Lower Risk of Revision With Patellar Tendon Autografts Compared With Hamstring Autografts: A Registry Study Based on 45,998 Primary ACL Reconstructions in Scandinavia

Tone Gifstad, Olav A. Foss, Lars Engebretsen, Martin Lind, Magnus Forssblad, Grethe Albrektsen and Jon Olav Drogset

Am J Sports Med 2014 42: 2319 originally published online September 8, 2014
DOI: 10.1177/0363546514548164

Lower Risk of Revision With Patellar Tendon Autografts Compared With Hamstring Autografts

A Registry Study Based on 45,998 Primary ACL Reconstructions in Scandinavia

Tone Gifstad,*†‡ MD, PhD, Olav A. Foss,†‡ MD, PhD, Lars Engebretsen,§ MD, PhD, Martin Lind,‖ MD, PhD, Magnus Forssblad,¶ MD, PhD, Grethe Albrektsen,‡ PhD, and Jon Olav Drogset,†‡ MD, PhD
Investigation performed at Trondheim University Hospital, Trondheim, Norway

Background: A number of studies have found comparable results after anterior cruciate ligament (ACL) reconstruction with patellar tendon autografts and hamstring autografts; however, few studies have been large enough to reveal differences in risk of revision with regard to clinical and demographic factors.

Purpose: To present the distribution of grafts for ACL reconstruction based on data in the Scandinavian ACL registries and to compare the risk of revision between patellar tendon autografts and hamstring autografts. Potential associations with other clinical and demographic factors were also explored.

Study design: Cohort study; Level of evidence, 2.

Methods: A total of 45,998 primary ACL reconstructions, including 6736 patellar tendon autografts and 38,666 hamstring autografts, were identified in the Scandinavian ACL registries. The overall median follow-up time was 3 years (range, 0-8 years). To compare the risk of revision between groups of patients, univariate Kaplan-Meier analysis (with log-rank test) and the Cox proportional hazard regression model were applied. The hazard rate ratio with 95% CI was reported as a measure of effect.

Results: Patellar tendon and hamstring autografts were used in 14.6% and 84.1% of the patients, respectively. The remaining patients received allografts, direct sutures, or other graft types (1.3%). The primary ACL injury occurred during soccer, team handball, or alpine activities in 67.5% of the patients in the patellar tendon group and 66.2% in the hamstring group. A total of 156 patients in the patellar tendon group and 1042 patients in the hamstring group underwent revision. The overall risk of revision was significantly lower in the patellar tendon group versus the hamstring group (hazard rate ratio = 0.63; 95% CI, 0.53-0.74), and it decreased with increasing age at surgery, although not strictly linearly. The lower risk of revision in the patellar tendon group was consistently observed across subgroups of patient sex, age, and concomitant cartilage injury ($P > .05$, test for interaction) but seemed to be slightly more pronounced for patients injured during certain pivoting activities (soccer, team handball, and alpine activities) compared with other activities (hazard rate ratio = 0.57 vs 0.81; $P = .058$, test for interaction).

Conclusion: The majority of primary ACL reconstructions in Scandinavia are performed with hamstring autografts. Results from the present large prospective study show that patients receiving patellar tendon autografts have a statistically significantly lower risk of revision compared with patients receiving hamstring autografts.

Keywords: anterior cruciate ligament reconstruction; registry; graft; revision

The Norwegian National Knee Ligament Registry (NKLR) was officially established in June 2004. Sweden and Denmark based their registries on the Norwegian model and started the registration of patients in January 2005 and July 2005. The 3 main purposes of the registries are to identify procedures and devices that are inferior to others, to improve results through feedback to surgeons, and to identify various prognostic factors.[3,9] Close to 100% compliance has been found when comparing the reported cases in NKLR to hospital protocols and the Norwegian Patient Registry.[9] A follow-up study reported a registration rate of 86% in the NKLR.[35] The Danish[16,27] and Swedish registries[32] have also reported high completeness and good

The American Journal of Sports Medicine, Vol. 42, No. 10
DOI: 10.1177/0363546514548164

validity of data. All 3 registries publish annual reports that are available online.[2,24,32]

Patellar tendon and hamstring autografts are the 2 most common grafts used for anterior cruciate ligament (ACL) reconstruction in Scandinavia. Allografts are regularly used in other parts of the world but are very uncommon in primary ACL reconstructions in Scandinavia. On the basis of data for a 2-year period, Granan et al[10] reported that 71% of patients in Denmark were reconstructed with hamstring autografts, 61% in Norway, and 86% in Sweden. The latest report from the Swedish registry describes the use of hamstring autografts in 98% of the patients.[32] Hamstring autografts are usually double-looped semitendinosus and gracilis tendon grafts. Various donor-site problems, such as anterior knee pain and kneeling pain, have been reported as a result of the harvesting of patellar tendon autografts,[13,23] while reduced hamstring strength,[1,22] pain from hardware,[6] and increased knee laxity[4,6] have been described with hamstring autografts. A Cochrane review by Mohtadi et al[23] concluded that insufficient data exist to favor one graft type. In the search for the optimal graft, laxity assessments, muscle strength measurements, and patient-reported outcome scores, as well as the risk of revision, are all factors that need to be considered. Revision ACL reconstruction is a relatively rare event, and large registry-based prospective studies are needed to reveal differences in risk of revision according to clinical and demographic factors. Few previous studies have had sufficiently large data sets to explore this issue. Two recent studies from the NKLR[26] and the Danish Knee Ligament Reconstruction Registry[28] observed an overall lower risk of revision for patellar tendon autografts compared with hamstring autografts. However, limited analyses within subgroups defined by clinical and demographic factors were conducted in these studies. The objective of the present study was to show the choice of graft types in the 2004-2011 period based on data from all the 3 Scandinavian ACL registries combined and to compare risk of revision between the 2 most common grafts used in Scandinavia: patellar tendon and hamstring autografts. We also examined the influence of clinical and demographic factors and explored whether association with graft type differed in subgroups defined by these factors.

MATERIALS AND METHODS

Data from the initialization of each registry (2004-2005) up to December 31, 2011, were requested from the 3 participating countries. All patients having a primary ACL reconstruction as their first registration in the registries were considered. Data were not requested for patients with additional injury to the posterior cruciate ligament, the lateral collateral ligament, and/or the posterolateral corner. Information utilized in the present study was date of primary surgery and potential date of revision, graft, age at surgery, sex, activity at the time when the primary injury occurred, location (right or left knee), and concomitant injuries. Meniscal injury was dichotomized (yes/no) and considered present if meniscal injury or meniscal treatment was specified. Similarly, if cartilage injury of any kind was registered, independent from location and extent, it was dichotomized. Injuries to the medial collateral ligament (MCL) were recorded, as were concomitant fractures and nerve and vascular injuries. The standard treatment of concomitant MCL injuries in the participating countries is nonoperative with bracing before the ACL reconstruction, in contrast to other concomitant ligament injuries, where surgery more often is considered. The MCL injury may influence the surgeon's graft decision, since it is an important stabilizer on the medial side of the knee along with the hamstring muscles. Therefore, it was one of the clinical factors considered. Graft diameter, time from injury to surgery, and time in surgery were also considered. A total of 45,998 patients undergoing primary ACL reconstructions were included in the study. The overall median follow-up time was 3 years (range, 0-8 years).

Ethics

All Norwegian registry participants gave a written consent before the primary ACL reconstruction. This form has been approved by the regional ethical committee, and the registry has been approved by the Norwegian Data Inspectorate. According to Danish[16] and Swedish laws,[32] no written consent from the patient is needed. Registration of data to national clinical databases approved by the National Board of Health was made compulsory in Denmark in 2006.[16] The study was approved by the Regional Committee for Medical Research Ethics, South East Norway.

Statistical Analyses

All data were received depersonalized from the registries. The combined file was processed in IBM SPSS Statistics 20. The total number of primary ACL reconstructions included in the Scandinavian ACL registries up to December 31, 2011, determined the sample size.

*Address correspondence to Tone Gifstad, MD, PhD, Orthopaedic Research Center, Trondheim University Hospital, Postbox 3250 Sluppen, NO-7006 Trondheim, Norway (e-mail: tone.gifstad@ntnu.no).
†Orthopaedic Research Center, Trondheim University Hospital, Trondheim, Norway.
‡Faculty of Medicine, Norwegian University of Science and Technology, Trondheim, Norway.
§Orthopaedic Center, Oslo University Hospital and Faculty of Medicine, University of Oslo, Oslo, Norway.
‖Division of Sportstraumatology, Department of Orthopaedics, Aarhus University Hospital, Aarhus, Denmark.
¶Capio Artro Clinic AB and Stockholm Sports Trauma Research Center, Stockholm, Sweden.
One or more of the authors has declared the following potential conflict of interest or source of funding: L.E. has received grants from Norwegian NIH, Health South East Norway, IOC, FIFA, Norwegian Lottery, Department of Culture Norway, Arthrex, Smith & Nephew, Fin-Ceramica, and TBF Tissue Engineering outside the submitted work.

TABLE 1
Distribution of Graft Choice in the Scandinavian Countries From 2004 to December 31, 2011[a]

Graft Type	Sweden (n = 19,295)	Denmark (n = 14,902)	Norway (n = 11,801)	Total (n = 45,998)
Patellar tendon autograft	1439 (7.5)	2000 (13.4)	3297 (27.9)	6736 (14.6)
Hamstring autograft	17,724 (91.9)	12,477 (83.7)	8465 (71.7)	38,666 (84.1)
Allograft	43 (<1.0)	30 (<1.0)	12 (<1.0)	85 (<1.0)
Direct suture	3 (<1.0)	3 (<1.0)	1 (<1.0)	7 (<1.0)
Other grafts	86 (<1.0)	392 (2.6)	26 (<1.0)	504 (1.1)

[a]Values are expressed as No. (%) within each country and the total material.

The nonparametric Mann-Whitney *U* test was used to compare distribution of age at surgery (continuous variable in 1-year intervals) and time in surgery (minutes) between patients receiving patellar tendon and hamstring autografts. Two-sided tests were used. To compare the risk of revision according to clinical and demographic factors, univariate Kaplan-Meier (K-M) survival analysis (with log-rank test) and the Cox proportional hazard (PH) regression model were applied. Time since primary ACL reconstruction was defined as time scale. A patient was considered to be at risk until date of revision or end of study (December 31, 2011). We had no information on death or emigrations. The expected proportion of revisions is presented: estimated as 1 minus the K-M survival probability. Variables that were associated with revision rates at a 10% level in the univariate K-M survival analyses ($P < .10$) were included in the multiple Cox PH regression model. Log-minus-log plots were made to check for assumptions and make decisions on how to include the variables in the regression model. Stratification was made on country (Sweden, Denmark, Norway), whereas all other variables were included as categorical variables. The hazard rate ratio (HR) with 95% CI, as an estimate of relative risk of revision, was calculated as a measure of effect. Both unadjusted and adjusted HR values are shown. Interaction terms were included in the Cox PH regression model one at the time to examine whether the association with graft type differed among subgroups defined by clinical and demographic factors. To reduce the number of parameters in the interaction models, age at surgery (in 1-year intervals) was included as a cubic polynomial when used as an adjustment variable, and it was categorized into a broader age interval (compared with original model) when testing for an effect modification by age.

RESULTS

Distribution of Clinical and Demographic Factors

The distribution of graft selection, for countries individually and grouped, is presented in Table 1. Patellar tendon and hamstring autografts were used in a total of 14.6% and 84.1% of the patients, respectively. The remaining patients received allografts, direct sutures, and other grafts (1.3%). The distribution of grafts for each year from 2004 to 2011 is presented in Figure 1. The use of hamstring autograft increased considerably during this period, whereas the use of patellar tendon autografts decreased accordingly. Subsequent analyses were restricted to patients receiving patellar tendon autografts (n = 6736) or hamstring autograft (n = 38,666), a total of 45,402 patients. The median follow-up time was 5 years (range, 0-8 years) in the patellar tendon group and 3 years (range, 0-8 years) in the hamstring group.

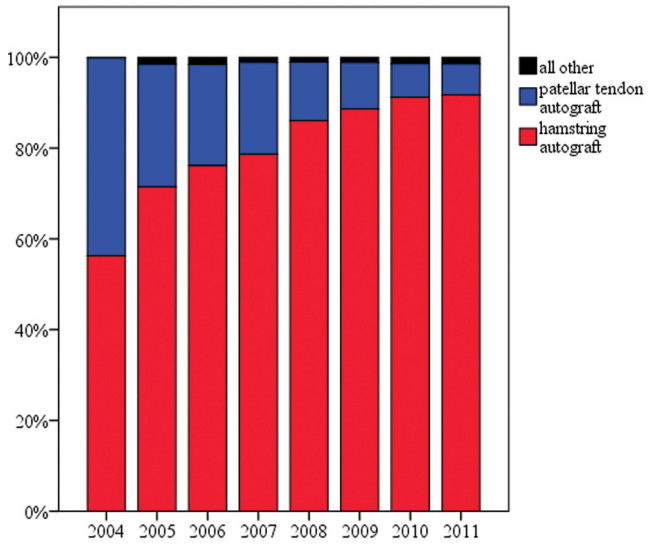

Figure 1. Distribution of graft in Scandinavian countries each year from 2004 to 2011.

Table 2 shows the distribution of clinical and demographic factors in the 2 main graft groups. The median age was 29 years (range, 13-71 years) in the patellar tendon group and 26 years (range, 7-90 years) in the hamstring group ($P < .001$) at the primary ACL reconstruction, with the largest 5-year age group consisting of patients 15 to 19 years old (20.5% of patients in the patellar tendon group and 24.7% of patients in the hamstring group in this age range). In both groups, a slightly higher proportion of the patients were male (62.9% in the patellar tendon group and 57.2% in the hamstring group). Among patients younger than 15 years, however, the proportion of female patients was largest (89.5% in the patellar tendon group and 65.3% in the hamstring group), with a similar pattern at age 15 to 19 years (54.0% female in the patellar tendon group and 58.9% in

TABLE 2
Distribution of Clinical and Demographic Factors at Primary ACL Reconstruction in Patients Receiving Patellar Tendon or Hamstring Autografts (N = 45,402)[a]

	Patellar Tendon Autograft (n = 6736)	Hamstring Autograft (n = 38,666)
Age at surgery, y		
<15	57 (<1.0)	1141 (3.0)
15-19	1378 (20.5)	9569 (24.7)
20-24	1226 (18.2)	7292 (18.9)
25-29	1084 (16.1)	5618 (14.5)
30-34	903 (13.4)	4568 (11.8)
35-39	854 (12.7)	4239 (11.0)
40-44	643 (9.5)	3430 (8.9)
≥45	591 (8.8)	2809 (7.3)
Sex		
Male	4239 (62.9)	22,132 (57.2)
Female	2497 (37.1)	16,534 (42.8)
Knee		
Right	3507 (52.1)	19,653 (50.8)
Left	3216 (47.8)	18,942 (49.0)
Unknown	10 (<1.0)	71 (<1.0)
Activity		
Soccer	2825 (41.9)	15,985(41.3)
Handball	859 (12.8)	4401 (11.4)
Alpine activities	863 (12.8)	5220 (13.5)
Other sports	1646 (24.4)	10,457 (27.0)
Traffic/work	350 (5.2)	1763 (4.6)
Other/unknown	193 (2.9)	840 (2.2)
Concomitant injuries		
Meniscus	2791 (41.4)	15,773 (40.8)
Cartilage	1486 (22.1)	8298 (21.5)
Medial collateral ligament	359 (5.3)	870 (2.3)
Other[b]	64 (1.0)	205 (<1.0)
Graft diameter, mm		
<8.0	15 (<1.0)	3103 (8.0)
8.0-9.0	51 (<1.0)	5522 (14.3)
9.0-9.9	142 (2.1)	2462 (6.4)
≥10.0	266 (3.9)	386 (1.0)
Unknown	6262 (93.0)	27,193 (70.3)

[a]Values are expressed as No. (% within each graft group). ACL, anterior cruciate ligament.
[b]Includes fractures, nerve, and vascular injuries.

the hamstring group; results not shown). Soccer, team handball, or alpine skiing/activities were reported as activity at the time when the primary injury occurred in 67.5% of the patients in the patellar tendon group and 66.2% in the hamstring group (Table 2). Graft diameter was available in only 7.0% of the patients in the patellar tendon group and 29.7% of the patients in the hamstring group.

The median time from injury to the primary ACL reconstruction was 8 months in both groups (range, 0-483 in the patellar tendon group and 0-551 in the hamstring group). Time in surgery was recorded in 2 of 3 countries. The median surgical time was 70 minutes (range, 20-260 minutes) in the patellar tendon group and 71 minutes (range, 17-284 minutes) in the hamstring group ($P = .010$). These time aspects were not considered in further analysis.

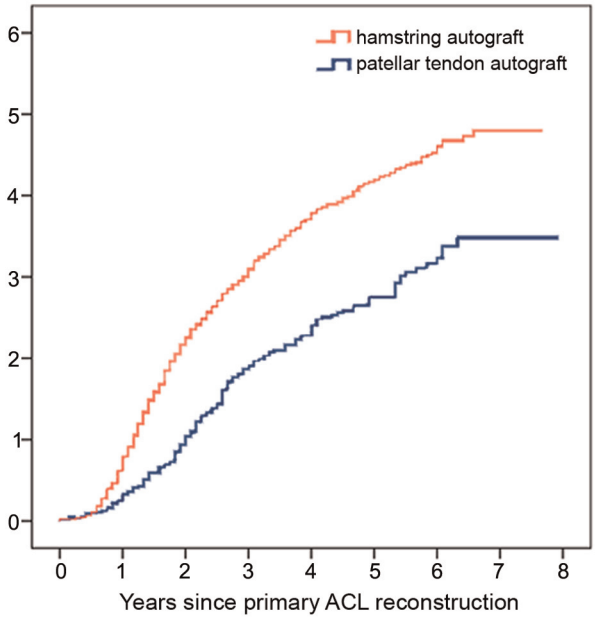

Figure 2. Expected proportion of revisions (%), estimated as 1 minus the Kaplan-Meier survival probabilities.

Risk of Revision by Clinical and Demographic Factors

Results from the univariate K-M survival analyses are shown in Table 3 and Figure 2. The present data included a total of 156 revisions in the patellar tendon group and 1042 revisions in the hamstring group. In general, the estimated proportion revisions was low (<5%) in nearly all groups at any point in time; very few revisions occurred during the first year of follow-up (Table 3). Five years after primary ACL reconstructions, the expected proportion revisions was 2.8% in the patellar tendon group and 4.2% in the hamstring group (Table 3 and Figure 2). With respect to revision-free time, the patellar tendon group had significantly better outcomes compared with the hamstring group ($P < .001$) (Figure 2), and older patients had better outcomes compared with younger patients. Activity at the time when the primary injury occurred and concomitant cartilage injury also had significant effect in the univariate K-M analysis. Female patients had a trend toward better outcome compared with male patients with respect to revision-free time ($P = .063$). No significant association was seen with side (right/left knee) or concomitant injury to the meniscus, the MCL, a nerve, vessels, or fractures at the time of the primary ACL reconstruction ($P > .10$) (Table 3), and these factors were not considered in further analyses.

Results from the Cox PH regression model are shown in Table 4 (no interaction model). Overall, the risk of revision was significantly lower in the patellar tendon group compared with the hamstring group (HR = 0.63; 95% CI, 0.53-0.74), and the association was almost unaffected by adjustment for other factors. The association with age at the primary surgery was also consistent and not influenced

TABLE 3
Results From Univariate Kaplan-Meier Survival Analyses
for Patients Receiving Patellar Tendon or Hamstring Autografts (N = 45,402)

			Expected Proportion of Revisions, %			
	No. of Patients	No. of Revisions	After 1 y	After 2 y	After 5 y	*P* Value[a]
Graft						<.001
Patellar tendon	6736	156	0.3	1.0	2.8	
Hamstring	38,666	1042	0.8	2.3	4.2	
Sex						.063
Male	26,371	664	0.8	2.0	3.7	
Female	19,031	534	0.7	2.1	4.3	
Knee[b]						.132
Right	23,160	586	0.7	1.9	3.8	
Left	22,161	612	0.8	2.2	4.1	
Age at surgery, y						<.001
<15	1198	56	1.3	3.9	7.2	
15-19	10,947	480	1.1	3.6	6.8	
20-24	8518	286	1.0	2.6	5.4	
25-29	6702	145	0.7	1.6	3.3	
30-34	5471	83	0.4	1.2	2.0	
35-39	5093	70	0.4	1.1	2.0	
40-44	4073	48	0.3	0.9	1.7	
≥45	3400	30	0.2	0.6	1.5	
Activity						<.001
Soccer	18,810	527	0.7	2.2	4.2	
Handball	5260	191	1.0	2.8	5.4	
Alpine	6083	110	0.4	1.3	2.8	
Other sport	12,103	285	0.7	1.9	3.5	
Traffic/work	2113	66	1.0	2.6	4.3	
Other/unknown	1033	19	0.6	1.1	2.6	
Meniscal injury						.839
Yes	18,564	494	0.8	2.0	4.1	
No	26,838	704	0.7	2.1	3.9	
Cartilage injury						<.001
Yes	9784	191	0.5	1.6	2.9	
No	35,618	1007	0.8	2.2	4.2	
Medial collateral ligament injury						.273
Yes	1229	30	0.8	1.8	3.3	
No	44,173	1168	0.7	2.1	4.0	
Other injury						.886
Yes	269	7	1.2	2.9	3.2	
No	45,133	1191	0.7	2.0	3.9	

[a]Log-rank test for difference in overall revision between groups.
[b]"Unknown" category was excluded due to lack of revisions.

by adjustment for other factors. The risk of revision in patients <15 years was rather similar to patients aged 15 to 19 years (HR = 1.03; 95% CI, 0.78-1.36), but a decrease in risk was seen for subsequent 5-year categories, although with a less steep decrease for age groups older than 30 years. The risk of revision for patients 45 years and older versus patients aged 15 to 19 years was 0.19 (95% CI, 0.13-0.28). The initial increased risk of revision for patients injured during team handball compared with patients injured in soccer was weakened and no longer statistically significant in the adjusted analysis. However, compared with soccer, those being injured during alpine activities had a significantly lower risk of revision (HR = 0.81; 95% CI, 0.66-1.00), and those injured in traffic or work had a significantly higher risk of revision (HR = 1.44; 95% CI, 1.12-1.87). The overall difference among activity groups was statistically significant also in the adjusted analysis ($P = .007$). The initial significant association with cartilage injury, however, disappeared in the adjusted analysis. Moreover, the association with sex was reversed when adjusting for other factors, but no significant association was found.

Results from the multiple regression model with an interaction term between graft type and each adjustment factor are shown in Table 5. Neither of the interaction tests reached statistical significance ($P > .05$), but some fluctuations in HR values for graft were seen. The lower risk of revision in patients receiving patellar tendon autografts

TABLE 4
Hazard Rate Ratio for Revision According to Clinical and Demographic Factors in Patients Undergoing Primary ACL Reconstruction (N = 45,402)[a]

	HR (95% CI)		
	Unadjusted	Adjusted[b]	Adjusted[c]
Graft			
Hamstring	—	—	—
Patellar tendon	0.64 (0.54-0.76)	0.59 (0.50-0.71)	0.63 (0.53-0.74)
Sex			
Male	—	—	—
Female	1.11 (0.99-1.25)	1.12 (0.99-1.25)	0.93 (0.82-1.06)
Age at surgery, y			
<15	1.07 (0.81-1.41)	1.06 (0.81-1.40)	1.03 (0.78-1.36)
15-19	—	—	—
20-24	0.77 (0.67-0.90)	0.77 (0.67-0.89)	0.78 (0.67-0.90)
25-29	0.47 (0.39-0.57)	0.47 (0.39-0.56)	0.47 (0.39-0.57)
30-34	0.32 (0.25-0.40)	0.31 (0.25-0.39)	0.31 (0.25-0.40)
35-39	0.29 (0.23-0.37)	0.28 (0.22-0.36)	0.28 (0.22-0.37)
40-44	0.25 (0.19-0.34)	0.24 (0.18-0.33)	0.25 (0.19-0.34)
≥ 45	0.20 (0.14-0.28)	0.19 (0.13-0.27)	0.19 (0.13-0.28)
Activity			
Soccer	—	—	—
Handball	1.28 (1.08-1.51)	1.23 (1.04-1.45)	1.09 (0.91-1.30)
Alpine activities	0.65 (0.53-0.79)	0.65 (0.53-0.79)	0.81 (0.66-1.00)
Other sports	0.83 (0.72-0.96)	0.85 (0.73-0.98)	1.05 (0.90-1.21)
Traffic/work	1.07 (0.83-1.38)	1.06 (0.82-1.37)	1.44 (1.12-1.87)
Other/unknown	0.57 (0.36-0.90)	0.54 (0.34-0.86)	0.78 (0.49-1.24)
Cartilage injury			
Yes	0.70 (0.60-0.82)	0.71 (0.61-0.84)	0.94 (0.80-1.10)
No	—	—	—

[a]Results are based on the Cox proportional hazards regression model. ACL, anterior cruciate ligament; HR, hazard rate ratio.
[b]Stratified for country: Sweden, Denmark, Norway.
[c]Mutual adjustment for all variables considered in a model stratified for country.

compared with hamstring autografts was consistently observed across sex and age groups except for a weaker and nonsignificant difference in patients aged 25 to 29 years. The reduction in risk of revision seemed to be more pronounced when the patients were injured during soccer, team handball, or alpine activities. When combining activity at the time when the primary injury occurred into 2 groups—certain pivoting activities (soccer, team handball, and alpine activities) and other (other sports, traffic/work)—the difference was on the border of statistical significance (HR = 0.57 vs 0.81; $P = .058$, test for interaction) (Table 5). The lower risk of revision for patients receiving patellar tendon autografts compared with hamstring grafts was rather similar in patients with concomitant injury compared with patients without such an injury.

DISCUSSION

Hamstring autografts are by far the most common graft type used in primary ACL reconstructions in Scandinavia. In the present registry-based study in the Scandinavian countries, a total of 14.6% of the patients received patellar tendon autografts and 84.1% received hamstring autografts, while the remaining received allografts, direct sutures, and other grafts. Five years after primary ACL reconstruction, 2.8% of the patients in the patellar tendon group and 4.2% in the hamstring group were expected to have undergone revision. Despite the low risk of revision in both groups, we observed a significant lower risk in patients receiving patellar tendon autografts compared with hamstring autografts, both overall and in subgroups of patients. The reduced risk in the patellar tendon group compared with the hamstring group seemed to be pronounced for patients injured during soccer, team handball, or alpine activities. Our results were based on information for a total of 45,402 ACL reconstructions, including 1198 revisions. To our knowledge, this is the largest data set examining risk of revision by graft type. The large data set made it possible to get fairly accurate risk-of-revision estimates from analysis adjusted for potential confounders, and it provided an opportunity to evaluate potential interaction effects. The Scandinavian ACL registries cover almost the complete population of patients undergoing ACL reconstructions in the Scandinavian countries. The findings in the present study are therefore believed to have high internal and external validity. The usefulness of data from large, population-based registries has been pointed out by others.[11,25,34]

TABLE 5
Hazard Rate Ratio for Revision by Graft Type in Subgroups of Clinical and Demographic Factors[a]

	No. of Revisions			
	Patellar Tendon Autograft	Hamstring Autograft	HR (95% CI), Patellar Tendon Autograft vs Hamstring Autograft (Ref)	*P* Value, Interaction[b]
Sex[c]				.46
Male	89	575	0.60 (0.48-0.76)	
Female	67	467	0.69 (0.53-0.89)	
Age at surgery, y[d]				.67
<20	58	478	0.61 (0.46-0.80)	
20-24	39	247	0.61 (0.43-0.85)	
25-29	26	119	0.81 (0.53-1.25)	
≥ 30	33	198	0.60 (0.41-0.87)	
Activity[c,e]				.36
Soccer	69	458	0.62 (0.48-0.79)	
Handball	21	170	0.49 (0.31-0.77)	
Alpine activities	11	99	0.52 (0.28-0.97)	
Other sports	42	243	0.82 (0.59-1.14)	
Traffic/work	11	55	0.79 (0.41-1.51)	
Activity group[f]				.058
Pivoting activities	94	727	0.57 (0.46-0.71)	
Other	53	298	0.81 (0.60-1.09)	
Cartilage injury[c]				.41
Yes	24	167	0.54 (0.35-0.83)	
No	132	875	0.66 (0.55-0.80)	

[a]HR, hazard rate ratio; Ref, reference.
[b]Test for interaction between graft and grouping factor, one at a time.
[c]Results from Cox proportional hazards regression model (interaction model) adjusted for country (stratum), sex, age (1-year intervals, cubic polynomial) at primary surgery, cartilage injury, and activity at the time when the primary injury occurred.
[d]Age included as categorical variable (4 groups).
[e]Other/unknown category excluded due to few of revisions (<10).
[f]Soccer, handball, and alpine activities were grouped as "pivoting activities" and other sports and traffic/work as "other."

Comparison With Other Studies

The graft distribution in ACL reconstruction varies in different parts of the world. A US-based study reported 25% patellar tendon autografts, 31% hamstring autografts, 42% allografts, and 2% other grafts.[20] Autografts were used for primary ACL reconstruction in 90% of the patients and allografts in 5% in a study from Ontario, Canada.[33] A database study from the United Kingdom published in 2001 showed that out of 4407 ACL reconstructions, patellar tendon autografts were used in 58%, hamstring autografts in 37%, and allografts in less than 1% of the patients.[5] Allografts are presently mainly used for revision ACL reconstructions and multiligament reconstructions in Scandinavia. The choice between patellar tendon autograft and hamstring autograft did not seem to be influenced by patient characteristics, since the distribution within clinical and demographic factors in the present study was rather similar between the 2 groups from a clinical point of view. With a large amount of patients, one would expect to find some statistically significant differences that would not be clinically relevant. Results from statistical tests for difference in clinical and demographic factors between graft groups were therefore not presented in the tables. The increasing use of hamstring grafts in the Scandinavian countries during the study period is probably related to local traditions and the increasing availability of cortical fixation devices for that graft type. In addition, review studies have reported similar clinical results for patellar tendon autografts and hamstring autografts, although fewer donor-site problems with the latter.[17,23] Because of the increasing use of hamstring autografts, the larger proportion of patients with a recent reconstruction in this group would lead to a shorter median follow-up time, as compared with those treated with patellar tendon autografts. In the analyses for exploring potential differences in risk of revision, time since primary operation was defined as time scale, and "time" was thus automatically adjusted for.

The number of patients in the present study was large enough for performing analysis specific to subgroups. These extended regression model analyses showed that the reduced risk for revision in the patellar tendon group compared with the hamstring group in general was quite consistently observed across subgroups defined by clinical and demographic factors. The present study based on data from all 3 Scandinavian countries therefore confirms but also adds significant information to the national data presented from the Danish Knee Ligament Reconstruction Registry[28] and the NKLR.[26] In view of the larger data set

available in the present study, more detailed categorization with age was possible, and we also present results for potential influencing factors not considered in the national studies,[26,28] such as coexisting injuries as well as activity at the time when the primary injury occurred. On the basis of a data set from the United States, Maletis et al[19] reported a lower risk of revision for patellar tendon autografts compared with hamstring autografts. In accordance with results from the present study, Magnussen et al[18] found a higher risk of revision for patients aged less than 20 years compared with patients older than 20 years based on reconstructions with hamstring autografts only. Consistent with our results, theirs revealed no significant differences in risk of revision between males and females,[18] nor did the findings of Maletis et al.[19] A main aim of the present study was to compare the risk of revision between the 2 most common grafts used in Scandinavia (patellar tendon and hamstring autografts) and to explore whether association with graft type differed in certain subgroups of factors. Although no significant interaction effects were found in our study, we observed a trend toward a more pronounced reduction in risk of revision in the patellar tendon group compared with the hamstring group in certain activity groups. Should a soccer or team handball player with a ruptured ACL receive a patellar tendon autograft over a hamstring autograft? In view of the findings in the present study, we believe that patellar tendon autografts may be suitable especially for patients returning to pivoting activities with high demands for stability. More stable knees have been reported when patellar tendon autografts are used for ACL reconstruction compared with hamstring autografts.[23] However, complete answers for small subgroups require an even larger data set than the present one and should be a subject for future registry-based research.

The lower risk of revision found with concomitant cartilage injury in the univariate analysis possibly reflects that these patients often can have a more serious knee injury that prevents them from returning to activities with significant risks of new injuries and possible reruptures and revision ACL reconstruction. Røtterud et al[30] reported inferior KOOSs (Knee injury and Osteoarthritis Outcome Scores) after ACL reconstruction when full-thickness cartilage injuries were present compared with patients with ACL reconstruction with normal cartilage. The present study reports only risk of revision and cannot present functional results or patient-reported outcomes. In the adjusted model (Table 4), there was no statistically significant difference in risk of revision between patients with and without cartilage injury.

Kamien et al[12] were not able to find any association between graft size and risk of revision in their study based on ACL reconstruction with hamstring autografts. Magnussen et al[18] found an increased risk of revision for hamstring autografts 8 mm in diameter or less in patients younger than 20 years. A total of 18 of 256 patients in that study underwent revision. Similar findings were also presented by Mariscalco et al.[21] The present study had very limited information on graft size, precluding analysis of this factor. Analysis of association between portals for tunnel drilling and revision rates was unsuitable for similar reasons. The Danish Knee Ligament Reconstruction Registry has published increased risk of revision after changing from transtibial to anteromedial drilling of the femoral tunnel.[29] We believe that these variables should be followed closely over the next years when more data become available.

Strengths and Limitations of the Study

The strength of the present study is clearly the large number of patients, together with the high registration rates in the participating countries, ensuring an unselected sample. Large prospective registry-based studies are clearly needed to report statistics on rare events such as revision ACL reconstructions.

A prospective registry-based study is an ideal setting for evaluating results given that outcome measures of interest are recorded. However, there are some limitations compared with randomized controlled trials. There is little room for data control, and one cannot rule out the possibility of errors during the registration. However, such errors would probably have only limited influence on the results when the total number of patients is high. In addition, one would not expect differences in these potential sources to bias between the 2 graft groups. Clinical follow-up evaluations are included in only 1 of the 3 Scandinavian ACL registries. Range of motion and laxity assessments—outcome variables traditionally reported in clinical ACL studies—were therefore not available in the present study. We used revision as an endpoint and could focus only on potential differences in risk of revision. We acknowledge that the registries have difficulties identifying patients with increased laxity that for various reasons do not undergo revision ACL reconstruction. In addition, a lower risk of revision does not automatically indicate better results. We cannot rule out the possibility that patients with patellar tendon autografts experience a less satisfactory knee function from the beginning and therefore avoid activities with substantial risk of new injuries and need for revisions. However, several clinical studies comparing patellar tendon autografts and hamstring autografts with respect to different clinical outcomes report no large differences in the mid- or long-term results between the 2 grafts.[8,14,15,31]

Information on death or emigration was not available in the present study. This may have led to a potential bias in the estimated hazard ratios. However, death is in general a rare event for younger individuals in the Scandinavian countries, and occurrence of death or emigration is not expected to differ between the groups that are compared. Thus, a potential bias would be expected to be minor. Limited experience with various grafts and surgical techniques may make the orthopaedic surgeon more reserved for making the decision regarding revision of one graft compared with another. When a country uses one graft in 98% of the primary ACL reconstructions, the experience with other methods is probably somewhat limited, especially among younger surgeons. It is difficult to judge whether this aspect influenced the estimated risk estimates in the present study. However, in most clinical settings in the Scandinavian countries, patients can quite easily be referred to surgeons with comprehensive experience with revision ACL reconstructions.

The Scandinavian ACL registries contain information on activity at the time when the primary injury occurred; however, they do not contain information describing the patient's main activity. For example, was the patient who was injured playing soccer actually a soccer player or a gymnast playing recreational soccer with friends? This should be kept in mind when advising patients on activity-specific risk of revision. Only the ACL registry in Denmark contains information on the level of sports activity assessed with the Tegner activity score.[16]

Future Research

Patients with nonoperative treatment of their ACL injuries are currently not included in the Scandinavian ACL registries. It is estimated that about half of the ACL injuries in Norway undergo reconstruction.[9] Frobell et al[7] found comparable 5-year follow-up results for patients with early ACL reconstruction and patients with initial rehabilitation with an opportunity for late reconstruction. The possibility of monitoring these patients in the registries would be of great interest, and it has begun in Sweden.[32] The patients in the Scandinavian ACL registries are asked to fill out the KOOS questionnaire preoperatively and 1 year (Denmark and Sweden), 2 years (Norway and Sweden), and 5 years (all 3 countries) after surgery. An ongoing study is examining these data to determine differences in outcome between the patellar tendon group and the hamstring group. This could reveal potential differences between the graft groups for patients not undergoing revision ACL reconstruction. The cause of revision ACL reconstruction is not always clear and is often due to a combination of both patient-related and surgical factors. This information is not complete in the Scandinavian ACL registries and was not addressed in the present study. Clinical studies, however, may provide better possibilities for such studies of more detailed patient history, clinical evaluation, and radiologic assessment.

CONCLUSION

Primary ACL reconstructions in Scandinavia are mainly performed with hamstring autografts. Only 1 of 7 patients receives patellar tendon autografts. The most common activities at the time when the primary ACL injuries occurred were soccer, team handball, and alpine activities in both these graft groups. The proportion of patients undergoing a revision after a primary ACL reconstruction in the Scandinavian ACL registries is in general low (<5% in nearly all groups at any point in time). However, patients receiving patellar tendon autografts had an overall lower risk of revision compared with patients receiving hamstring autografts in the present study. The dominating use of hamstring autografts should be reconsidered.

ACKNOWLEDGMENT

The authors thank the staff at each of the 3 ACL registries for the extraction of data files.

REFERENCES

1. Aune AK, Holm I, Risberg MA, Jensen HK, Steen H. Four-strand hamstring tendon autograft compared with patellar tendon-bone autograft for anterior cruciate ligament reconstruction. *Am J Sports Med*. 2001;29(6):722-728.
2. Danish Knee Ligament Reconstruction Register. http://www.saks.nu/registre/acl/aarsrapporter-fra-acl-databasen.
3. Engebretsen L, Forssblad M. Why knee ligament registries are important. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(2):115-116.
4. Feller JA, Webster KE. A randomized comparison of patellar tendon and hamstring tendon anterior cruciate ligament reconstruction. *Am J Sports Med*. 2003;31(4):564-573.
5. Francis A, Thomas RD, McGregor A. Anterior cruciate ligament rupture: reconstruction surgery and rehabilitation: a nation-wide survey of current practice. *Knee*. 2001;8(1):13-18.
6. Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR Jr. Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. *Am J Sports Med*. 2003;31(1):2-11.
7. Frobell RB, Roos HP, Roos EM, Roemer FW, Ranstam J, Lohmander LS. Treatment for acute anterior cruciate ligament tear: five year outcome of randomised trial. *BMJ*. 2013;346:f232.
8. Gifstad T, Sole A, Strand T, Uppheim G, Grontvedt T, Drogset JO. Long-term follow-up of patellar tendon grafts or hamstring tendon grafts in endoscopic ACL reconstructions. *Knee Surg Sports Traumatol Arthrosc*. 2012;21(3):576-583.
9. Granan LP, Bahr R, Steindal K, Furnes O, Engebretsen L. Development of a national cruciate ligament surgery registry: the Norwegian National Knee Ligament Registry. *Am J Sports Med*. 2008;36(2):308-315.
10. Granan LP, Forssblad M, Lind M, Engebretsen L. The Scandinavian ACL registries 2004-2007: baseline epidemiology. *Acta Orthop*. 2009;80(5):563-567.
11. Janssen KW, Orchard JW, Driscoll TR, van Mechelen W. High incidence and costs for anterior cruciate ligament reconstructions performed in Australia from 2003-2004 to 2007-2008: time for an anterior cruciate ligament register by Scandinavian model? *Scand J Med Sci Sports*. 2012;22(4):495-501.
12. Kamien PM, Hydrick JM, Replogle WH, Go LT, Barrett GR. Age, graft size, and Tegner activity level as predictors of failure in anterior cruciate ligament reconstruction with hamstring autograft. *Am J Sports Med*. 2013;41(8):1808-1812.
13. Kartus J, Movin T, Karlsson J. Donor-site morbidity and anterior knee problems after anterior cruciate ligament reconstruction using autografts. *Arthroscopy*. 2001;17(9):971-980.
14. Liden M, Ejerhed L, Sernert N, Laxdal G, Kartus J. Patellar tendon or semitendinosus tendon autografts for anterior cruciate ligament reconstruction: a prospective, randomized study with a 7-year follow-up. *Am J Sports Med*. 2007;35(5):740-748.
15. Liden M, Sernert N, Rostgard-Christensen L, Kartus C, Ejerhed L. Osteoarthritic changes after anterior cruciate ligament reconstruction using bone-patellar tendon-bone or hamstring tendon autografts: a retrospective, 7-year radiographic and clinical follow-up study. *Arthroscopy*. 2008;24(8):899-908.
16. Lind M, Menhert F, Pedersen AB. The first results from the Danish ACL reconstruction registry: epidemiologic and 2 year follow-up results from 5,818 knee ligament reconstructions. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(2):117-124.
17. Magnussen RA, Carey JL, Spindler KP. Does autograft choice determine intermediate-term outcome of ACL reconstruction? *Knee Surg Sports Traumatol Arthrosc*. 2011;19(3):462-472.
18. Magnussen RA, Lawrence JT, West RL, Toth AP, Taylor DC, Garrett WE. Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft. *Arthroscopy*. 2012;28(4):526-531.
19. Maletis GB, Inacio MC, Desmond JL, Funahashi TT. Reconstruction of the anterior cruciate ligament: association of graft choice with increased risk of early revision. *Bone Joint J*. 2013;95(5):623-628.

20. Maletis GB, Inacio MC, Funahashi TT. Analysis of 16,192 anterior cruciate ligament reconstructions from a community-based registry. *Am J Sports Med*. 2013;41(9):2090-2098.
21. Mariscalco MW, Flanigan DC, Mitchell J, et al. The influence of hamstring autograft size on patient-reported outcomes and risk of revision after anterior cruciate ligament reconstruction: a Multicenter Orthopaedic Outcomes Network (MOON) Cohort Study. *Arthroscopy*. 2013;29(12):1948-1953.
22. Matsumoto A, Yoshiya S, Muratsu H, et al. A comparison of bone-patellar tendon-bone and bone-hamstring tendon-bone autografts for anterior cruciate ligament reconstruction. *Am J Sports Med*. 2006;34(2):213-219.
23. Mohtadi NG, Chan DS, Dainty KN, Whelan DB. Patellar tendon versus hamstring tendon autograft for anterior cruciate ligament rupture in adults. *Cochrane Database Syst Rev*. 2011;9:CD005960.
24. Norwegian Cruciate Ligament Register. http://nrlweb.ihelse.net/.
25. Paxton EW, Namba RS, Maletis GB, et al. A prospective study of 80,000 total joint and 5000 anterior cruciate ligament reconstruction procedures in a community-based registry in the United States. *J Bone Joint Surg Am*. 2010;92(suppl 2):117-132.
26. Persson A, Fjeldsgaard K, Gjertsen JE, et al. Increased risk of revision with hamstring tendon grafts compared with patellar tendon grafts after anterior cruciate ligament reconstruction: a study of 12,643 patients from the Norwegian Cruciate Ligament Registry, 2004-2012. *Am J Sports Med*. 2014;42(2):285-291.
27. Rahr-Wagner L, Thillemann TM, Lind MC, Pedersen AB. Validation of 14,500 operated knees registered in the Danish Knee Ligament Reconstruction Register: registration completeness and validity of key variables. *Clin Epidemiol*. 2013;5:219-228.
28. Rahr-Wagner L, Thillemann TM, Pedersen AB, Lind M. Comparison of hamstring tendon and patellar tendon grafts in anterior cruciate ligament reconstruction in a nationwide population-based cohort study: results from the Danish registry of knee ligament reconstruction. *Am J Sports Med*. 2014;42(2):278-284.
29. Rahr-Wagner L, Thillemann TM, Pedersen AB, Lind MC. Increased risk of revision after anteromedial compared with transtibial drilling of the femoral tunnel during primary anterior cruciate ligament reconstruction: results from the Danish Knee Ligament Reconstruction Register. *Arthroscopy*. 2013;29(1):98-105.
30. Røtterud JH, Risberg MA, Engebretsen L, Aroen A. Patients with focal full-thickness cartilage lesions benefit less from ACL reconstruction at 2-5 years follow-up. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(8):1533-1539.
31. Sajovic M, Strahovnik A, Dernovsek MZ, Skaza K. Quality of life and clinical outcome comparison of semitendinosus and gracilis tendon versus patellar tendon autografts for anterior cruciate ligament reconstruction: an 11-year follow-up of a randomized controlled trial. *Am J Sports Med*. 2011;39(10):2161-2169.
32. Swedish National ACL Register. http://www.aclregister.nu.
33. Wasserstein D, Khoshbin A, Dwyer T, et al. Risk factors for recurrent anterior cruciate ligament reconstruction: a population study in Ontario, Canada, with 5-year follow-up. *Am J Sports Med*. 2013;41(9):2099-2107.
34. Yoon H. The UK National Ligament Registry. *Knee*. 2013;20(6):365-366.
35. Ytterstad K, Granan LP, Ytterstad B, et al. Registration rate in the Norwegian Cruciate Ligament Register: large-volume hospitals perform better. *Acta Orthop*. 2012;83(2):174-178.