5 and 16 years for male patients. Patients were observed until age 18, and any subsequent surgeries were noted. Demographic factors, tear type and location, associated injuries, and treatment type were analyzed.

Results: Mean patient age at surgery was 13.3 years, and 37% of patients were female. A total of 1040 arthroscopic meniscal surgeries in 880 pediatric patients were evaluated. There were 160 reoperations in 138 patients, representing a reoperation rate of 15%. These included 98 reoperations on the ipsilateral knee in 88 patients and 62 operations for injuries to the contralateral knee in 50 patients; 53% of surgeries were meniscal repair, as opposed to partial meniscectomy, and the most common technique was an all-inside repair (91%). Significant differences were identified between male and female patients. Male patients were more likely to have lateral meniscus (74% vs 65%), posterior horn (71% vs 60%), peripheral (45% vs 30%), and vertical tears (31% vs 21%); concomitant ACL injury (50% vs 40%); and an associated osteochondritis dissecans lesion (7% vs 4%). Female patients were more likely to have medial meniscus (24% vs 17%), anterior horn (25% vs 15%), and degenerative tears (34% vs 26%); discoid meniscus (33% vs 24%); and isolated meniscal tears (47% vs 33%).

Conclusion: This evaluation of a large series of patients has helped characterize injury patterns associated with pediatric meniscal surgeries. Most meniscal tears were repaired (53%) and were associated with additional injuries (62%), especially anterior cruciate ligament injuries (48%). More than 25% of patients had a discoid meniscus. Injury patterns differed significantly between male and female patients.

Keywords: meniscal injury; pediatric; meniscectomy; meniscal repair; epidemiology

Historically, it has been reported that meniscal injuries are much less common in children than in adults.[2,22] However, the reported incidence of meniscal tears in children has continued to rise,[10,25] likely due to more intense athletic activity, early sports specialization, year-round competition, and increasing awareness of and screening for these injuries.[16,25]

Meniscal injuries requiring surgery are treated with partial meniscectomy or meniscal repair.[6] In children, a greater portion of the meniscus is vascularized, which makes it more amenable to repair, so repairs tend to have better outcomes than in adults.[4] Current treatment goals focus on preservation of meniscus tissue whenever possible. Accordingly, in recent years, a trend has been seen toward repair over partial meniscectomy, especially in younger patients.[18,25] The overall incidence of meniscal surgery has increased, and the incidence of meniscal repair has outpaced the rate of increase in meniscectomies (increase of 55% compared with 38%, respectively, between 2007 and 2011).[25]

Prior studies have reported several risk factors for meniscal injuries, including adolescent age, male sex, type

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of sporting activity, higher body mass index (BMI), and delayed repair of a concomitant anterior cruciate ligament (ACL) injury.[3,7,13,15,22,23,25] Because treatment decisions may be based on injury patterns and associated injuries, the purpose of this study was to investigate the epidemiological patterns of surgically treated meniscal tears in pediatric patients to better characterize tear location and morphologic features as well as associated injuries.

METHODS

After gaining institutional review board approval, we performed a retrospective chart review of all pediatric patients treated surgically at our institution for a meniscal tear between January 1, 2000, and December 31, 2015. Patients were included if their initial surgery occurred between ages 5 and 14 years for female patients and ages 5 and 16 years for male patients. If a patient fit the age range for the initial surgery, all subsequent surgeries that the patient received at our institution before age 18 were also included in our analysis. Patients who had undergone trephination or who were originally treated at another institution were excluded. All surgeries were performed by 1 of 4 fellowship-trained orthopaedic surgeons, and the postoperative weightbearing and return to activity protocols were identical.

Age, sex, weight, BMI, discoid meniscus, and associated injuries were recorded. Operative notes were reviewed to determine the operative side and meniscus, vascular zone of tear, tear location and morphologic features, and method of surgical treatment. The vascular zone of tear was classified as red-red, red-white, or white-white. Tear location was grouped into anterior horn, midbody, posterior horn, intrasubstance delamination, or multiple locations. The type of tear was classified as horizontal, vertical, bucket handle, flap, parrot beak, radial, degenerative, oblique, or complex.

Associated ACL tears, parameniscal cysts, medial collateral ligament (MCL) injuries, tibial spine fractures, and osteochondritis dissecans (OCD) lesions were noted. Surgeries were classified as either partial meniscectomy or meniscal repair. Repairs were categorized as all-inside, inside-out, outside-in, or a combination of approaches. All-inside repairs were performed through use of the Arthrex Meniscal Cinch Implant. Rasping was performed at the tear margins. Concomitant ACL reconstruction or prior surgery on the same knee was also noted.

Statistical Analysis

Demographic characteristics were summarized by standard descriptive summaries (eg, means and standard deviations for continuous variables such as age, percentages for categorical variables such sex). For categorical variables, a chi-square test was used. Statistical significance was set at an alpha level of $P = .05$. Analyses were performed by use of Stata Statistical Software release 14 (StataCorp LP).

RESULTS

Between January 2000 and December 2015, there were 1040 arthroscopic meniscal surgeries performed on 880 patients who met inclusion and exclusion criteria. The average age of patients at the time of surgery was 13.4 years (range, 5.2-18.0 years), and the sample included 414 (39%) female patients. A concomitant ACL repair or reconstruction was performed in 477 surgeries (45%). A total of 160 subsequent surgeries were performed in 138 patients after their index operation, representing a reoperation rate of 15%. These surgeries included 98 reoperations on the ipsilateral knee in 88 patients and 62 operations for injuries to the contralateral knee in 50 patients (Table 1).

A summary of the tear characteristics, associated injuries, and surgeries of the entire study group is shown in Table 2.

Significant differences were identified between male and female patients. Male patients were more likely to have lateral meniscal tears (74% vs 65%; $P = .002$), posterior horn tears (71% vs 60%; $P < .001$), peripheral tears (45% vs 30%; $P = .001$), vertical tears (31% vs 21%; $P = .003$), concomitant ACL tear (50% vs 40%; $P = .001$), and an associated OCD lesion (7% vs 4%; $P = .038$). Female patients were more likely to have medial meniscal tears (24% vs 17%; $P = .008$), anterior horn tears (25% vs 15%; $P < .001$), intrasubstance delamination (22% vs 15%; $P = .014$), degenerative tears (34% vs 26%; $P = .012$), discoid meniscus (33% vs 24%; $P = .001$), and isolated meniscal tears (47% vs 33%; $P < .001$). A full comparison of male and female patients is detailed in Table 3.

Patients who had a discoid meniscus were compared with patients who did not have a discoid meniscus. Patients with a discoid meniscus had increased rates of anterior horn tears (25% vs 16%; $P = .004$), intrasubstance delamination (60% vs 2%; $P < .001$), horizontal tears (21% vs 11%; $P < .001$), degenerative tears (47% vs 22%; $P < .001$), isolated tears (81% vs 22%; $P < .001$), parameniscal cysts

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Ethical approval for this study was obtained from The Children's Hospital of Philadelphia Institutional Review Board (protocol 15-012614).

TABLE 1
Patient Demographics and Surgical Information

	Value
Age, y, mean (range)	13.3 (5.2-18.0)
Female sex, n (%)	391 (37)
Body mass index, mean (range)	22.4 (12.8-60.4)
Knee, right/left, n (%)	519/521 (50/50)
Total procedures, knees/patients, n	1040/880
Total subsequent surgeries, knees/patients, n	160/138
Ipsilateral surgery	98/88
Contralateral injuries	62/50
Meniscectomy, n (%)	489 (47)
Meniscal repair, n (%)	551 (53)
All inside	498 (91)
Inside out	45 (8)
Outside in	38 (7)
Concomitant anterior cruciate ligament reconstruction, n (%)	465 (45)

TABLE 2
Overall Tear Patterns and Associated Injuries[a]

		Overall Proportion[b]	Reinjury Rate
Meniscus	Medial meniscus	20	17
	Lateral meniscus	71	7
	Both menisci	9	12
Tear location	Anterior horn	19	13
	Midbody	30	10
	Posterior horn	67	9
	Intrasubstance delamination	18	3
	Multiple locations	27	9
Zone	Red-red zone	40	5
	Red-white zone	54	12
	White-white zone	43	13
Tear type	Bucket handle	24	13
	Horizontal tear	13	13
	Vertical tear	27	4
	Flap	8	8
	Parrot beak	8	6
	Radial	8	9
	Degenerative	29	12
	Complex	8	10
	Oblique	1	20
Associated lesion	Discoid meniscus	27	8
	Isolated meniscal tear	38	11
	Anterior cruciate ligament tear	46	5
	Parameniscal cyst	2	26
	Medial collateral ligament injury	3	10
	Tibial spine fracture	3	0
	Osteochondritis dissecans lesion	6	13

[a]Values are expressed as proportion (ie, percentage) of patients with repeat surgery on the ipsilateral knee.

[b]Percentages may total more than 100% because patients may have met criteria for multiple categories.

TABLE 3
Comparison of Characteristics, Tear Patterns, and Associated Injuries in Female and Male Patients[a]

		Female	Male	*P*
Meniscus	Medial meniscus	24	17	**.008**
	Lateral meniscus	65	74	**.002**
	Both menisci	11	8	.223
Tear location	Anterior horn	25	15	**<.001**
	Midbody	28	32	.306
	Posterior horn	60	71	**<.001**
	Intrasubstance delamination	22	15	**.014**
	Multiple locations	27	27	.953
Zone	Red-red zone	30	45	**.001**
	Red-white zone	55	54	.826
	White-white zone	44	42	.548
Tear type	Bucket handle	20	26	.079
	Horizontal tear	14	13	.595
	Vertical tear	21	31	**.003**
	Flap	7	8	.389
	Parrot beak	8	9	.720
	Radial	8	8	.846
	Degenerative	34	26	**.012**
	Complex	7	9	.332
	Oblique	1	2	.402
Associated lesion	Discoid meniscus	33	24	**.001**
	Isolated meniscal tear	47	33	**<.001**
	Anterior cruciate ligament tear	40	50	**.001**
	Meniscal cyst	2	2	.945
	Medial collateral ligament injury	3	3	.897
	Tibial spine fracture	3	3	.835
	Osteochondritis dissecans lesion	4	7	**.038**
Repeat surgeries	Reinjury rate	11	8	.127

[a]Values are expressed as percentages. The percentages may total more than 100% because patients may have met criteria for multiple categories. Bolded *P* values indicate statistically significant differences between female and male patients ($P \leq .05$).

(4% vs 1%; $P = .012$), and OCD lesions (11% vs 4%; $P < .001$). Patients without a discoid meniscus had increased rates of midbody tears (35% vs 18%; $P < .001$), posterior horn tears (81% vs 31%; $P < .001$), tears in multiple locations (29% vs 21%; $P = .009$), bucket-handle tears (30% vs 6%; $P < .001$), vertical tears (34% vs 6%; $P < .001$), ACL tears (62% vs 5%; $P < .001$), MCL injuries (4% vs 0%; $P = .002$), and tibial spine fractures (4% vs 0%; $P = .004$). Full comparison is detailed in Table 4.

DISCUSSION

Although much has been written about meniscal injuries in adults, less is known about injury patterns in pediatric meniscal tears. The purpose of this study was to evaluate a large series of patients to better illustrate trends in pediatric meniscal injury, such as patterns in tear type,

TABLE 4
Comparison of Characteristics, Tear Patterns, and Associated Injuries in Patients With or Without Discoid Meniscus[a]

		Discoid Meniscus	No Discoid Meniscus	*P*
Tear location	Anterior horn	25	16	**.004**
	Midbody	18	35	**<.001**
	Posterior horn	31	81	**<.001**
	Intrasubstance delamination	60	2	**<.001**
	Multiple locations	21	29	**.009**
Zone	Red-red zone	42	39	.681
	Red-white zone	52	54	.749
	White-white zone	41	43	.754
Tear type	Bucket handle	6	30	**<.001**
	Horizontal tear	21	11	**<.001**
	Vertical tear	6	34	**<.001**
	Flap	8	8	.885
	Parrot beak	7	9	.377
	Radial	6	9	.335
	Degenerative	47	22	**<.001**
	Complex	6	9	.129
	Oblique	1	1	.645
Associated lesion	Isolated meniscal tear	81	22	**<.001**
	Anterior cruciate ligament tear	5	62	**<.001**
	Parameniscal cyst	4	1	**.012**
	Medial collateral ligament injury	0	4	**.002**
	Tibial spine fracture	0	4	**.004**
	Osteochondritis dissecans lesion	11	4	**<.001**
Repeat surgeries	Reinjury rate	7	10	.288

[a]Values are expressed as percentages. The percentages may total more than 100% because patients may have met criteria for multiple categories. Bolded *P* values indicate statistically significant differences between patients with and without a discoid meniscus ($P \leq .05$).

location, and associated injuries, which potentially affect treatment approaches and outcomes. Risk factors for treatment failure include complex and bucket-handle tears, medial meniscal tears, and skeletal immaturity.[12] In our study, an overall reoperation rate of approximately 15% was found, including contralateral meniscal injury. Repeat ipsilateral injury was 11% in female patients compared with 8% in male patients ($P = .127$) and 10% in patients without a discoid meniscus versus 7% in patients with a discoid meniscus ($P = .288$). Differences in injury pattern may have affected the rates of treatment failure; however, stricter follow-up criteria are necessary to fully assess treatment failures and outcomes of treatment approaches for specific injuries.

Previous authors have reported a trend toward meniscal repair in younger patients because of a higher success rate compared with adults and the desire to reduce the risk of subsequent osteoarthritis.[5,20,25] Despite this, not all tear types are amenable to repair. Tear type may affect treatment success, with greater outcomes for simple tears compared with bucket-handle or complex tears.[11] In our series, male patients had more vertical tears (31% vs 21%; $P = .003$). Female patients, in contrast, had a higher rate of degenerative tears (34% vs 26%; $P = .012$), which can be more difficult to repair and have a higher failure rate.[11]

Tear location may also influence treatment decisions. For instance, the most common repair type in our study was an all-inside approach. However, all-inside repairs may be more difficult to perform in anterior horn tears, which were found more often in female patients in our study, and these tears may be more readily treated by an outside-in approach.[14] Additionally, it is not entirely clear whether the healing potential in the medial and lateral menisci differs.[21] Male patients were found to have more posterior horn tears (71% vs 60%; $P < .001$), which have been reported to have inferior healing potential compared with lesions extending into the middle segments.[19] The vascular zone of meniscal tears has also been shown to be an important factor in healing. Tears of the peripheral third of the meniscus, which were found in a higher proportion of male patients (45% vs 30%; $P = .001$), have demonstrated greater healing potential than more central tears.[1] However, the healing rate may not differ significantly between tears in the red-red zone compared with those in the red-white zone.[9]

Prior studies have noted a high proportion of isolated injuries in children (71%-100%).[1] However, in our series, associated lesions were observed in the majority of patients, with only 38% of meniscal tears occurring in isolation. The reason for this discrepancy is unclear, although it may be related to the population base or referral pattern at our institution. ACL ruptures were seen in approximately 46% of patients, although more commonly in male patients (50% vs 40%; $P = .001$). Of note, meniscal repairs during ACL reconstruction have a higher success rate compared with isolated meniscal injuries,[8,12,17] perhaps because of increased perfusion in response to ACL rupture or because of altered mechanics of the knee to protect the repair from the conditions that may have led to meniscal injury in the first place.[4,12] This difference in ACL tears may also help to explain some of the other differences in injury patterns. For instance, ACL injury is more commonly associated with acute lateral meniscal tears, as seen in the male patients in our study.

This study constitutes the largest series of meniscal tears in pediatric patients and provides a comprehensive summary of the meniscal injuries seen at a large, urban, tertiary referral center for sports injuries in children. The large catchment area affords a variety of patient populations, including urban, suburban, and rural. Our patients were consecutive and were not screened in any way other than age.

There are several limitations to this study. The majority of the data were abstracted from medical records and operative notes, and thus we were not able confirm other factors that may have been significant for healing potential.[21,24] In addition, our follow-up lacked patient-reported outcomes. Because outcome data were limited to the patients who required subsequent surgery at out institution, we were not

able to comment on which patients may have remained symptomatic or which patients benefited most from specific treatments. Patients may have presented to other medical institutions for follow-up care, and clinical data from these visits was not be available for our analysis. Additionally, our study is vulnerable to selection bias inherent in its retrospective design.

CONCLUSION

This study is the largest analysis of meniscal tears in children and gives valuable insight into the injury patterns of different types of meniscal tears seen in skeletally immature patients. Given the study size and breadth of the catchment area, this study may provide the most reliable data on patterns of meniscal tears in this population to date.

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