AJSM PreView, published on July 17, 2013 as doi:10.1177/0363546513495641

Trends in Meniscus Repair and Meniscectomy in the United States, 2005-2011

Geoffrey D. Abrams,*† MD, Rachel M. Frank,† MD, Anil K. Gupta,† MD, MBA, Joshua D. Harris,† MD, Frank M. McCormick,† MD, and Brian J. Cole,† MD, MBA
Investigation performed at the Department of Orthopedic Surgery, Rush University Medical Center, Chicago, Illinois

Background: Meniscus deficiency may lead to degenerative arthritis in the knee. There is a significant emphasis on meniscus preservation, particularly in the young patient, to reduce the risk of arthritis.

Purpose: To report on the incidence of meniscus repair and meniscectomy, with and without concomitant anterior cruciate ligament (ACL) reconstruction, in the United States (US) over the past 7 years.

Study Design: Descriptive epidemiology study.

Methods: Patients who underwent arthroscopic meniscectomy (*Current Procedural Terminology* [*CPT*] codes 29880 and 29881), meniscus repair (*CPT* codes 29882 and 29883), and ACL reconstruction (*CPT* code 29888) for the years 2005 through 2011 were identified using the PearlDiver Patient Record Database. Age group and sex were collected for each patient. Patient groups included meniscectomy alone, meniscus repair alone, meniscus repair followed by meniscectomy, ACL reconstruction with concomitant meniscus repair, and ACL reconstruction with concomitant meniscus repair followed by meniscectomy. Linear regression and Student *t* tests were utilized for comparisons, with an α value of .05 set as significant.

Results: The database represented approximately 9% of the US population under 65 years of age. There was no significant change in the number of patients in the covered population during the study time frame ($P = .138$). From 2005 to 2011, there were a total of 387,833 meniscectomies, 23,640 meniscus repairs, and 84,927 ACL reconstructions. There was a significant increase in the total number of isolated meniscus repairs performed ($P = .001$) and a doubling of the incidence of repairs from 2005 to 2011. There was no significant increase in the total number of meniscectomies performed ($P = .712$), while the incidence of meniscectomies increased only 14% from 2005 to 2011. There was no significant change in the number of meniscus repairs performed at the same time as ACL reconstruction during the study time frame. The total number and incidence of meniscectomies after repair with and without ACL reconstruction significantly decreased.

Conclusion: There has been an increased number of isolated meniscus repairs being performed in the US over the past 7 years without a concomitant increase in meniscectomies over the same time frame. These data suggest that meniscus repairs are preferentially being performed over meniscectomies.

Keywords: meniscus; repair; ACL; knee; meniscectomy; osteoarthritis

Meniscus tears are common injuries and may result either from acute knee trauma or by more degenerative processes.[12,18] Current options for a meniscus injury include nonoperative treatment, meniscectomy, repair, and transplantation.[23] Meniscus repair is preferred to meniscectomy, when possible, as meniscus-deficient knees are at a significantly increased risk of developing osteoarthritis (OA).[13] When meniscus deficiency exists, meniscus replacement may also be an option in a subset of patients.[11,28] This is because the function of the meniscus is to provide for an even load distribution across the joint, thereby decreasing peak contact forces on the tibiofemoral articular cartilage.[4,6,10] In the setting of concomitant anterior cruciate ligament (ACL) injuries, it has been estimated that approximately 50% of meniscus tears are amenable to repair and may heal with increased frequency (as compared with a meniscus tear without an ACL tear) because of the biological milieu created by the ACL reconstruction.[2,7,24]

Given the association with meniscus deficiency and OA, there has been an emphasis placed on physician education

*Address correspondence to Geoffrey D. Abrams, MD, Rush University Medical Center, Department of Orthopedic Surgery, 1611 West Harrison Street, Suite 300, Chicago, IL 60612 (e-mail: gabrams@gmail.com).
†Department of Orthopedic Surgery, Rush University Medical Center, Chicago, Illinois.

One or more of the authors has declared the following potential conflict of interest or source of funding: B.J.C.: royalties (Arthrex Inc, DJ Orthopaedics, Elsevier, Lippincott, Smith & Nephew, WB Saunders), paid presentations (Genzyme), paid consultant (Zimmer, Arthrex Inc, Carticept, Biomimmetic, Allosource, DePuy), and research support (Regentis, Arthrex Inc, Smith & Nephew, DJ Orthopaedics, Zimmer, DePuy).

The American Journal of Sports Medicine, Vol. XX, No. X
DOI: 10.1177/0363546513495641

regarding meniscus repair and preservation at national orthopaedic surgery meetings as well as printed educational material (Bedi A, Verdonk R, Kaeding CC. "Instructional Course Lecture 332. Meniscus Repair and Transplantation: Update on Surgical Techniques and Clinical Outcomes." Presented at the 2012 AAOS Annual Meeting, 2012).[29] This education includes instructional course lectures, presentations of original research, case discussions by experts in the area of knee arthroscopic surgery and orthopaedic sports medicine, and news bulletins/magazines published by a variety of orthopaedic organizations. Furthermore, the literature has seen an increase in the number of studies investigating methods, techniques, and outcomes after meniscus repair. A Medline search for articles from 2008 to 2012 with the subject "meniscus repair" returned 311 investigations, while the same search returned only 173 hits for studies published from 2000 to 2004. It is unknown, however, whether this education about the long-term effects of meniscus deficiency and emphasis on meniscus preservation has translated into increasing rates of meniscus repairs in the United States (US).

The purpose of this study was to report the annual number of meniscus repairs and meniscectomies, either with or without concomitant ACL reconstruction, over the past 7 years in the US for privately insured non-Medicare patients. The authors hypothesized that the rate and trend of meniscus repairs would increase from 2005 to 2011 and that a majority of meniscus repairs would be performed in the age group of 25 years and younger. Further, the number of patients undergoing concomitant meniscus repair (vs meniscectomy) with ACL reconstruction would increase over the study's time frame.

MATERIALS AND METHODS

The PearlDiver Patient Record Database (PearlDiver Inc, Fort Wayne, Indiana) was queried for the years 2005 through 2011. There were no Medicare claims data included in the current dataset. The number of patients having a record of *Current Procedural Terminology* (*CPT*) codes 29880 (arthroscopy, knee, surgical; with meniscectomy [medial AND lateral, including any meniscal shaving] including debridement/shaving of articular cartilage [chondroplasty], same or separate compartment(s), when performed), 29881 (arthroscopy, knee, surgical; with meniscectomy [medial OR lateral, including any meniscal shaving] including debridement/shaving of articular cartilage [chondroplasty], same or separate compartment(s), when performed), 29882 (arthroscopy, knee, surgical; with meniscus repair [medial OR lateral]), 29883 (arthroscopy, knee, surgical; with meniscus repair [medial AND lateral]), and 29888 (arthroscopically aided anterior cruciate ligament repair/augmentation or reconstruction) were recorded.

Data were stratified to create groups undergoing (1) isolated meniscus repair, (2) isolated meniscectomy, (3) isolated meniscus repair followed by meniscectomy, (4) concomitant meniscus repair and ACL reconstruction, and (5) concomitant meniscus repair and ACL reconstruction followed by meniscectomy.

The PearlDiver database is a publicly available, Health Insurance Portability and Accountability Act (HIPAA)–compliant national database compiled from a collection of private insurer records, with UnitedHealth Group (Minneapolis, Minnesota) representing the largest contributing individual health plan. The database specifically has more than 2 billion individual patient records and contains *CPT* and *International Classification of Diseases, 9th Revision* (*ICD-9*) codes related to orthopaedic procedures. From 2005 to 2011, the database captured 22.4 to 26.3 million patients (8.3%-9.9% of the US population) for each year included in the analysis. In addition to *CPT* and *ICD-9* codes, demographic data such as age and sex were also recorded.

Kolmogorov-Smirnov testing revealed a Gaussian distribution of the data. Linear regression was utilized to compare the trends in meniscectomy, meniscus repair, and ACL reconstruction from 2005 through 2011. Comparisons were also made between the number of patients undergoing meniscus repair followed by meniscectomy as well as concomitant ACL reconstruction and meniscus repair followed by meniscectomy at any time in the captured follow-up period. Analysis of variance (ANOVA) and the Student *t* test were used to compare the number of patients in each age category as well as the percentage of male and female patients in each group. An α value of .05 was set as significant.

RESULTS

The database consisted of an average of 24.8 million people per year. From 2005 to 2011, there were a total of 387,833 meniscectomies, 23,640 meniscus repairs, and 84,927 ACL reconstructions (Table 1). Of those having meniscus repairs, 1826 went on to have meniscectomies at any time during the follow-up period. An additional 13,508 patients had concomitant ACL reconstruction and meniscus repair, with 833 of these patients undergoing eventual meniscectomy. The incidence (per year) of all outcome measures is presented in Table 2. There was no significant change in the number of patients in the covered population during the study time frame ($P = .138$)

Within the meniscectomy cohort, there was a significantly higher proportion of patients in the 45- to 54-year age group as compared with the other age groups ($P = .002$). For meniscus repair, there were significantly more patients in the age group of younger than 25 years versus the other age cohorts ($P < .001$). Male patients made up 59.5% of the isolated meniscus repair group and 60.3% of the concomitant meniscus repair and ACL reconstruction group (Table 1).

There was no significant increase in the number of meniscectomies (51,699/year vs 54,109/year, respectively; $P = .712$) or ACL reconstructions (11,106/year vs 12,365/year, respectively; $P = .074$) in comparing the years 2005 and 2011 (Figure 1). There was, however, an 11.4% increase in the number of meniscus repairs performed during this time frame (3196/year vs 3561/year, respectively; $P = .001$) (Figure 2). The incidence of meniscectomies increased by 14%; however, the incidence of meniscus

TABLE 1
Patient Information by Sex and Age for Those Undergoing Meniscectomies, Meniscus Repairs, and ACL Reconstructions during the Study Time Frame[a]

	2005	2006	2007	2008	2009	2010	2011
Meniscectomy							
Total	51,703	55,773	56,404	58,967	56,070	54,818	54,110
Sex							
Female	22,030 (42.6)	24,165 (43.3)	24,178 (42.9)	25,281 (42.9)	24,002 (42.8)	23,942 (43.7)	23,368 (43.2)
Male	29,673 (57.4)	31,608 (56.7)	32,226 (57.1)	33,686 (57.1)	32,068 (57.2)	30,876 (56.3)	30,742 (56.8)
Age, y							
<25	4450 (8.6)	4912 (8.8)	5069 (9.0)	5398 (9.2)	5170 (9.2)	5145 (9.4)	5216 (9.6)
25-34	4586 (8.9)	4812 (8.6)	4613 (8.2)	4987 (8.5)	4735 (8.4)	4354 (7.9)	4191 (7.8)
35-44	10,624 (20.6)	11,011 (19.7)	10,770 (19.1)	10,979 (18.6)	10,484 (18.7)	9936 (18.1)	9533 (17.6)
45-54	17,056 (33.0)	18,375 (33.0)	18,742 (33.2)	19,608 (33.3)	19,015 (33.9)	18,181 (33.2)	17,814 (32.9)
55-64	14,211 (27.5)	15,886 (28.5)	16,387 (29.1)	17,089 (29.0)	16,560 (29.5)	17,330 (31.6)	17,433 (32.2)
>64	971 (1.9)	984 (1.8)	1043 (1.9)	1164 (2.0)	326 (0.6)	49 (0.1)	60 (0.1)
Meniscus repair							
Total	3197	3249	3259	3428	3502	3447	3561
Sex							
Female	1240 (38.8)	1237 (38.1)	1310 (40.2)	1325 (38.7)	1339 (38.2)	1353 (39.3)	1401 (39.3)
Male	1957 (61.2)	2012 (62.0)	1949 (59.8)	2103 (61.4)	2163 (61.8)	2094 (60.8)	2160 (60.7)
Age, y							
<25	1362 (42.6)	1513 (46.6)	1531 (47.0)	1737 (50.7)	1704 (48.7)	1741 (50.5)	1967 (55.2)
25-34	672 (21.0)	665 (20.5)	668 (20.5)	665 (19.4)	730 (20.9)	705 (20.5)	695 (19.5)
35-44	627 (19.6)	585 (18.0)	598 (18.4)	568 (16.6)	580 (16.6)	571 (16.6)	510 (14.3)
45-54	349 (10.9)	335 (10.3)	317 (9.7)	347 (10.1)	355 (10.1)	298 (8.7)	299 (8.4)
55-64	194 (6.1)	158 (4.9)	155 (4.8)	131 (3.8)	146 (4.2)	140 (4.1)	104 (2.9)
>64	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
ACL reconstruction							
Total	11,108	11,678	11,855	12,984	12,642	12,305	12,365
Sex							
Female	4464 (40.2)	4634 (39.7)	4732 (39.9)	5159 (39.7)	5156 (40.8)	5230 (42.5)	5131 (41.5)
Male	6644 (59.8)	7044 (60.3)	7123 (60.1)	7825 (60.3)	7486 (59.2)	7075 (57.5)	7234 (58.5)
Age, y							
<25	4160 (37.5)	4480 (38.4)	4740 (40.0)	5109 (39.4)	5173 (40.9)	5099 (41.5)	5330 (43.1)
25-34	2785 (25.1)	2893 (24.8)	2764 (23.3)	3057 (23.6)	2932 (23.2)	2723 (22.1)	2760 (22.3)
35-44	2702 (24.3)	2759 (23.6)	2733 (23.1)	2938 (22.6)	2768 (21.9)	2701 (22.0)	2520 (20.4)
45-54	1305 (11.8)	1335 (11.4)	1390 (11.7)	1608 (12.4)	1552 (12.3)	1484 (12.1)	1441 (11.7)
55-64	226 (2.0)	285 (2.4)	296 (2.5)	367 (2.8)	309 (2.4)	354 (2.9)	353 (2.9)
>64	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

[a]Values are shown as n (%). *Current Procedural Terminology* (*CPT*) codes were as follows: meniscectomy, codes 29880/29881; meniscus repair, codes 29882/29883; and ACL reconstruction, code 29888. ACL, anterior cruciate ligament.

TABLE 2
Incidence per Year of Primary Outcomes Measures Within the PearlDiver Patient Record Database[a]

	2005	2006	2007	2008	2009	2010	2011
Meniscectomy	0.21	0.22	0.22	0.22	0.23	0.23	0.24
Meniscus repair	0.01	0.01	0.01	0.01	0.01	0.01	0.02
ACL reconstruction	0.05	0.05	0.05	0.05	0.05	0.05	0.06
ACL reconstruction with meniscus repair	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Meniscectomy after meniscus repair	12.4	12.5	11.1	9.0	3.8	3.0	3.3
Meniscectomy after ACL reconstruction/meniscus repair	10.9	11.0	9.1	7.4	2.5	2.4	2.5

[a]Values are shown as percentages, expressed as the number of procedures per year divided by the total captured population for the indicated year (meniscectomy, meniscus repair, anterior cruciate ligament [ACL] reconstruction, ACL reconstruction with meniscus repair) or divided by the patients previously undergoing the procedure of interest (meniscectomy after meniscus repair, meniscectomy after ACL reconstruction/meniscus repair).

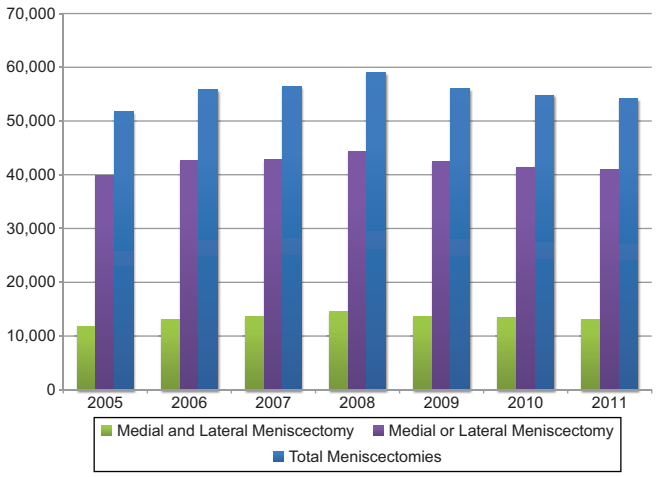

Figure 1. Total number of meniscectomies in the study population reported by year for the years 2005-2011.

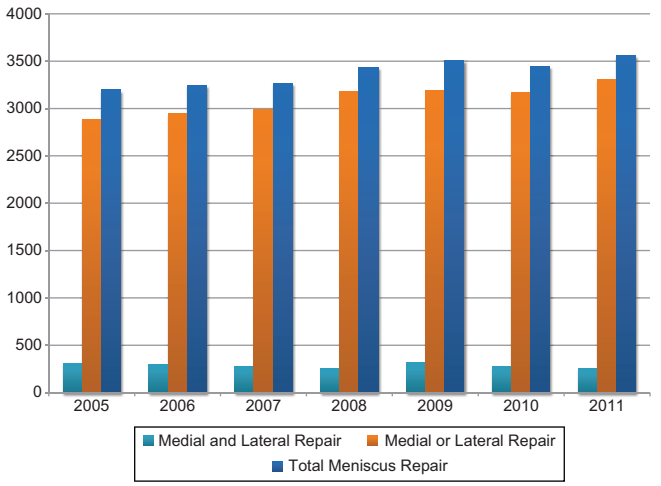

Figure 2. Total number of meniscus repairs in the study population reported by year for the years 2005-2011.

repairs increased by 100% during the study time frame (Table 2). The number of meniscus repairs performed at the same time as ACL reconstructions increased by 48.3% from 2005 to 2011 (1527/year vs 2265/year, respectively; $P < .001$), but the incidence did not significantly change (Table 2). Meniscectomies after previous concomitant ACL reconstruction and meniscus repair significantly decreased during the 2005 to 2009 time frame (167/year vs 52/year, respectively; $P = .007$) (Figure 3). This decrease also held for meniscectomy after isolated meniscus repair during the years 2005 to 2009 (392/year vs 192/year, respectively; $P = .049$) (Figure 3). There were also significant decreases in the incidence of both of these outcome measures, with a 69% reduction in meniscectomy after repair (average incidence of 9.8%) and a 77% decrease in meniscectomy after combined ACL reconstruction with meniscus repair (average incidence of 8.2%) (Table 2). There was no difference in the rate of decline between these measures.

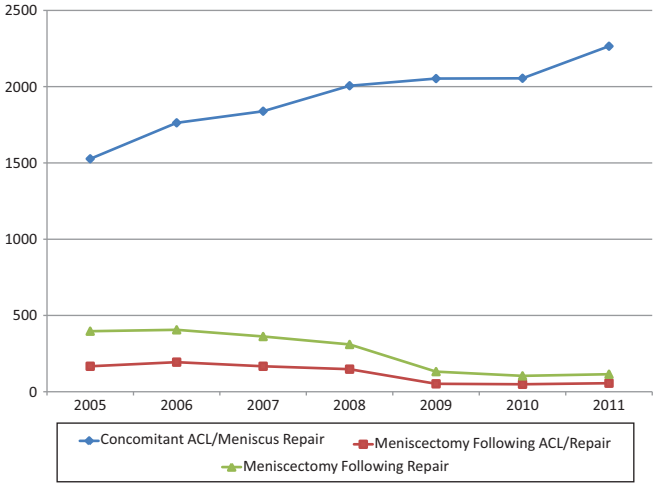

Figure 3. Total number of concomitant meniscus repairs and anterior cruciate ligament reconstructions as well as meniscectomies after previous repairs during the study time frame.

DISCUSSION

The current investigation found a significant increase in the number of meniscus repairs being performed over the past 7 years. This increase was not because of an overall increase in the number of meniscus procedures being performed, as the total number did not significantly increase during the study time frame. There was an 11.4% increase in the total number of meniscus repairs in the setting of an isolated meniscus tear, while the rate of repairs increased 48.3% when an ACL reconstruction was performed. The incidence of meniscectomies increased by 14%, while the incidence of meniscus repairs increased by 100% during the study time frame. In addition, we found that meniscectomy rates after prior repair with or without ACL reconstruction decreased from 2005 to 2009 and that young male patients more commonly received meniscus repairs.

Assuming that meniscus repair failure is defined as meniscectomy after meniscus repair, the failure rate in our population was approximately 9.8% after isolated meniscus repairs and 8.2% for meniscus repairs with ACL reconstruction. This is in line with a recent systematic review that showed an approximately 16.5% failure rate after isolated meniscus repairs at 0 to 4 years' follow-up (consistent with the length of follow-up in this investigation).[27] The same study reported reoperation rates of 12.4% and 8.0% for meniscus repairs performed with concomitant ACL reconstruction in the medial and lateral compartments, respectively. The slight difference in reported reoperation rates is likely caused by patient dropouts on a year-to-year basis within the included database cohorts of this investigation. The trend of repairs performed at the same time as ACL reconstruction leading to lower reoperation rates, however, is consistent.

There are many factors that influence a physician's practice pattern and habits, but the increased emphasis and education regarding the chondroprotective effects of the meniscus may be a major reason for the rise in the number of meniscus repairs performed from 2005 to 2011. The meniscus is a critical load-bearing structure and essentially functions to optimize contact area, evenly distribute load across the cartilage surface, and assist with knee stability. Lee et al[19] demonstrated that segmental medial meniscectomy is nearly equivalent to total meniscectomy when considering contact forces in the medial compartment. Similarly, Ode et al[26] found that complete radial tears of the lateral meniscus lead to significantly increased mean contact pressures and decreased contact areas when compared with the intact meniscus state. In addition to load dispersion, the posterior medial meniscus also acts as a secondary restraint to anterior translation of the tibia on the femur.[1] Because the posterior horn of the medial meniscus is relatively nonmobile, it experiences more shear stress in the ACL-deficient knee.[21] In the setting of ACL deficiency, therefore, this portion of the meniscus is particularly at risk for degeneration and tearing.[22]

While the above factors are likely to play a major role in the increase in the number of meniscus repair procedures, other factors may include advances in arthroscopic technique and instrumentation as well as a decrease in postoperative activity restrictions after repair. In the past, meniscus repair was performed through a formal joint arthrotomy. The increased morbidity to the patient, in addition to the difficulty in reaching more central tears, may have discouraged some physicians from performing repairs in borderline cases.[15,16] Advances in arthroscopic technique and technology, including the development of all-inside techniques, have made meniscus repair a more palatable procedure for surgeons.[14] In addition, some surgeons have been less cautious with postoperative rehabilitation, and some have allowed full weightbearing immediately after surgery.[33] This may provide for a more rapid return to activities of daily living, making the procedure more acceptable for patients, and therefore cause surgeons to perform meniscus repair more frequently. Other factors that may play a role include the possibility that, because of advances in equipment and technique as well as the easier dissemination of surgical technique information, general orthopaedic surgeons are now more comfortable with performing meniscus repairs. Furthermore, improved reimbursement rates for meniscus repair codes, in addition to the focus on meniscus preservation, may incentivize surgeons toward repair over meniscectomy. The decreased rate in meniscectomy after both meniscus repair as well as concomitant ACL reconstruction and meniscus repair is likely related to some of these same factors. Operative technique and knowledge of factors that stimulate meniscus healing (ie, trephination) improved clinical decision making, and the development of meniscus repair–specific rehabilitation protocols has likely contributed to this decrease.

Clinical results have supported the biomechanical data demonstrating the negative consequences of the meniscus-deficient knee. Stein et al[30] reported on the clinical benefits of meniscus repair versus meniscectomy in the prevention of radiographic arthritic changes in the knee. The authors found that 81% of patients with prior meniscus repairs showed no radiographic signs of arthritis at an average of 8.8 years' follow-up. This was significantly improved over the meniscectomy group in which only 40% of patients showed no arthritic progression.[30] Similarly, the chondroprotective effect of arthroscopic meniscus repair versus meniscectomy when performed with concomitant ACL reconstruction has been demonstrated in multiple studies.[3,16,17,20,25,31,32] This is most likely because healing rates of meniscus repairs performed in conjunction with ACL reconstruction have been shown to be significantly better than those performed in isolation.[2,7,24]

Given these data, meniscus repair has been advocated over meniscectomy whenever possible, particularly in the younger or adolescent patient. Our data show that a majority of meniscus repairs were performed in those younger than 25 years of age. This was in contrast to meniscectomy, which most commonly occurred in the older age groups. This overall increase in the meniscus repair rate is likely caused by the knowledge regarding the chondroprotective effects of the meniscus, but one cannot discount the fact that technical advances have allowed more surgeons to perform repairs. The fact that a majority of meniscus repairs occurred in the younger age population is also 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. For adults, the meniscus is vascular only in the peripheral 10% to 30% of its substance.[9] In children and adolescents, however, the blood supply to the meniscus is highly variable, and the central and middle thirds may still have vascular channels.[8] This is relevant, as the blood supply to the tissues at the location of the tear is directly related to its healing potential.[5] The findings of male patients having a greater proportion of meniscus repairs in this investigation may reflect the fact that the average young male patient may partake in an increased number of high-risk activities that predispose to knee injuries and subsequent meniscus tears.

Limitations to this study include the fact that the database did not capture other important demographic and epidemiological factors, including height, weight, body mass index, location of meniscus tear, type of meniscus repair, and activity level. These factors may ultimately play a role in both the decision to repair the meniscus as well as retear rates leading to future meniscectomy. Furthermore, as with any retrospective database investigation, the accuracy of coding within the system is critical to the validity of our findings. Given that this was a private health insurance database, however, the dictated operative reports from the procedures must be in agreement with the billing and diagnosis codes. In addition, as this database is based only on billing codes, the dataset was not able to decipher whether subsequent meniscectomy after meniscus repair occurred in the same compartment. Even assuming a worst-case scenario in which a majority of subsequent meniscectomies after repair were not performed in the same compartment, this would artificially raise the reported number of meniscectomies. This would lead to an even smaller proportion of meniscectomies after repair

in the involved compartment than reported in our results, further strengthening our statistical significance for this measure. Lastly, the database does not account for patients who drop out of the included health plans on a year-to-year basis. Because of this, the number of meniscectomies after the index meniscus repair may be underestimated. We chose, however, to report the 2005 to 2009 data for meniscectomy after repair in this particular analysis to ensure that we have at least 2-year follow-up information after repair to allow us to capture adverse events related to the repair, such as retears.

There are several strengths to this study. This study utilizes a large database of non-Medicare diagnosis and billing codes that represents almost 10% of the entire population of the US. Given that Medicare patients were excluded, it actually covers more than 10% of the total population younger than 65 years of age. Such a database allows for an accurate sample and distribution of patients throughout the US, and thus, our data are likely applicable to the practice tendencies of surgeons across the country. Furthermore, data acquisition and compilation are blinded, increasing the validity and decreasing any source of potential bias with regard to data reporting.

CONCLUSION

As education and peer-reviewed literature regarding the importance of meniscus preservation increase, it follows that the efforts to repair meniscus tears rather than perform meniscectomy, particularly in young patients, should follow. The current study shows that over the past 7 years, there was a significantly increased number of meniscus repairs being performed in the US. The findings presented in this investigation may be reflective of the focus on physician education regarding the importance of meniscus preservation and an increase in the number of publications regarding the topic.

REFERENCES

1. Ahn JH, Bae TS, Kang KS, Kang SY, Lee SH. Longitudinal tear of the medial meniscus posterior horn in the anterior cruciate ligament-deficient knee significantly influences anterior stability. *Am J Sports Med*. 2011;39(10):2187-2193.
2. 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;38(3):472-477.
3. Ahn JH, Wang JH, Yoo JC. Arthroscopic all-inside suture repair of medial meniscus lesion in anterior cruciate ligament–deficient knees: results of second-look arthroscopies in 39 cases. *Arthroscopy*. 2004;20(9):936-945.
4. Andersson-Molina H, Karlsson H, Rockborn P. Arthroscopic partial and total meniscectomy: a long-term follow-up study with matched controls. *Arthroscopy*. 2002;18(2):183-189.
5. 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(3):131-141.
6. Baratz ME, Fu FH, Mengato R. Meniscal tears: the effect of meniscectomy and of repair on intraarticular contact areas and stress in the human knee. A preliminary report. *Am J Sports Med*. 1986;14(4):270-275.
7. 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(2):176-181.
8. Carter CW, Kocher MS. Meniscus repair in children. *Clin Sports Med*. 2012;31(1):135-154.
9. Clark CR, Ogden JA. Development of the menisci of the human knee joint: morphological changes and their potential role in childhood meniscal injury. *J Bone Joint Surg Am*. 1983;65(4):538-547.
10. Cox JS, Nye CE, Schaefer WW, Woodstein IJ. The degenerative effects of partial and total resection of the medial meniscus in dogs' knees. *Clin Orthop Relat Res*. 1975;109:178-183.
11. De Coninck T, Huysse W, Willemot L, Verdonk R, Verstraete K, Verdonk P. Two-year follow-up study on clinical and radiological outcomes of polyurethane meniscal scaffolds. *Am J Sports Med*. 2013;41(1):64-72.
12. Englund M, Guermazi A, Gale D, et al. Incidental meniscal findings on knee MRI in middle-aged and elderly persons. *N Engl J Med*. 2008;359(11):1108-1115.
13. Fairbank JC, Pynsent PB, van Poortvliet JA, Phillips H. Mechanical factors in the incidence of knee pain in adolescents and young adults. *J Bone Joint Surg Br*. 1984;66(5):685-693.
14. Haas AL, Schepsis AA, Hornstein J, Edgar CM. Meniscal repair using the FasT-Fix all-inside meniscal repair device. *Arthroscopy*. 2005;21(2):167-175.
15. Hanks GA, Gause TM, Handal JA, Kalenak A. Meniscus repair in the anterior cruciate deficient knee. *Am J Sports Med*. 1990;18(6):606-611, discussion 612-613.
16. Hanks GA, Gause TM, Sebastianelli WJ, O'Donnell CS, Kalenak A. Repair of peripheral meniscal tears: open versus arthroscopic technique. *Arthroscopy*. 1991;7(1):72-77.
17. Jager A, Khoudeir S, Braune C, Herresthal J. [Can meniscal suture repair in athletes prevent early development of osteoarthritis without compromising the preinjury sports activity level]. *Sportverletz Sportschaden*. 2002;16(2):70-73.
18. Jeong HJ, Lee SH, Ko CS. Meniscectomy. *Knee Surg Relat Res*. 2012;24(3):129-136.
19. Lee SJ, Aadalen KJ, Malaviya P, et al. Tibiofemoral contact mechanics after serial medial meniscectomies in the human cadaveric knee. *Am J Sports Med*. 2006;34(8):1334-1344.
20. Majewski M, Stoll R, Widmer H, Muller W, Friederich NF. Midterm and long-term results after arthroscopic suture repair of isolated, longitudinal, vertical meniscal tears in stable knees. *Am J Sports Med*. 2006;34(7):1072-1076.
21. Markolf KL, Jackson SR, McAllister DR. Force measurements in the medial meniscus posterior horn attachment: effects of anterior cruciate ligament removal. *Am J Sports Med*. 2012;40(2):332-338.
22. Markolf KL, Mensch JS, Amstutz HC. Stiffness and laxity of the knee: the contributions of the supporting structures. A quantitative in vitro study. *J Bone Joint Surg Am*. 1976;58(5):583-594.
23. McCarty EC, Marx RG, DeHaven KE. Meniscus repair: considerations in treatment and update of clinical results. *Clin Orthop Relat Res*. 2002;402:122-134.
24. Melton JT, Murray JR, Karim A, Pandit H, Wandless F, Thomas NP. Meniscal repair in anterior cruciate ligament reconstruction: a long-term outcome study. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(10):1729-1734.
25. Muellner T, Egkher A, Nikolic A, Funovics M, Metz V. Open meniscal repair: clinical and magnetic resonance imaging findings after twelve years. *Am J Sports Med*. 1999;27(1):16-20.
26. Ode GE, Van Thiel GS, McArthur SA, et al. Effects of serial sectioning and repair of radial tears in the lateral meniscus. *Am J Sports Med*. 2012;40(8):1863-1870.
27. 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.
28. Saltzman BM, Bajaj S, Salata M, et al. Prospective long-term evaluation of meniscal allograft transplantation procedure: a minimum of 7-year follow-up. *J Knee Surg*. 2012;25(2):165-175.

29. Shelton WR, Sgaglione NA. *Meniscal Repair and Replacement*. Rosemont, Illinois: American Academy of Orthopaedic Surgeons; 2011.
30. Stein T, Mehling AP, Welsch F, von Eisenhart-Rothe R, Jager A. Long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. *Am J Sports Med*. 2010;38(8):1542-1548.
31. Tandogan RN, Taser O, Kayaalp A, et al. Analysis of meniscal and chondral lesions accompanying anterior cruciate ligament tears: relationship with age, time from injury, and level of sport. *Knee Surg Sports Traumatol Arthrosc*. 2004;12(4):262-270.
32. Tuckman DV, Bravman JT, Lee SS, Rosen JE, Sherman OH. Outcomes of meniscal repair: minimum of 2-year follow-up. *Bull Hosp Jt Dis*. 2006;63(3-4):100-104.
33. Vascellari A, Rebuzzi E, Schiavetti S, Coletti N. All-inside meniscal repair using the FasT-Fix meniscal repair system: is still needed to avoid weight bearing? A systematic review. *Musculoskelet Surg*. 2012;96(3):149-154.