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Are Meniscus and Cartilage Injuries Related to Time to Anterior Cruciate Ligament Reconstruction?

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Background: Functional instability after anterior cruciate ligament injury can be successfully treated with ligament reconstruction. However, the associated meniscus and cartilage lesions often cannot be repaired and may have long-term detrimental effects on knee function.

Purpose: The authors used the large database within the Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry to evaluate time to surgery, age, and gender as risk factors for meniscus and cartilage injury and associations with meniscus repair rates in patients.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A retrospective review of the Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry was performed. The associations between time to surgery, age, and gender with meniscus and cartilage lesions and meniscus repair were analyzed using binary logistic regression modeling to calculate odds ratios (ORs) while adjusting for potential confounding variables.

Results: A total of 1252 patients met the inclusion criteria. The risk of medial meniscus injury increased only with time to surgery (6–12 months: OR = 1.81, 95% confidence internal [CI] 1.29-2.54, $P = .001$; and >12 months: OR = 2.19, 95% CI 1.58-3.02, $P < .001$). The risk of lateral meniscus injury decreased only with female gender (OR = 0.65, 95% CI 0.51-0.83, $P = .001$). The risk of cartilage injury increased with age (OR = 1.05 per year, 95% CI 1.04-1.07, $P < .001$) and time to surgery >12 months (OR = 1.57, 95% CI 1.12-2.20, $P = .009$), but decreased with female gender (OR = 0.71, 95% CI 0.54-0.92, $P = .009$). Medial meniscus repairs relative to medial meniscus injury decreased with increasing time to surgery (3-6 months: OR = 0.61, 95% CI 0.37-1.00, $P = .050$; and >12 months: OR = 0.41, 95% CI 0.25-0.67, $P < .001$) and increasing age (OR = 0.96 per year, 95% CI 0.94-0.98, $P < .001$).

Conclusion: Increased risk of medial meniscus injury and decreased repair rate were strongly associated with increasing time to surgery. Increased risk of cartilage injury was associated with increasing age, increasing time to surgery, and male gender.

Keywords: anterior cruciate ligament (ACL) reconstruction; meniscus injury; cartilage injury; time to surgery

Injury to the anterior cruciate ligament (ACL) is a common source of knee instability with estimates of a 1 in 3000 incidence of this injury in the general population.[6] Ligament reconstruction is highly successful in restoring knee stability and may allow return to high-demand sporting activity.[6,17] Associated knee injuries, such as meniscus tears or cartilage lesions, are often present at the time of ligament reconstruction.[2,8,11]

Some meniscus and cartilage injuries are not amenable to surgical restoration of normal anatomy. The initial treatment in these situations often involves removal of loose, unstable tissue. Meniscus deficiency is known to place increased stress on the articular surface.[1,12] These associated lesions could occur with the initial ACL injury, from a previous injury, or from subsequent instability episodes.

Eliminating recurrent instability episodes by either avoiding activities such as high-demand pivoting sports that may cause giving way, or by undergoing ligament reconstruction before returning to such activities, may prevent meniscus and cartilage lesions. Delay in such interventions may lead to secondary injuries associated with giving-way episodes. This postulate, that late ACL reconstruction is associated with more meniscus and cartilage lesions, has been evaluated in several studies with varying sample sizes, patient populations, and results.‖ However, the interplay between

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‖References 3, 5, 7, 9, 10, 13-16, 18-20.

time to surgery (TS), age, and gender, especially related to meniscus repair rates, have not been reported, partially because of the smaller sample sizes of the previous studies. These are important factors that may influence a surgeon in advising a patient regarding the timing of his or her ACL reconstruction.

The purpose of this study was to use the large database within the Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry obtained from a regional general community population to (1) compare our findings with those of previous studies; (2) take advantage of the larger sample size to explore associations between time to surgery, age, and gender with meniscus injury, cartilage injury, and combined meniscus and cartilage injury pattern; and (3) determine the effect of TS, age, and gender on meniscus repair rates.

MATERIALS AND METHODS

The Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry is a longitudinal cohort of patients with prospective preoperative, intraoperative, and postoperative data collection. It was established in 2005 and registers patients within our large health maintenance organization from a large regional general community population. A cross-sectional analysis of patients from 3 different locations, with 20 participating surgeons, registered between February 1, 2005 and June 30, 2008, was performed.

For each patient, the data regarding TS, age, gender, previous knee surgery, concomitant ligament injury, meniscus injury and treatment, and any cartilage injury were collected. The TS was calculated as the time from the date of injury to the date of surgery. The date of injury was obtained from the patient's history. The injuries were recorded at the time of surgery by the surgeon. Patients with any history of previous knee surgery or multiligament injury were excluded from the study. A chart review was performed in our electronic medical record system when data were missing from the registry form.

The diagnosis of an ACL tear was made by the surgeon based on history and physical examination. Occasionally, MRI was used as an adjunct in initial evaluation. The decision to undergo ACL reconstruction was an elective decision made by the patient after being presented with treatment options and standard indications per surgeon preference. Those patients electing to have nonoperative treatment were not included in the registry or study. Meniscus repair was performed at the surgeon's intraoperative discretion. Cartilage injury was recorded as positive for any lesions noted intraoperatively (Noyes grade 1 through 3). Subclassification based on lesion grade, location, or treatment was not analyzed in this study.

The TS, age, and gender were the independent variables. The outcome variables were lateral meniscus injury, lateral meniscus repair, medial meniscus injury, medial meniscus repair, and any cartilage injury. Meniscus and cartilage injury were measured relative to the total number of patients in each group. Medial and lateral meniscus repair were measured relative to the number of patients in each group with medial and lateral meniscus injury, respectively. Additional outcome variables were isolated ACL injury without meniscus or cartilage injuries, and the combination pattern of ACL injury with associated meniscus and cartilage injuries.

Statistical Analyses

Time to surgery was analyzed as a continuous variable and as a categorical variable. All models with the continuous variable showed almost exact similar association estimates and had acceptable and comparable Hosmer-Lemeshow goodness-of-fit tests as the models with the categorical variable. Because continuous data are more difficult to interpret, the categorical variable model for TS was used. Gender was also evaluated as a categorical variable. Univariate analysis of the TS versus the various outcome variables was performed to estimate clinically relevant TS groups. The TS groups selected were 0 to 3 months, 3 to 6 months, 6 to 12 months, and greater than 12 months. Age was evaluated as a continuous variable.

The patient demographics were analyzed by comparing the 3 study variables among each other. The categorical variables, TS and gender, were compared using χ^2 and Fisher exact tests. The continuous variable, age, was compared with TS and gender using a nonparametric Kruskal-Wallis 1-way analysis of variance test.

Binary logistic regression models were created to evaluate the association between TS and the outcome variables while adjusting for the potential confounders, gender and age. Associations were reported in odds ratios (ORs) with 95% confidence intervals (CIs). In each model, all independent variables were assessed for collinearity using tolerance values <0.10 as diagnostic criteria; no collinearity was observed. All reported P values were 2-sided with statistical significance considered at a P value less than .05. All analyses were performed using SPSS for Windows Release 14.0.0 (SPSS Inc, Chicago, Illinois).

RESULTS

During the study period, 1501 patients were entered into the Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry, for whom preoperative and intraoperative data were collected. Within this cohort, 185 patients who had prior knee surgery, 60 patients who had multiligament knee injury, and 4 patients who lacked information regarding the date of injury were excluded, leaving a total of 1252 patients for our study group.

Analysis of patient demographics showed trends in TS, gender, and age, each of which were statistically independent by logistic regression. First, female patients had an earlier TS than males ($P < .001$) (Table 1). Second, female patients were younger than males at the time of surgery ($P < .001$) (Table 2). Third, younger patients had an earlier TS than older patients ($P < .001$) (Table 1).

Meniscus injuries also showed associations with TS and gender, but not age (Table 3). Medial meniscus injury was associated with TS, with the 6 to 12 months and >12 months groups both showing an increased risk of medial meniscus

TABLE 1
Study Population Demographics by Time to Surgery[a]

	Time to Surgery								
	0-3 Months		3-6 Months		6-12 Months		>12 Months		
	n	%	n	%	n	%	n	%	*P* Value
Total study population	340	27.2	352	28.1	246	19.6	314	25.1	
Gender									
Male	181	22.0	230	28.0	173	21.1	237	28.9	<.001
Female	159	36.9	122	28.3	73	16.9	77	17.9	
Mean age (SD), y	24.4 (10.2)		26.6 (11.3)		27.0 (10.9)		29.8 (9.4)		<.001

[a]SD, standard deviation.

injury compared with the 0 to 3 months group (OR = 1.81, 95% CI 1.29-2.54, *P* = .001 and OR = 2.19, 95% CI 1.58-3.02, *P* < .001, respectively). There was no statistically significant association between age or gender and medial meniscus injury. Lateral meniscus injury was negatively associated with female gender, showing a decreased risk of lateral meniscus injury compared with males (OR = 0.65, 95% CI 0.51-0.83, *P* = .001). There were no statistically significant associations with TS or age and lateral meniscus injury.

Injury to cartilage was associated with all 3 independent variables: TS, age, and gender (Table 3). Time to surgery >12 months was associated with an increasing risk of cartilage injury compared with the 0 to 3 months group (OR = 1.57, 95% CI 1.12-2.20, *P* = .009). Increasing age was associated with an increasing risk of cartilage injury (OR = 1.05 per year, 95% CI 1.04-1.07, *P* < .001). Female gender was associated with a decreasing risk of cartilage injury compared with males (OR = 0.71, 95% CI 0.54-0.92, *P* = .009).

The isolated ACL injury pattern without concomitant meniscus or cartilage injury was negatively associated with TS and age, but was not associated with gender (Table 3). The likelihood of this isolated ACL injury pattern decreased with greater time to surgery (TS 6-12 months: OR = 0.46, 95% CI 0.30-0.70, *P* < .001; TS >12 months: OR = 0.61, 95% CI 0.42-0.90, *P* = .012) and with increasing age (OR = 0.97 per year, 95% CI 0.96-0.98, *P* < .001). Conversely, the ACL injury pattern with concomitant meniscus and cartilage injury was associated with TS, age, and gender (Table 3). The risk of ACL injury pattern with meniscus and cartilage injury increased with greater TS (TS >12 months: OR = 1.55, 95% CI 1.09-2.20, *P* = .016) and with increasing age (OR = 1.04 per year, 95% CI 1.03-1.05, *P* < .001). This risk decreased with female gender compared with males (OR = 0.57, 95% CI 0.43-0.75, *P* < .001).

Meniscus repair rates were negatively associated with TS and age (Table 3). For medial meniscus repair rates, both the 3 to 6 months and >12 months groups were associated with a decreased medial meniscus repair rate compared with the 0 to 3 months group (OR = 0.61, 95% CI 0.37-1.00, *P* = .050; and OR = 0.41, 95% CI 0.25-0.67, *P* < .001, respectively). Increasing age was associated with a decreasing medial meniscus repair rate (OR = 0.96 per year, 95% CI 0.94-0.98, *P* < .001). There were no statistically significant associations between gender and medial meniscus repair.

TABLE 2
Study Population Average Age by Time to Surgery and Gender[a]

Gender	Time to Surgery	Mean	SD	*P* Value
Male	0-3 months	26.5	9.9	.001
	3-6 months	27.8	10.8	
	6-12 months	27.6	10.3	
	>12 months	29.6	8.7	
	Total	28.0	10.0	
Female	0-3 months	21.9	10.0	<.001
	3-6 months	24.4	11.8	
	6-12 months	25.5	12.0	
	>12 months	30.4	11.1	
	Total	24.7	11.4	

[a]SD, standard deviation.

For lateral meniscus repair rates, there were no statistically significant associations with TS, gender, or age.

DISCUSSION

Functional instability after ACL injury can be successfully treated with ligament reconstruction.[6,17] However, the associated meniscus and cartilage lesions often cannot be repaired and may have long-term detrimental effects on knee function.[1,2,8,11,12] The purpose of this study was to use the large database within the Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry obtained from a regional general community population to (1) compare our findings with those of previous studies; (2) take advantage of the larger sample size to explore associations between TS, age, and gender with meniscus injury, cartilage injury, and combined meniscus and cartilage injury pattern; and (3) determine the effect of TS, age, and gender on meniscus repair rates.

Previous studies with similar associations of increased meniscus and cartilage injury with increasing TS have been reported.[¶] Most were smaller case series,[3,7,9,13,14,16,19] with only a few being larger sample-size studies[5,10,15,18,20] similar

[¶]References 3, 5, 7, 9, 10, 13-16, 18-20.

TABLE 3
Binary Logistic Regression Model of the Associations of Time to Surgery, Gender, and Age With Meniscus Injury, Cartilage Injury, and Meniscus Repair[a]

		95% Confidence Interval		
	Odds Ratio	Lower	Upper	*P* Value
Medial meniscus injury				
Female vs male	0.80	0.63	1.03	.080
Age (per 1-year increment)	1.01	1.00	1.02	.102
0-3 months (reference category)	-	-	-	-
3-6 months	1.35	0.99	1.84	.058
6-12 months	1.81	1.29	2.54	.001
>12 months	2.19	1.58	3.02	<.001
Medial meniscus repair (n = 573)				
Female vs male	1.02	0.69	1.49	.934
Age (per 1-year increment)	0.96	0.94	0.98	<.001
0-3 months (reference category)	-	-	-	-
3-6 months	0.61	0.37	1.00	.050
6-12 months	0.76	0.45	1.27	.292
>12 months	0.41	0.25	0.67	<.001
Lateral meniscus injury				
Female vs male	0.65	0.51	0.83	.001
Age (per 1-year increment)	1.00	0.99	1.01	.495
0-3 months (reference category)	-	-	-	-
3-6 months	1.16	0.85	1.57	.345
6-12 months	1.24	0.89	1.73	.211
>12 months	1.08	0.78	1.49	.643
Lateral meniscus repair (n = 545)				
Female vs male	0.76	0.49	1.19	.230
Age (per 1-year increment)	0.98	0.97	1.00	.071
0-3 months (reference category)	-	-	-	-
3-6 months	1.21	0.71	2.06	.493
6-12 months	1.60	0.91	2.81	.103
>12 months	1.19	0.67	2.10	.557
Cartilage injury				
Female vs male	0.71	0.54	0.92	.009
Age (per 1-year increment)	1.05	1.04	1.07	<.001
0-3 months (reference category)	-	-	-	-
3-6 months	1.28	0.91	1.78	.151
6-12 months	1.34	0.93	1.93	.112
>12 months	1.57	1.12	2.20	.009
Isolated ACL				
Female vs male	1.28	0.96	1.70	.088
Age (per 1-year increment)	0.97	0.96	0.98	<.001
0-3 months (reference category)	-	-	-	-
3-6 months	0.78	0.55	1.09	.147
6-12 months	0.46	0.30	0.70	<.001
>12 months	0.61	0.42	0.90	.012
ACL + MM/LM + cartilage				
Female vs male	0.57	0.43	0.75	<.001
Age (per 1-year increment)	1.04	1.03	1.05	<.001
0-3 months (reference category)	-	-	-	-
3-6 months	1.11	0.77	1.58	.584
6-12 months	1.21	0.83	1.78	.322
>12 months	1.55	1.09	2.20	.016

[a]ACL, anterior cruciate ligament; MM, medial meniscus; LM, lateral meniscus.

to ours, evaluating multiple variables with a regression analysis. Some of these studies also included gender,[15] age,[10,15,18,20] and sports level[15,18] as variables. Our study reports associations among TS, gender, and age, and evaluates meniscus repair rate as an outcome variable.

Our patient demographics showed that female patients tended to be younger than 20 years of age at the time of surgery, and were more likely to have had surgery within 6 months of injury. Male patients tended to have surgery more commonly in the 20- to 40-year age range, and were

more equally distributed between early and late surgeries. This is most likely a reflection of contrasting age-related activity level between men and women. That is, women are more likely to peak in sports participation during their younger years, whereas men tend to participate in sports across a longer age span.[4]

Our data regarding gender associations, controlling for TS and age, showed that male patients had a higher rate of lateral meniscus injury, cartilage injury, and combined ACL, meniscus, and cartilage injury. O'Connor et al[15] showed that men had a consistently higher occurrence rate of meniscus injuries than did women, and that the risk of meniscus injuries increased at a higher rate over time among women. While these gender differences may be a result of men having a higher-energy initial injury or increased number of instability episodes before surgical intervention, this was not specifically evaluated in this study. Thus, female patients having surgery were younger and had a shorter time from injury to surgery. Even controlling for these gender differences in TS and age, female patients had fewer associated injuries when compared with males.

In our study, male gender was associated with a higher risk of lateral meniscus injury, but TS and age were not. Similarly, Tandogan et al[18] showed that the frequency of lateral meniscus tears remained fairly constant at 2 years' TS, and several of the smaller case series also showed that the lateral meniscus injury rates remained steady with increasing TS.[3,13,14] This might suggest that lateral meniscus injuries are more likely to occur at the time of injury, and medial meniscus injuries are more likely to occur during postinjury recurrent instability episodes. Some reports suggest that the increase in meniscus injury rate with time is partially attributable to deterioration in meniscus status from the time of initial injury.[7,9,19]

Other studies have cited that increased TS is a risk factor for increased medial meniscus injury, and that TS is a greater risk factor than age.[5,18,20] The remaining studies did not separate medial and lateral meniscus injury in their analysis, but did show that meniscus tears increased with TS.[10,15,16] Our study confirms previous findings that the 6-month and the 12-month TS points result in increased risk of medial meniscus injury, and further delineates associations between factors.

Cartilage changes may be preexisting and/or related to aging alone, and unrelated to the ACL injury and its treatment. In our study, age, TS greater than 12 months, and male gender all had a strong increase in the odds of having a cartilage injury. Similar findings regarding risk of age and TS for cartilage lesions were presented in a few of the other larger studies[10,15,18,20] and in several of the smaller case series.[3,9,14]

In our study, the isolated ACL injuries were more common in early TS and younger patients, whereas the ACL injuries with concomitant meniscus and cartilage injury pattern were more common with late TS, men, and older patients. Similarly, Granan et al[10] showed that cartilage lesions were nearly twice as frequent if there was a meniscus tear, and vice versa. Yüksel et al[20] showed the risk factor for coexistence of multiple lesions to be higher with age greater than 30 years and TS greater than 12 months.

To our knowledge, our study is the first to evaluate meniscus repair rate as associated with TS, age, and gender. Although lateral meniscus repair rate did not have any statistically significant associations, medial meniscus repair rate decreased with TS beyond 12 months and with increasing age. Therefore, with increasing TS, associated medial meniscus injury becomes more common and surgical repair becomes less likely. This is a key finding in our study that may influence a surgeon's recommendation on the timing of surgical intervention for ACL injuries. The medial meniscus may be susceptible in ACL-deficient knees that undergo recurrent instability because it is a secondary stabilizer to anterior translation. If such tears can be successfully repaired even with delayed surgical intervention, the long-term effect of delayed intervention and associated tears may be minimal. However, if a patient is more likely to have meniscus tears that are not repairable, restoration of normal knee mechanics and preservation of joint integrity may be compromised.

The strengths of this study include the large sample size of our cohort and the assessment of many different variables in our regression models. The large sample, which was derived from a community-based health maintenance organization, makes the findings applicable to the general population. The sample size of 1252 provided enough patients within each subgroup to show statistically significant differences. As such, we were able to analyze 3 independent variables and 6 outcome variables. By creating regression models and adjusting for confounding factors, the associations with the outcome variables were determined from the trends observed in the patient demographics. Our study is novel in including evaluation of all of these variables for relationships among each other, including separation of medial and lateral meniscus and also including meniscus repair rates.

The limitations of this study include possible omission of certain confounders that could not be measured by the registry, the limitations of the statistical methods applied, and possible selection and surgeon preference bias. Variables such as activity level before injury and during the time between injury and surgery, mechanism of injury, and body mass index could also be related to associated injuries or confound the associations observed in our study. While difficult to measure, more instability episodes before surgery and higher-energy contact injuries probably are more likely to be associated with concomitant meniscus or cartilage injuries. Eliminating recurrent instability episodes, by either avoiding activities such as high-demand pivoting and twisting sports that can cause giving way or by undergoing ligament reconstruction prior to returning to such activities, may prevent meniscus and cartilage lesions.

The regression models were robust with findings of strong statistical significance with odds ratios that were clinically meaningful. However, odds ratios measure effect size, describing the strength of association or nonindependence between 2 binary data values. They do not measure relative risk, which may be clinically more applicable and intuitive. The odds ratio can overestimate the actual effect.

As an ACL registry-based study, selection bias could be present as all patients who elected to have operative treatment were included and those who elected nonoperative treatment were not included. Those who elected to continue

nonsurgical treatment were likely coping with their ACL-deficient knee, and may have been less likely to have persistent instability and subsequent meniscus or cartilage injury. This patient selection bias could not be measured or estimated from this study, and may overestimate the proportion of patients having meniscus or cartilage injuries in the >12 months TS group. To confirm the reported trends, we also analyzed TS as a continuous variable. All models with the continuous variables showed similar association estimates and have acceptable (and comparable) Hosmer-Lemeshow goodness-of-fit tests as the ones presented in this article with the categorical variable. Nevertheless, the results of this study are applicable to those patients electing to have ACL reconstruction rather than all patients with an ACL injury.

Finally, there were 20 surgeons involved in the registry at the time of the study. Surgeon bias could have a nonstandardized influence on which patients elected to undergo surgery, the timing of the surgery, and the decision to choose meniscus repair over partial meniscectomy. All involved surgeons were fellowship-trained and established ACL surgeons with a general consensus on the indications for ACL diagnosis and reconstruction and for meniscus repair.[5] As such, it is unlikely that their indications for meniscus repairs would vary across the spectrum of patients at different TS intervals.

CONCLUSION

Female patients were younger at the time of surgery and had an earlier TS than males. Younger patients had an earlier TS than older patients. Male gender was associated with an increased risk of lateral meniscus injury, cartilage injury, and combined ACL, meniscus, and cartilage injury. Age was associated with an increased risk of cartilage injury, decreased medial meniscus repair rate, and increased ACL injuries with concomitant meniscus and cartilage injury pattern. Finally, longer TS increased the risk of medial meniscus injury, cartilage injury, and ACL injury with concomitant meniscus and cartilage injury pattern, and was associated with a decreased medial meniscus repair rate.

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