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What is This?

# Risk Factors for Meniscectomy After Meniscal Repair

Stephen Lyman,*† PhD, Chisa Hidaka,† MD, Ana S. Valdez,† BA, Iftach Hetsroni,‡ MD,
Ting Jung Pan,† MPH, Huong Do,† MS, Warren R. Dunn,§ MD, MPH,
and Robert G. Marx,‡ MD, MSc
*Investigation performed at the Hospital for Special Surgery, New York, New York*

**Background:** Previous research suggests that a substantial percentage of meniscal repairs fail, resulting in a subsequent meniscectomy. Risk factors for failure have been investigated using small cohorts, providing ambiguous results.

**Purpose:** To measure the frequency of and elucidate risk factors for subsequent meniscectomies after meniscal repair using a large study population from multiple surgical centers.

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

**Methods:** A total of 9529 patients who underwent 9609 outpatient meniscal repairs between 2003 and 2010 were identified from a statewide database of all ambulatory surgery in New York. Patients who subsequently underwent a meniscectomy were then identified. A Cox regression analysis was used to calculate the hazard ratio and 95% confidence intervals. The model included patient age, sex, comorbidities, concomitant arthroscopic procedures, laterality of the meniscus, and surgeon's yearly meniscal repair volume.

**Results:** The overall frequency of subsequent meniscectomies was 8.9%. Patients were at a decreased risk for subsequent meniscectomies if they underwent a concomitant anterior cruciate ligament (ACL) reconstruction ($P < .001$). Patients undergoing isolated meniscal repairs (without concomitant ACL reconstruction) were at a decreased risk if they were older ($P < .001$), had a lateral meniscal injury ($P = .002$), or were operated on by a surgeon with a higher annual meniscal repair volume (>24 cases/year; $P < .001$).

**Conclusion:** A meniscectomy after meniscal repair is performed infrequently, supporting the notion that repairing a meniscus is a safe and effective procedure in the long term. The risk for undergoing subsequent meniscectomies is decreased in patients undergoing a concomitant ACL reconstruction, in cases of isolated meniscal repairs for patients of older age, and in patients undergoing meniscal repair by surgeons with a high case volume.

**Keywords:** knee; meniscus; meniscal repair; meniscectomy; knee arthroscopic surgery

Meniscal injuries are the most common surgically treated condition of the knee. The incidence of meniscal tears is estimated to be 60 to 70 per 100,000 people, with as many as 850,000 meniscal procedures performed yearly in the United States.[6,22,37,47] Most meniscal injuries are treated by total or partial meniscectomy, but many studies have suggested that a repair may be a superior option, resulting in a lower likelihood of progresson to degenerative arthritis in the affected knee.[15,18,25,29,34,36,38-41] The theoretical advantage of a meniscal repair over meniscectomy is that the native anatomy is retained by suturing the meniscus back into place, providing additional stability to the knee.[20,22,30,34,44] A meniscectomy often removes only a portion of the meniscus but may leave the knee without its normal architecture and at a higher risk for osteoarthritis.[18,36,40,41,43]

Failure of a meniscal repair usually results in subsequent meniscectomies. Current data on failed repairs are inconsistent, with estimates of failure ranging from 5% to 43.5%, depending upon the study and follow-up time.[1,14,20,25,40,41,43,49] The rate of healing is more favorable for smaller tears, acute tears, and repairs performed with a concomitant anterior cruciate ligament (ACL)

reconstruction.[17,21,37,39,41,44,47,49] In some regard, arthroscopic evaluations are a "gold standard" for follow-up, but this method is invasive, is expensive, and can show evidence of degeneration in a clinically asymptomatic knee.[1] The prohibitive expense also limits the use of magnetic resonance imaging (MRI) or computed tomography (CT) arthrography as well as clinical measures of function for large-scale population-based studies of meniscal repair.[43,44] A need for reoperations after meniscal repair was used as the standard outcome measure in 26 of 32 studies evaluating meniscal repairs, according to a recent review.[40] The rate of reoperation appears to be a clinically relevant indicator that accounts for a "worst-case" outcome.

The aim of this investigation was to measure the frequency of meniscal repairs, discover the failure rate for a meniscal repair as reflected by subsequent meniscectomies, and determine the risk factors for a subsequent meniscectomy after repair in a large population-based cohort.

## MATERIALS AND METHODS

The Statewide Planning and Research Cooperative System (SPARCS) database from the New York State Department of Health, a census of all hospital admissions and ambulatory surgery procedures within the state, was used to identify primary meniscal repairs performed on New York State residents in an ambulatory surgery setting between 2003 and 2010. Using this time period allowed us to identify and follow specific patients through unique patient identifiers and also to use Current Procedural Terminology, 4th edition (CPT4) modifiers to determine the laterality of the index and subsequent meniscal procedures. The SPARCS data are based on the uniform billing abstract (UB-04) for all patient discharges and ambulatory surgery visits.

The CPT4 coding was used for all procedures, while the *International Classification of Diseases, 9th Edition, Clinical Modification* (ICD-9-CM) coding was used for all diagnoses. Unique patient identifiers were used to identify all patients undergoing meniscal repair (CPT4 29882 or 29883). We also identified any concomitant procedures, specifically meniscectomy (CPT4 29880 or 29881), ACL reconstruction (CPT4 29888), chondroplasty (29877), microfracture (29879), and synovectomy (29875 or 29876). These concomitant knee procedures at the time of the index surgery were evaluated as potential risk factors for subsequent meniscectomies. Patients with meniscal repairs on both knees during the study period were followed independently (9609 meniscal repairs in 9529 patients).

All patient identifiers were followed forward over time to identify subsequent meniscectomy procedures (CPT4 29880 or 29881). The CPT4 codes have a modifier code available, which can be used to identify the laterality (left/right) for procedures, and only patients with this laterality indicator present in the index and subsequent procedure were included in the cohort (36 cases were excluded because of missing laterality).

Detailed clinical information was not available about the mechanism of injury, the duration of symptoms, or the severity of cartilage or meniscal damage because of the administrative nature of the database. However, through the use of ICD-9-CM diagnostic coding, we were able to determine if the underlying meniscal lesion represented the lateral (717.4 and 836.1) or medial (717.0-3 and 836.0) meniscus. Data were also available for patient age, sex, insurance status, year of surgery, and comorbid conditions (eg, history of myocardial infarction, liver disease). The Deyo modification of the Charlson Comorbidity Index was used to identify comorbidities.[12,16]

Physician license numbers are available in the SPARCS database for each ambulatory surgery case. Surgeon knee arthroscopic surgery and meniscal repair volumes were calculated for the 12 months before the index meniscal repair.

Descriptive statistics included means ± standard deviations, medians (interquartile ranges [IQRs]), and minimum and maximum values for continuous variables. Categorical variables were summarized using frequency counts and percentages. Multivariable analysis was performed using a Cox proportional hazards regression. This time-to-event analysis calculated survival curves and hazard ratios (HRs), 95% confidence intervals (95% CIs), and *P* values. The assumption of proportional hazards was violated between patients with concomitant ACL reconstruction and isolated meniscal repair. Therefore, we performed separate Cox regression analyses for patients with and without concomitant ACL reconstructions. All potential risk factors were eligible for inclusion to adjust for potential unmeasured confounding.[23] These included age (categorized into <20, 20-29, 30-39, and ≥40 years), sex, comorbidity, condition of meniscus, medial/lateral meniscus, other concomitant knee surgery, and surgeon volume. A *P* value of <.05 was considered statistically significant in the identification of risk factors in this model. Time from the index meniscal repair to subsequent meniscectomies was calculated in days for all patients who underwent subsequent surgery (on the same knee). Patients who did not undergo a subsequent meniscectomy had their follow-up time calculated as the number of days between their date of surgery and December 31, 2010.

## RESULTS

Between 2003 and 2010, there were 9609 meniscal repairs performed in an ambulatory surgery setting among New York State residents (Table 1). The frequency of meniscal repairs was 1090 cases in 2003 and remained steady at about 1100 until 2006, after which yearly increases raised the number to 1601 by 2010 (Figure 1).

The median age at the first arthroscopic surgery was 27 years (IQR, 18-41 years), and 64.4% (n = 6181) of the patients were male. Most of the injuries were to the medial meniscus (71.7%). A vast majority of patients had no comorbid conditions (95.9%). Slightly less than half (41.7%; n = 3985) of all meniscal repairs were isolated procedures, and a similar proportion (40.5%; n = 3876) was performed with a concomitant ACL reconstruction (Table 1).

The median follow-up time was 156 weeks (IQR, 65-284 weeks). Subsequent meniscectomies were required for 847

TABLE 1
Patient Demographics and Surgeon's
Annual Volume (N = 9609)[a]

|  | Value |
|---|---|
| Age, y | |
| Mean ± SD | 30.8 ± 14.9 |
| Median (IQR) | 27 (18-41) |
| Sex, n (%) | |
| Male | 6181 (64.4) |
| Female | 3424 (35.6) |
| Meniscal lesion, n (%) | |
| Medial | 4588 (48.0) |
| Lateral | 2223 (23.3) |
| Both medial and lateral | 2261 (23.7) |
| Not specified | 489 (5.1) |
| Comorbidities, n (%) | |
| None | 9165 (95.9) |
| 1 | 377 (3.9) |
| ≥2 | 19 (0.2) |
| Follow-up, wk | |
| Mean ± SD | 177.3 ± 124.5 |
| Median (IQR) | 156 (65-284) |
| First procedure, n (%) | |
| Isolated | 3985 (41.7) |
| With ACL reconstruction | 3876 (40.5) |
| With meniscectomy | 1606 (16.8) |
| Second procedure, n (%) | |
| Subsequent meniscectomy | 847 (8.9) |
| Isolated | 594 (70.1) |
| With ACL reconstruction | 96 (11) |
| With meniscal repair | 40 (4.7) |
| With other knee procedures | 117 (17.8) |
| Time to meniscectomy, wk | |
| Mean ± SD | 88.1 ± 79.0 |
| Median (IQR) | 58 (32-119) |
| 95% CI | 82.7-93.4 |
| Surgeon's annual meniscal repair volume | |
| Mean ± SD | 9.2 ± 12.7 |
| Median (IQR) | 5 (1-10) |

[a]ACL, anterior cruciate ligament; IQR, interquartile range.



**Figure 1.** Number of meniscal repairs in New York State.

(8.9%) patients. The median time to a meniscectomy for these patients was 58 weeks (IQR, 32-119 weeks) (Table 1).

In preliminary Cox regression analyses using all patients and adjusting for all covariates, patients undergoing concomitant ACL reconstructions were found to be less likely to have a subsequent meniscectomy (HR, 0.74; 95% CI, 0.64-0.86; $P < .001$). However, because of this variable, the proportional hazards assumption was violated. Therefore, we assessed all other risk factors using separate Cox regression analyses for isolated meniscal repair and meniscal repair in the setting of concomitant ACL reconstructions (Table 2).

Multivariable analysis identified 3 statistically significant independent risk factors for a patient's likelihood to undergo a subsequent meniscectomy after meniscal repair. Among available patient characteristics, only age exhibited an association with patients aged >40 years having a decreased risk of meniscectomies compared with patients aged <20 years (HR, 0.53; CI, 0.40-0.70; $P < .001$) (Table 2),
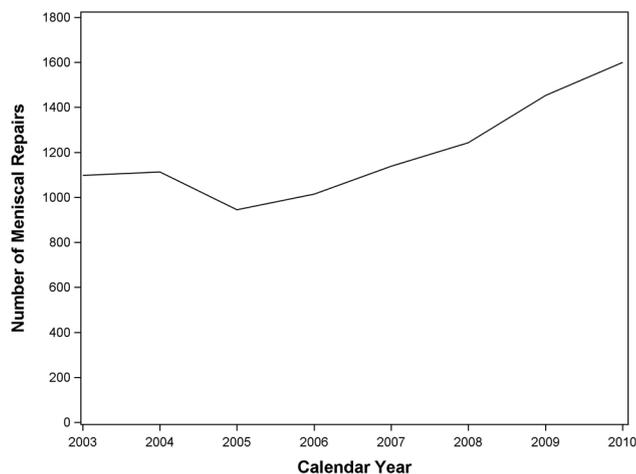
and this was only in patients undergoing isolated meniscal repairs. In patients undergoing concomitant ACL reconstructions, an increased risk approached but did not reach statistical significance in male patients ($P = .057$). With regard to the injured meniscus, lateral meniscal repair was associated with a decreased risk of subsequent meniscectomies in patients undergoing isolated repairs (HR, 0.71; CI, 0.56-0.89; $P = .003$) and also in those undergoing concomitant ACL repairs (HR, 0.67; CI, 0.48-0.94; $P = .021$) (Table 2). In cases of isolated meniscal repairs, an injury in both menisci protected the patient from subsequent surgery (HR, 0.70; CI, 0.49-1.00; $P = .02$) (Table 2). Isolated meniscal repairs by surgeons who performed >24 meniscal repairs per year had less than half the risk of subsequent meniscectomies compared with those by surgeons performing <24 cases per year (HR, 0.37; CI, 0.21-0.64; $P < .001$) (Table 2 and Figure 2), although the median annual meniscal repair volume of all surgeons was 5 (IQR = 1-10) (Table 1). A protective effect of surgeon's annual volume of meniscal repairs with concomitant ACL reconstructions approached but did not reach statistical significance ($P = .054$) (Table 2). The number of knee arthroscopic surgeries (any procedure, including but not exclusively meniscal repairs) performed by the surgeon each year had no effect (data not shown).

## DISCUSSION

This research was designed to quantify, at the population level, the frequency and risk factors for a meniscectomy after meniscal repair, which is an outcome that can be considered a proxy for failure of the repair. The number of meniscal repair cases rose from 1090 in 2003 to a peak of approximately 1601 cases per year by 2010. Given the substantial research associating meniscectomies with the development of early arthritis that was published just before this period,[‖] and the concomitant promotion of

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[‖]References 1, 6, 13, 14, 22, 25, 34, 38, 39, 43.

TABLE 2
Risk Factors for Meniscectomies After Isolated Meniscal Repair or Meniscal Repair With Concomitant ACL Reconstructions[a]

| | Isolated Meniscal Repair (n = 4003, Event = 424) | | Concomitant ACL Reconstruction (n = 3890, Event = 285) | |
|---|---|---|---|---|
| | Hazard Ratio (95% CI) | P Value | Hazard Ratio (95% CI) | P Value |
| Age, y | | | | |
| 20-29 vs <20 | 1.07 (0.84-1.36) | .610 | 0.81 (0.60-1.10) | .177 |
| 30-39 vs <20 | 0.80 (0.60-1.07) | .131 | 0.75 (0.53-1.06) | .107 |
| ≥40 vs <20 | 0.53 (0.40-0.70) | <.001 | 0.99 (0.71-1.37) | .927 |
| Male sex | 1.03 (0.84-1.27) | .770 | 1.29 (0.99-1.67) | .057 |
| Comorbidity | 0.70 (0.39-1.25) | .223 | 1.22 (0.69-2.13) | .495 |
| Annual meniscal repair volume | | | | |
| ≥24 vs <24 | 0.37 (0.21-0.64) | <.001 | 0.63 (0.39-1.01) | .054 |
| Meniscal lesion | | | | |
| Lateral vs medial | 0.71 (0.56-0.89) | .003 | 0.67 (0.48-0.94) | .021 |
| Both vs medial | 0.70 (0.49-1.00) | .050 | 0.94 (0.73-1.22) | .649 |

[a]Multivariable analysis was performed using a Cox proportional hazards regression to calculate risk factors for subsequent meniscectomies after meniscal repair. ACL, anterior cruciate ligament; event, subsequent meniscectomy.
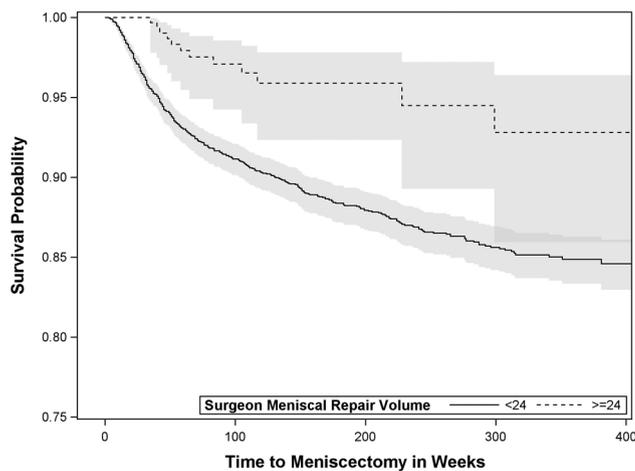


**Figure 2.** Survival of isolated meniscal repairs by surgeons performing <24 or >24 cases per year.

meniscal repair as a procedure that could preserve joint stability and prevent degeneration,[4,25-27,38,39] the increased frequency of meniscal repairs may represent an increase in the use of meniscal repairs as an alternative to meniscectomy rather than an increase in the frequency of meniscal injuries. To investigate these questions further, we are planning a future study to compare the frequency and effectiveness of meniscal repairs versus meniscectomies among patients eligible for either procedure.

The failure rate of 8.9% in this study is in the lower range of rates described by others; however, previous studies have been conducted on smaller numbers of patients within single practices,[¶] and some used the abnormal appearance of the meniscus on MRI, CT arthrography, or

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[¶]References 1, 15, 20, 25, 40, 41, 43, 44, 49.

second-look arthroscopic surgery as the primary measure of failure, regardless of clinical symptoms.[1,43] In contrast, a subsequent meniscectomy represents a definitive "worst-case" criterion for failure. Another possible explanation for the reduced failure rate in our study compared with previous investigations is the effect of changes in meniscal repair techniques, which have been modified over time. Older studies or studies performed in other geographical areas may represent the outcome of techniques that are different from those most common in New York State between 2003 and 2010. The recent study of Wasserstein et al[49] reported a reoperation rate that was nearly twice as high as ours; however, they did not specify what the subsequent procedure was or, in many cases, on which leg (ipsilateral or contralateral) the subsequent procedure was performed, making their study difficult to compare directly with ours. Patients who moved out of state after their primary procedure or those who elected to have their subsequent procedure performed outside of New York State may account for a systematic, although likely limited, underestimation in our study. Overall, our study suggests that when a large cohort is considered, the rate of clinical failure of meniscal repairs is lower than previously documented.

Meniscal repairs performed in the setting of concomitant ACL reconstructions had a lower risk of failure than isolated meniscal repairs. After isolated meniscal repairs, factors that were protective against meniscectomy were older age, involvement of the lateral meniscus, and higher annual meniscal repair volume for the surgeon performing the index meniscal repair (Table 2). It is likely that, aside from involvement of the lateral meniscus, the same protective factors were not apparent in patients undergoing concomitant ACL reconstructions because in those cases, the reason for failure of the meniscal repair related not only to failure of the meniscal repair itself but also to a lack of knee stability or even frank failure of the ACL reconstruction.

Among available patient characteristics, age was a strong predictor of a second surgery after isolated meniscal repair,

with patients under the age of 30 years experiencing significantly higher rates of subsequent meniscectomies than older patients. This was a somewhat surprising finding, as previous studies have suggested that the best candidates for a meniscal repair are young patients who may have a greater capacity for healing[21] and who are at an increased risk for developing early osteoarthritis after meniscectomy.[18] On the other hand, our data are consistent with recent findings by Noyes and Barber-Westin[37-39] that meniscal repairs healed equally well in younger and older patients, even when the injury was in the avascular middle zone, where healing has been previously thought to be less likely.

That concomitant ACL reconstruction results in improved outcome in meniscal repair has been shown in several previous studies, and several authors have posited that this is because traumatic injuries heal better than degenerative injuries.[3,10,19,32,34,36,37,48] Another reason that concomitant ACL reconstructions may decrease the risk of failure may relate to factors such as hemarthrosis during injury or concomitant surgery. Blood and/or bone marrow progenitor cells are reported to improve healing after cartilage, ACL, and/or meniscal injuries.[5,20,21,26,27,45,46] In addition, the prolonged recovery and rehabilitation protocols after concomitant ACL reconstructions may result in a protectively low postoperative activity level.

Lower preoperative or postoperative activity levels in older versus younger patients may also underlie the protective effect of older age in patients undergoing isolated meniscal repairs. It is possible that patients aged <30 years were more active or engaged in higher demand activities that resulted in tears that, because of their location or size, did not heal as well as those in patients aged >40 years. On the other hand, in older patients, who are generally not believed to heal well, surgeons might have been more judicious, choosing only to repair tears that were small or located in a vascularized zone. After surgery, young athletes demonstrate adherence rates as low as 40% and are less rigorous than older patients in carrying out rehabilitation and physical therapy protocols.[2,8,9,11,42] Young athletes also gravitate toward higher risk competitive and recreational activities and experience a greater urgency to return to sports, potentially prematurely.[24,33] Although some studies have suggested that a young patient's self-identification as an athlete is positively associated with home exercise adherence, many athletes struggle with lengthy time restrictions from competitive activity.[7,32] Accordingly, the literature supports the use of age-specific tactics for managing postoperative physical therapy and preventing future injuries,[6,7,11,31,33,50] and our findings support these previous observations. Older age was not a protective factor after meniscal repairs in the context of concomitant ACL reconstructions, and this is consistent with the idea that a lower activity level, and not age per se, is the reason for the protective effect in patients older than 40 years. Our database did not allow us to measure activity level directly, but our findings suggest that a future study of postoperative activity may provide insight into new strategies for improving outcomes of meniscal repairs in young patients and maintaining an active lifestyle in older patients.

Two additional findings corroborated previous reports regarding meniscal injury and repair. Our finding that the risk of failure was decreased after lateral meniscal repairs is in agreement with previous studies reporting that lateral meniscal tears are more likely to heal or remain asymptomatic.[19] We also found a higher incidence of repairs on the medial side, consistent with current epidemiological evidence that an injury to the medial meniscus is more common than on the lateral side.[6,14,29] These findings support the concept that higher biomechanical loads at the medial meniscus and its decreased mobility in the anteroposterior plane as compared with the lateral meniscus, as well as the function of the medial meniscus as a secondary restraint to anterior translation (particularly in ACL-deficient knees), make the medial meniscus more vulnerable to injuries and more difficult to treat.[14,17,19,22,30,34,36]

The protective effect of surgical volume is not surprising, given its robust documentation in the orthopaedic literature. Previous reports indicate that patients undergoing knee arthroscopic surgery by surgeons with higher yearly volumes are at a lower risk for nonroutine discharge from the hospital as well as surgical site infections.[28,35] Our study goes further, showing that expertise in a specific procedure, for which volume can be considered a rough measure, can be protective. Wasserstein et al[49] recently reported a modest nonsignificant effect of surgeon's meniscal repair volume (odds ratio of 1.25 for lowest volume surgeons) but used all subsequent knee surgeries as the outcome rather than subsequent meniscectomies. Despite this difference, ours and several previous studies of surgical volume underscore that surgeons who perform a higher number of a particular type of case per year have superior outcomes. If our findings are confirmed by others, a quantifiable measure of expertise (eg, performing >24 meniscal repairs per year) could be established, serving as the basis for developing policies that promote the utilization of high-volume surgical specialists to decrease health care costs and improve patient outcomes. This approach could possibly be used to improve care delivery and outcomes in any procedure in which the volume-outcome association is demonstrably robust. In the case of meniscal repairs, such an approach may be particularly important, as it was the only controllable factor in our study that improved patient outcome.

Using administrative databases for research involves inherent limitations. The information for each meniscal repair or meniscectomy is limited to CPT4 and ICD-9 codes, which do not always specify the extent or location of the tear. Given our finding that younger patients are at a higher risk for subsequent surgeries, a more detailed study in which tear size and location, as well as postoperative activity levels, can be assessed may lead to the development of selection criteria that improves surgical outcomes.

Although database studies have inherent limitations, the large sample size and use of the SPARCS database are major strengths of this study. These large numbers allow for an objective quantification of the risk factors associated with subsequent meniscectomies after meniscal

repair in this population. Hospitals are required by law to report to the SPARCS database, and therefore, the data are expected to be a complete record of all meniscal procedures performed in New York State between 2003 and 2010. It is unlikely that the few cases that might be missing from the database are systematically biased toward or away from our findings regarding subsequent meniscectomies.

In conclusion, we observed an 8.9% frequency of subsequent meniscectomies at a median follow-up of 156 weeks (3.0 years) after meniscal repair, suggesting that the procedure may be more successful than previously reported. The incidence of subsequent meniscectomies, a definitive indicator of the failure of a meniscal repair, is decreased in patients aged >40 years, injuries on the lateral meniscus, repairs performed with a concomitant ACL reconstruction, and cases by a surgeon performing >24 meniscal repairs per year. Because surgeon volume was the only controllable risk factor identified, our findings underscore the importance of further investigations of the volume-outcome association in meniscal repair.

## REFERENCES

1. Ahn JH, Lee YS, Yoo JC, Chang MJ, Koh KH, Kim MH. Clinical and second-look arthroscopic evaluation of repaired medial meniscus in anterior cruciate ligament-reconstructed knees. *Am J Sports Med*. 2010;39(3):472-477.
2. Andersen MB, Williams JM. A model of stress and athletic injury: prediction and prevention. *J Sport Exerc Psychol*. 1988;10(3):294-306.
3. Arnoczky SP, Warren RF. The microvasculature of the meniscus and its response to injury: an experimental study in the dog. *Am J Sports Med*. 1983;11:131-141.
4. Arnoczky SP, Warren RF, Spivak JM. Meniscal repair using an exogenous fibrin clot: an experimental study in dogs. *J Bone Joint Surg Am*. 1988;70:1209-1217.
5. Bae DK, Yoon KH, Song SJ. Cartilage healing after microfracture in osteoarthritic knees. *Arthroscopy*. 2006;22(4):367-374.
6. Baker BE, Peckham AC, Pupparo F, Sanborn JC. Review of meniscal injury and associated sports. *Am J Sports Med*. 1985;13(1):1-4.
7. Barber FA. Accelerated rehabilitation for meniscus repairs. *Arthroscopy*. 1994;10(2):206-210.
8. Brewer BW, Cornelius AE, Van Raalte JL, et al. Age-related differences in predictors of adherence to rehabilitation after anterior cruciate ligament reconstruction. *J Athl Train*. 2003;38(2):158-162.
9. Brewer BW, Van Raalte JL, Cornelius AE, et al. Psychological factors, rehabilitation adherence, and rehabilitation outcome after anterior cruciate ligament reconstruction. *Rehabil Psychol*. 2000;45(1):20-37.
10. Cannon WD Jr, Vittori JM. The incidence of healing in arthroscopic meniscal repairs in anterior cruciate ligament reconstructed knees versus stable knees. *Am J Sports Med*. 1992;20:176-181.
11. Cano LA, Zafra AO, Toro EO, Ros FE. Mood states and adherence to rehabilitation for injured athletes. *Apunts Med Esport*. 2009;161:29-37.
12. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40:373-383.
13. DeHaven KE. Decision making factors in the treatment of meniscal lesions. *Clin Orthop Relat Res*. 1990;252:49-54.
14. DeHaven KE. Meniscus repair. *Am J Sports Med*. 1999;27:242-250.
15. DeHaven KE, Lohrer WA, Lovelock JE. Long-term results of open meniscal repair. *Am J Sports Med*. 1995;23:524-530.
16. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *J Clin Epidemiol*. 1992;45:613-619.
17. Eggli S, Wegmuller H, Kosina J, Huckell C, Jakob RP. Long-term results of arthroscopic meniscal repair: an analysis of isolated tears. *Am J Sports Med*. 1995;23:715-720.
18. Fairbank T. Knee joint changes after meniscectomy. *J Bone Joint Surg Br*. 1948;30(4):664-670.
19. Fitzgibbons RE, Shelbourne KD. ''Aggressive'' nontreatment of lateral meniscal tears seen during anterior cruciate ligament reconstruction. *Am J Sports Med*. 1995;23:156-159.
20. Freedman KB, Nho SJ, Cole BJ. Marrow stimulating technique to augment meniscus repair. *Arthroscopy*. 2003;19(7):794-798.
21. Gobbi A, Bathan L, Boldrini L. Primary repair combined with bone marrow stimulation in acute anterior cruciate ligament lesions: results in a group of athletes. *Am J Sports Med*. 2009;37:571-578.
22. Greis PE, Bardana DD, Holmstrom MC, Burks RT. Meniscal injury, I: basic science and evaluation. *J Am Acad Orthop Surg*. 2002;10:168-176.
23. Harrel FE. *Regression Modeling Strategies: With Applications to Linear Models, Logistic Regression, and Survival Analysis*. New York: Springer Publishing; 2001.
24. Healy WL, Iorio R, Lemos MJ. Athletic activity after total knee arthroplasty. *Clin Orthop Relat Res*. 2000;380:65-71.
25. Heckmann TP, Barber-Westin SD, Noyes FR. Meniscal repair and transplantation: indications, techniques, rehabilitation, and clinical outcome. *J Orthop Sports Phys Ther*. 2006;36(10):795-814.
26. Ishimura M, Ohgushi H, Habata T, Tamai S, Fujisawa Y. Arthroscopic meniscal repair using fibrin glue, part 1: experimental study. *Arthroscopy*. 1997;13(5):551-557.
27. Ishimura M, Ohgushi H, Habata T, Tamai S, Fujisawa Y. Arthroscopic meniscal repair using fibrin glue, part II: clinical applications. *Arthroscopy*. 1997;13(5):558-563.
28. Jain N, Pietrobon R, Guller U, Shankar A, Ahluwalia AS, Higgins LD. Effect of provider volume on resource utilization for surgical procedures of the knee. *Knee Surg Sports Tramatol Arthrosc*. 2005;13:302-312.
29. Jones JC, Burks R, Owens BD, Sturdivant RX, Svoboda SJ, Cameron KL. Incidence and risk factors associated with meniscal injuries among active-duty military service members. *J Athl Train*. 2012;47(1):67-73.
30. Jonsson H, Karrholm J, Elmqvist LG. Kinematics of active knee extension after tear of the anterior cruciate ligament. *Am J Sports Med*. 1989;17(6):796-802.
31. Kuster MS. Exercise recommendations after total join replacement: a review of the current literature and proposal of scientifically based guidelines. *Sports Med*. 2002;32(7):433-445.
32. Lehtonen A, Viljanto J, Karkkainen J. The mucopolysaccharides of herniated human intervertebral discs and semilunar cartilages. *Acta Chir Scand*. 1967;133:303-306.
33. Levy AR, Polman RCJ, Borkoles R. Examining the relationship between perceived autonomy support and age in the context of rehabilitation adherence in sport. *Rehabil Psychol*. 2008;53(2):224-230.
34. McCarty EC, Marx RG, DeHaven KE. Meniscus repair: considerations in treatment and update of clinical results. *Clin Orthop Relat Res*. 2002;402:122-134.
35. Meyer E, Weitzel-Kage D, Sohr D, Gastmeier P. Impact of department volume on surgical site infections following arthroscopy, knee replacement or hip replacement. *BMJ Qual Saf*. 2011;20:1069-1074.
36. Newman AP, Daniels AU, Burks RT. Principles and decision making in meniscal surgery. *Arthroscopy*. 1993;9(1):33-51.
37. Noble J, Hamblen DL. The pathology of the degenerate meniscus lesion. *J Bone Joint Surg Br*. 1975;57(2):180-186.
38. Noyes FR, Barber-Westin SD. Arthroscopic repair of meniscal tears extending into the avascular zone in patients younger than 20 years of age. *Am J Sports Med*. 2002;30(4):598-600.
39. Noyes FR, Barber-Westin SD. Arthroscopic repair of meniscus tears extending into the avascular zone with or without anterior cruciate ligament reconstruction in patients 40 years of age and older. *Arthroscopy*. 2000;16(8):822-829.

40. Paxton ES, Stock MV, Brophy RH. Meniscal repair versus partial meniscectomy: a systematic review comparing reoperation rates and clinical outcomes. *Arthroscopy*. 2011;27(9):1275-1288.
41. Pujol N, Barbier O, Boisrenoult P, Beaufils P. Amount of meniscal resection after failed meniscal repair. *Am J Sports Med*. 2011;39(8):1648-1652.
42. Quatman CE, Quatman CC, Hewett TE. Prediction and prevention of musculoskeletal injury: a paradigm shift in methodology. *Br J Sports Med*. 2009;43:1100-1107.
43. Rockborn P, Messner K. Long-term results of meniscus repair and meniscectomy: a 13 year functional and radiographic follow-up study. *Arthroscopy*. 2000;8:2-10.
44. Salata MJ, Gibbs AE, Sekiya JK. A systematic review of clinical outcomes in patients undergoing meniscectomy. *Am J Sports Med*. 2010;38:1907-1916.
45. Steadman JR, Cameron-Donaldson ML, Briggs KK, Rodkey WG. A minimally invasive technique (''healing response'') to treat proximal ACL injuries in skeletally immature athletes. *J Knee Surg*. 2006;19(1):8-13.
46. Steadman JR, Rodkey WG, Rodrigo JJ. Microfracture: surgical technique and rehabilitation to treat chondral defects. *Clin Orthop Relat Res*. 2001;391(Suppl):S362-S369.
47. Tenuta JJ, Arciero RA. Arthroscopic evaluation of meniscal repairs: factors that effect healing. *Am J Sports Med*. 1994;22(6):797-802.
48. Toman CV, Dunn WR, Spindler KP, et al. Success of meniscal repair at anterior cruciate ligament reconstruction. *Am J Sports Med*. 2009;37:1111-1115.
49. Wasserstein D, Dwyer T, Gandhi R, Austin PC, Mahomed N, Ogilvie-Harris D. A matched-cohort population study of reoperation after meniscal repair with and without concomitant anterior cruciate ligament reconstruction. *Am J Sports Med*. 2013;41(2):349-355.
50. Weiss MR. Psychological aspects of sport-injury rehabilitation: a developmental perspective. *J Athl Train*. 2003;38(2):172-175.

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