Original Research

Effect of Concomitant Meniscal Lesions and Meniscal Surgery in ACL Reconstruction With 5-Year Follow-Up: A Nationwide Prospective Cohort Study From Norway and Sweden of 8408 Patients

Svend Ulstein,*†‡ MD, PhD, Asbjørn Årøen,†‡§ MD, PhD, Lars Engebretsen,‡§ MD, PhD, Magnus Forssblad,‖ MD, PhD, and Jan Harald Røtterud,†‡ MD, PhD

Investigation performed at the Department of Orthopaedic Surgery, Akershus University Hospital, Lørenskog, Norway

Background: Increased knowledge of the factors predicting outcome after anterior cruciate ligament reconstruction (ACLR) is needed.

Purpose: To determine the effect of concomitant meniscal lesions, and the surgical management thereof, on patient-reported outcomes 5 years after ACLR.

Study Design: Prospective cohort study; Level of evidence, 2.

Methods: A total of 15,706 patients who underwent primary unilateral ACLR between 2005 and 2008 were enrolled prospectively and evaluated longitudinally. All patients were part of the Norwegian and Swedish national knee ligament registries. Outcomes at 5-year follow-up were evaluated with the Knee injury and Osteoarthritis Outcome Score (KOOS). A multivariable linear regression model was used to assess possible effects on prognosis, as measured by KOOS, of a concomitant meniscal lesion and its associated surgical treatment.

Results: At a mean follow-up of 5.1 ± 0.2 years, KOOS data were available from 8408 patients: 4774 (57%) patients with no and 3634 (43%) patients with concomitant meniscal lesions (mean patient age, 33.8 ± 10.7 years). Patients with concomitant meniscal lesions reported equal crude mean scores compared with patients without meniscal lesions in all KOOS subscales 5 years after ACLR. The mean improvement in scores from preoperative to the 5-year follow-up was greater for patients with a concomitant meniscal lesion for the KOOS Pain, Activities of Daily Living (ADL), and Sport and Recreation subscales. In the adjusted regression analyses, using patients without concomitant meniscal lesions as the reference, neither no treatment nor resection or repair of medial meniscal lesions were significantly associated with KOOS scores 5 years after ACLR. Except for the ADL subscale, in which a repaired lateral meniscal lesion was associated with better outcome, no significant associations between any of the lateral meniscal lesion treatment categories and KOOS outcome at 5-year follow-up were identified.

Conclusion: Concomitant meniscal lesions at the time of ACLR conferred no negative effects on patient-reported outcomes 5 years after ACLR. The improvement in selected KOOS subscales from preoperative to the 5-year follow-up was significantly greater for patients with concomitant meniscal lesions than for patients without such lesions.

Keywords: anterior cruciate ligament; ACL reconstruction; meniscal injury; meniscal repair; concomitant meniscal injury; patient-reported outcome

Patient-reported outcome measures (PROMs) have become the mainstay in understanding patients' perceptions of treatment outcomes in medicine, particularly in the field of orthopaedic surgery. The Scandinavian knee ligament registries allow for large-scale monitoring and comparison of PROMs for subgroups of patients. As responder analyses have revealed that only 55% to 66% of patients who undergo surgery after anterior cruciate ligament (ACL) injury perceive their symptoms as acceptable postoperatively, increased knowledge of the factors that might contribute to outcomes is required.[12,24]

The Orthopaedic Journal of Sports Medicine, 9(10), 23259671211038375
DOI: 10.1177/23259671211038375

Presumably, 1 such factor is concomitant intra-articular injuries. With reported incidences of 35% to 43%, concomitant meniscal lesions are common in the setting of ACL reconstruction (ACLR).[22] As concomitant meniscal lesions are reported to be a negative prognostic factor in some studies,[6,11,25] with mixed effects[2,5] or no effect in others,[16,22] current evidence is divergent with respect to the effect on PROMs of such concomitant lesions. There has been a notable transition in the surgical approach to concomitant meniscal lesions the past decade; in 2005, just over 15% of meniscal lesions reported to the Norwegian Knee Ligament Registry (NKLR) were repaired. This has increased gradually to about 59% in 2019.[10] We do not know whether this transition is related to surgeons' having changed their assessment of concomitant meniscal injuries, advancements in surgical equipment, or emerging evidence of associations between unrepaired meniscal lesions and radiographic premature osteoarthritis (OA).[4,14,15] However, with regard to PROMs, there is limited knowledge on the effect of concomitant meniscal lesions both before and after this transition in surgical management.[18]

Firm knowledge on the prognosis and factors involved in predicting outcome is needed if the information and advice on treatment are to be correct. Large, population-based studies with adequate time to follow-up are particularly useful in that respect.

The primary objective of the present prospective, nationwide population-based cohort study was to determine the effect of concomitant meniscal lesions at the time of ACLR on the Knee injury and Osteoarthritis Outcome Score (KOOS) at 5 years after surgery. Secondary outcomes included the effect of surgical management of concomitant meniscal lesions on patient-reported outcomes 5 years after surgery, and the proportion of patients with a KOOS quality-of-life score below 44 (a prespecified cutoff value consistent with a nonsatisfactory result defined as treatment failure).[2,7]

METHODS

Norwegian and Swedish National Knee Ligament Registries

Following institutional review board approval, data were assembled from the NKLR and the Swedish Knee Ligament Register (SKLR). The NKLR was established in June 2004 and the SKLR in January 2005, with the main purposes of registering all surgical procedures performed on knee ligaments on a nationwide scale and prospectively monitoring outcomes.[8,9] There are no major cross-cultural differences in the collection or handling of data between the 2 countries, and in both registries, the surgeons' reporting rates are above 85%.[1,9]

As a part of the surgeons' voluntary immediate postoperative registration of patient, knee, and surgery-specific variables, the surgeons report meniscal lesions and any surgical intervention.

Knee injury and Osteoarthritis Outcome Score

The KOOS was selected as the patient-reported outcome measure in both NKLR and SKLR. The questionnaire consists of 42 questions distributed between 5 separately scored subscales; Pain, Symptoms, Activities of Daily Living (ADL); function in Sport and Recreation (Sport/Rec); and knee-related Quality of Life (QoL). Moreover, it is considered to be a valid, reliable and responsive PROM for patients with ACL and meniscal injury as well as other knee injuries.[13,21] The data assembly is voluntary, and patients complete an informed consent form prior to surgery, allowing for later use of their registry data, including the KOOS questionnaire.

Patients

The current study was a longitudinal 5-year follow-up of a nationwide, population-based cohort consisting of all patients, regardless of age, who underwent unilateral primary ACLR surgery between January 1, 2005, and December 31, 2008. All patients were registered in the NKLR or the SKLR. During this timeframe, a total of 15,783 patients were registered prospectively. This cohort has been described previously in a study on the incidence and risk of full-thickness cartilage lesions in ACL-injured knees[23] and in studies reporting on the 2- and 5-year outcomes after ACLR in patients with concomitant cartilage lesions.[22,28]

A total of 77 patients were ineligible for inclusion because of missing information on the surgical treatment of the concomitant meniscal injury, leaving a cohort of 15,706 patients.

At a mean follow-up of 5.1 ± 0.2 years, KOOS data were available from 8408 (54%) ACL-reconstructed patients (mean patient age, 33.8 ± 10.7 years). Of these, 4774 (57%) patients had no concomitant meniscal lesions, and 3634 (43%) had concomitant meniscal lesions. Patient flow during inclusion and follow-up is shown in Figure 1.

*Address correspondence to Svend Ulstein, MD, PhD, Orthopaedic Clinic, Akershus University Hospital, Sykehusveien 25, 1478 Nordbyhagen, Norway (email: svenduls@hotmail.com) (Twitter: @SvendUlstein).
†Department of Orthopaedic Surgery, Akershus University Hospital, Lørenskog, Norway.
‡Oslo Sports Trauma Research Center, Oslo, Norway.
§Institute of Clinical Medicine, University of Oslo, Oslo, Norway.
‖Stockholm Sports Trauma Research Center, Karolinska Institutet, Stockholm, Sweden.
Final revision submitted May 5, 2021; accepted May 21, 2021.
One or more of the authors has declared the following potential conflict of interest or source of funding: Funding was received in the form of grant support from Akershus University Hospital and research support from The Oslo Sports Trauma Research Center (to S.U.). AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from the regional ethical committee of South-Eastern Norway (ID 2017/122).

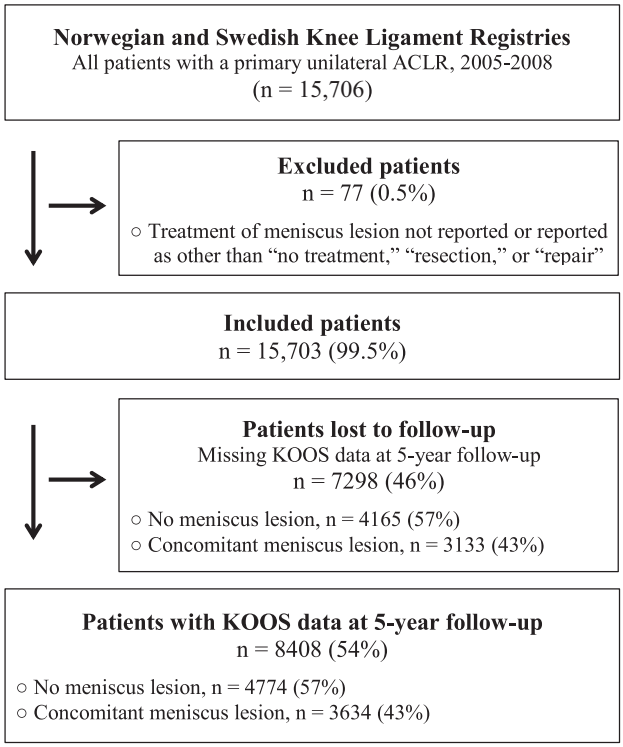

Figure 1. Flowchart of the patients during inclusion and follow-up. ACLR, anterior cruciate ligament reconstruction; KOOS, Knee injury and Osteoarthritis Outcome Score.

Baseline characteristics at the time of ACLR for patients included in the study population and for patients lost to follow-up (n = 7298; 46%) are listed in Table 1, and the breakdown of concomitant meniscal lesions by type and treatment is shown in Table 2. Except for the sex and age distribution, the baseline characteristics of the study population and those lost to follow-up were comparable. The patients available for the 5-year follow-up tended to be older age and with a higher proportion of women than those lost to follow-up.

Statistical Analysis

Crude mean KOOS scores at the 5-year follow-up were estimated and stratified by patients with and without concomitant meniscal lesions. Patients with a concomitant meniscal lesion were further stratified according to the intra-articular localization of the concomitant meniscal injury—that is, medial compartment (medial meniscus) and lateral compartment (lateral meniscus)—and finally according to surgical management of the concomitant meniscal lesion (no treatment, resection, or repair).

Multivariable linear regression analyses were used to assess possible effects on prognosis, as measured by the KOOS at the 5-year follow-up, of a concomitant meniscal lesion and its associated surgical treatment. The results are presented as both unadjusted and adjusted for possible confounding from sex, age at surgery (continuous variable), previous ipsilateral knee surgery (yes/no), concomitant ligament injury (yes/no), concomitant cartilage lesions

TABLE 1
Baseline Characteristics at the Time of ACLR for the Study Cohort and Patients Lost to Follow-Up[a]

	No Meniscal Lesions (n = 4774)	Meniscal Lesions (n = 3634)	Total Study Cohort (N = 8408)	Lost to Follow-Up (n = 7298)
Age at surgery, y	27 [9-69]	27 [10-67]	27 [9-69]	24 [8-64]
Time from injury to surgery, mo	8 [0-521)	10 [0-482]	9 [0-521]	9 [0-400]
Female sex	2415 (51)	1678 (46)	4093 (49)	2567 (35)
Previous ipsilateral knee surgery	1320 (28)	903 (25)	2223 (26)	1914 (26)
Concomitant ligament injury[b]	348 (7)	267 (7)	615 (7)	493 (7)
Concomitant meniscal lesion	NA	3634	3634 (43)	3133 (43)
ACL graft				
Hamstring tendons	3659 (77)	2769 (76)	6428 (76)	5762 (79)
Bone–patellar tendon—bone	1016 (21)	805 (22)	1821 (22)	1383 (19)
Other/unknown	99 (2)	60 (2)	159 (2)	153 (2)
Concomitant cartilage lesions	1027 (22)	1208 (33)	2235 (27)	1907 (26)
ICRS grades 1-2	791 (17)	883 (24)	1674 (20)	1458 (20)
ICRS grades 3-4	236 (5)	325 (9)	561 (7)	449 (6)
Preoperative KOOS				
Pain	75.8 ± 17.0	73.4 ± 18.3	74.4 ± 17.6	73.9 ± 18.0
Symptoms	72.7 ± 17.5	70.0 ± 18.5	71.4 ± 18.0	70.2 ± 18.0
ADL	84.8 ± 16.7	82.6 ± 18.2	83.8 ± 17.4	82.9 ± 17.6
Sport/Rec	44.0 ± 26.9	40.4 ± 27.3	42.4 ± 27.1	41.8 ± 27.1
QoL	35.1 ± 18.3	33.1± 17.9	34.2 ± 18.2	33.5 ± 18.2

[a]Data are reported as median [range], No. of patients (%), or mean ± SD. ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; ADL, Activities of Daily Living; ICRS, International Cartilage Regeneration & Joint Preservation Society; KOOS, Knee injury and Osteoarthritis Outcome Score; NA, not applicable; QoL, Quality of Life.

[b]Medial collateral ligament, lateral collateral ligament, posterior cruciate ligament, or posterolateral corner.

(International Cartilage Regeneration & Joint Preservation Society grade 3 or 4), time from injury to surgery (continuous variable), type of ACL graft (hamstring, patellar tendon, or other), and the preoperative KOOS. In all regression analyses, no concomitant meniscal lesion was used as the reference for the effect of concomitant meniscal lesions. Chi-square tests were used to analyze between-group differences in proportions of patients reporting KOOS QoL <44 (treatment failure). $P < .05$ was considered statistically significant. Crude mean KOOS scores, the standardized regression coefficients (β), and odds ratios (ORs) are presented with 95% CIs. SPSS software Version 24.0 (IBM) was used for all statistical analyses.

RESULTS

Crude Mean KOOS Scores

The crude mean KOOS scores at 5-year follow-up as well as the change over time from preoperative to the 5-year follow-up for patients with and without concomitant meniscal lesions are presented in Table 3 and Figure 2.

Patients with concomitant meniscal lesions reported equal crude mean scores compared with patients without meniscal lesions in all KOOS subscales 5 years after ACLR. Moreover, patients with concomitant meniscal lesions reported greater mean improvement over time than patients without such concomitant lesions in the KOOS subscales Pain, ADL, and Sport/Rec, as displayed in Figure 2.

The mean KOOS scores stratified by anatomic localization and treatment of the concomitant meniscal lesion are presented in Table 4. There were no major between-group differences in crude mean KOOS scores at the 5-year follow-up, either when comparing patients with a concomitant medial meniscal lesion with patients with a concomitant lateral meniscal lesion or when comparing the allocated surgical treatments within a knee compartment, or between the 2 knee compartments.

With significantly greater changes over time in the KOOS subscales Pain, ADL, and Sport/Rec, patients who had their medial meniscal lesion resected at the time of ACLR improved more than patients with no surgical treatment to their meniscal lesion. With the exception of Sport/Rec, where significantly greater improvement was reported by patients having had their medial meniscal lesion resected, patients with medial meniscal repair reported equal mean changes over time in KOOS to patients receiving either no treatment or resection of their concomitant medial meniscal lesions.

Patients with a concomitant lateral meniscal repair had larger mean changes over time in the KOOS subscales of Pain, Symptoms, ADL, and QoL compared with patients that received no surgical treatment to their lateral meniscal lesions, but reached statistical significance only in the ADL subscale. Compared with patients with no surgical treatment to their lateral meniscal lesion, patients who had

TABLE 2
Concomitant Meniscal Lesions

	Meniscal Lesions (n = 3634)		Total Study Cohort (N = 8408)	Lost to Follow-Up (n = 7298)
	Medial	Lateral		
No. of meniscal lesions	2300	1842	4142	3561
Treatment, No. of patients (%)				
No treatment	341 (15)	384 (21)	725 (9)	665 (9)
Resection	1513 (66)	1256 (68)	2769 (33)	2375 (33)
Repair	446 (19)	202 (11)	648 (8)	521 (7)

TABLE 3
Crude Mean Scores at the 5-year Follow-Up, and Change Over Time After ACL Reconstruction for Patients With and Without Concomitant Meniscal Lesions[a]

	No Meniscal Lesions (n = 4774)		Meniscal Lesions (n = 3634)	
KOOS	Patients, n	Mean (95% CI)	Patients, n	Mean (95% CI)
At 5-year follow-up				
Pain	4774	85.6 (85.2-86.1)	3633	85.5 (85.0-86.1)
Symptoms	4773	79.6 (79.1-80.1)	3633	78.7 (78.1-79.3)
ADL	4769	91.4 (91.0-91.8)	3630	91.2 (90.8-91.7)
Sport/Rec	4585	69.5 (68.8-70.3)	3476	69.6 (68.8-70.5)
QoL	4723	66.6 (65.7-67.3)	3594	66.5 (65.7-67.3)
Change over time[b]				
Pain	3295	10.4 (9.8-11.1)	2723	12.6 (11.9-13.3)
Symptoms	3300	7.5 (6.8-8.2)	2735	8.8 (8.0-9.6)
ADL	3287	7.1 (6.5-7.6)	2717	9.2 (8.5-9.8)
Sport/Rec	3153	25.6 (24.6-26.7)	2602	29.0 (27.8-30.2)
QoL	3252	32.7 (31.8-33.6)	2698	34.2 (33.2-35.2)

[a]ACL, anterior cruciate ligament; ADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, Quality of Life.
[b]Mean difference in scores between preoperatively and 5-year follow-up.

their lateral meniscal lesion resected generally reported a larger mean change over time in KOOS, but this reached statistical significance only in the Pain subscale.

Multivariable Linear Regression

The results from the multivariable regression analysis with the unadjusted and adjusted effects of not treated, resected, or repaired concomitant medial or lateral meniscal lesions on each of the KOOS subscales at 5-year follow-up are listed in Table 5. In the unadjusted analyses, with patients without concomitant meniscal lesions as reference, a repaired medial meniscal lesion was significantly associated with inferior scores in the KOOS subscales of Symptoms, Sport/Rec, and QoL. With the exception of the ADL subscale, medial meniscal resection was not associated with inferior KOOS at 5-year follow-up. There were no significant associations between not treated medial meniscal lesions and KOOS at 5-year follow-up.

Except from the Symptoms subscale, for which a resected lateral meniscal lesion was negatively associated with outcome, there were no significant associations between any of the lateral meniscal lesion categories (not treated, resected, or repaired) and KOOS outcome at 5-year follow-up.

In the adjusted analyses, with patients without concomitant meniscal lesions as the reference, neither not treated, resected, nor repaired medial meniscal lesions were significantly associated with KOOS 5 years after ACLR (Table 5). Except for the ADL subscale, for which a repaired lateral meniscal lesion was associated with better outcome, there were no significant associations between any of the lateral meniscal lesion treatment categories and KOOS outcome at 5-year follow-up (Table 5).

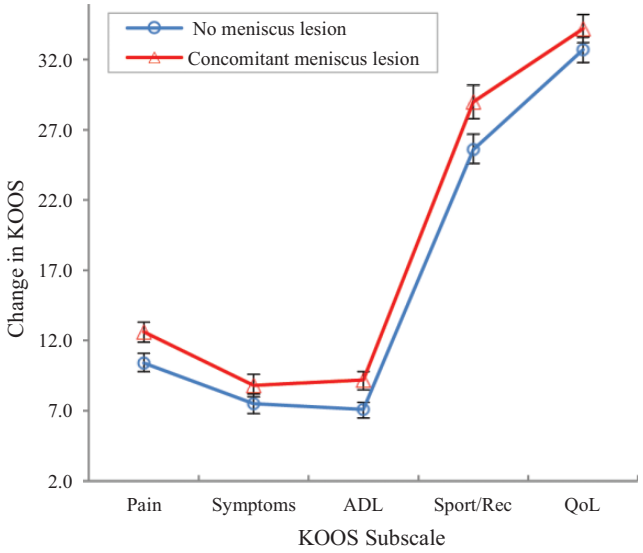

Figure 2. Profiles of mean change over time (baseline to 5-year follow-up) in KOOS values of patients without and patients with concomitant meniscal lesions. Point estimates are illustrated with 95% CIs. ADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, knee-related Quality of Life; Sport/Rec, Sport and Recreation.

Treatment Failure

Treatment failure defined as a KOOS QoL score below 44 (a prespecified cutoff value consistent with a nonsatisfactory result) was identified in 1850 (22%) patients at the

TABLE 4
Crude Mean KOOS Scores for Patients With Concomitant Meniscal Lesion at 5-year Follow-Up, and Change Over Time After ACL Reconstruction[a]

	Medial Meniscal Lesion (n = 2300)			Lateral Meniscal Lesion (n = 1482)		
KOOS	No Treatment (n = 341)	Resection (n = 1513)	Repair (n = 446)	No Treatment (n = 384)	Resection (n = 1256)	Repair (n = 202)
At 5-year follow-up[b]						
Pain	86.8 (85.1-88.4)	85.1 (84.2-86.0)	83.9 (82.3-85.5)	86.6 (85.1-88.0)	85.7 (84.8-86.7)	86.8 (84.7-88.8)
Symptoms	80.5 (78.6-82.4)	78.6 (77.7-79.6)	76.9 (75.1-78.7)	80.4 (78.7-82.1)	78.2 (77.1-79.2)	77.8 (75.3-80.3)
ADL	92.1 (90.7-93.6)	90.5 (89.7-91.3)	90.8 (89.5-92.2)	92.6 (91.4-93.8)	91.1 (90.3-91.9)	93.1 (91.5-94.7)
Sport/Rec	70.0 (67.3-72.7)	69.9 (68.6-71.2)	66.6 (64.1-69.0)	69.5 (67.0-72.0)	69.4 (68.0-70.8)	69.5 (66.0-73.0)
QoL	68.5 (66.0-71.0)	65.9 (64.6-67.1)	64.1 (61.8-66.3)	65.9 (63.5-68.3)	67.1 (65.7-68.4)	67.1 (63.9-70.3)
Change over time[b]	n = 246-255[c]	n = 1043-1109[c]	n = 337-360[c]	n = 283-295[c]	n = 908-946[c]	n = 163-169[c]
Pain	9.5 (7.3-11.7)	14.1 (12.9-15.2)	11.5 (9.4-13.7)	9.2 (7.2-11.3)	12.7 (11.5-13.9)	13.2 (10.2-16.2)
Symptoms	6.0 (3.2-8.8)	9.9 (8.6-11.3)	8.7 (6.3-11.2)	6.9 (4.5-9.4)	8.1 (6.7-9.6)	10.0 (6.6-13.5)
ADL	6.5 (4.6-8.4)	10.4 (9.4-11.5)	9.1 (7.1-11.1)	6.3 (4.5-8.1)	8.4 (7.3-9.5)	12.4 (9.5-15.3)
Sport/Rec	25.0 (21.1-28.9)	31.7 (29.9-33.5)	26.4 (23.0-29.9)	23.6 (19.8-27.4)	28.8 (26.7-30.9)	27.8 (22.8-32.7)
QoL	33.6 (30.4-36.8)	35.8 (34.2-37.4)	31.9 (29.0-34.7)	30.6 (27.5-33.8)	33.6 (32.0-35.5)	34.8 (30.5-39.0)

[a]Scores are reported as mean (95% CI). ACL, anterior cruciate ligament; ADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, Quality of Life; Sport/Rec, Sport and Recreation.
[b]Mean difference in scores between preoperatively and 5-year follow-up.
[c]Range of patients with both preoperative and 5-year follow-up subscale score.

TABLE 5
Unadjusted and Adjusted Regression Analyses of the Association Between 5-Year KOOS Results and Treatment of Concomitant Medial and Lateral Meniscal Lesions at the Time of ACL Reconstruction[a]

		Treatment Type					
		No Treatment[b]		Resection[b]		Repair[b]	
KOOS Subscale	Patients, N	β (95% CI)	*P*	β (95% CI)	*P*	β (95% CI)	*P*
Medial Meniscal Lesions							
Pain							
Unadjusted	6017	1.0 (–1.1 to 3.0)	NS	–0.9 (–1.9 to 0.2)	NS	–1.6 (–3.3 to 0.1)	NS
Adjusted	5767	0.7 (–1.2 to 2.5)	NS	0.4 (–0.7 to 1.4)	NS	–0.3 (–1.9 to 1.3)	NS
Symptoms							
Unadjusted	6016	0.7 (–1.6 to 3.0)	NS	–1.2 (–2.4 to 0.0)	.050	–2.7 (–4.7 to –0.8)	.007
Adjusted	5765	0.3 (–1.9 to 2.5)	NS	–0.9 (–2.1 to 0.3)	NS	–1.0 (–2.9 to 0.9)	NS
ADL							
Unadjusted	6012	0.6 (–1.2 to 2.4)	NS	–1.0 (–1.9 to –0.1)	.029	–0.5 (–2.0 to 1.0)	NS
Adjusted	5753	0.5 (–1.1 to 2.1)	NS	0.4 (–0.4 to 1.3)	NS	0.3 (–1.1 to 1.7)	NS
Sport/Rec							
Unadjusted	5794	1.2 (–2.1 to 4.5)	NS	0.1 (–1.6 to 1.8)	NS	–2.9 (–5.7 to –0.2)	.039
Adjusted	5507	1.5 (–1.7 to 4.6)	NS	1.1 (–0.5 to 2.8)	NS	–0.9 (–3.6 to 1.9)	NS
QoL							
Unadjusted	5953	2.7 (–0.3 to 5.8)	NS	–1.0 (–2.5 to 0.6)	NS	–2.7 (–5.3 to –0.1)	.043
Adjusted	5692	2.9 (–0.1 to 5.8)	NS	–0.4 (–2.0 to 1.1)	NS	–0.8 (–3.4 to 1.7)	NS
Lateral Meniscal Lesions							
Pain							
Unadjusted	6017	0.2 (–1.7 to 1.6)	NS	0.2 (–1.0 to 1.3)	NS	1.0 (–1.5 to 3.5)	NS
Adjusted	5767	–0.1 (–1.9 to 1.6)	NS	0.6 (–0.4 to 1.7)	NS	2.0 (–0.3 to 4.3)	NS
Symptoms							
Unadjusted	6016	0.2 (–2.0 to 2.3)	NS	–1.7 (–3.0 to –0.5)	.007	–1.4 (–4.2 to 1.3)	NS
Adjusted	5765	0.4 (–1.6 to 2.5)	NS	–1.1 (–2.4 to 0.1)	NS	0.5 (–2.3 to 3.2)	NS
ADL							
Unadjusted	6012	0.7 (–1.0 to 2.3)	NS	0.0 (–1.0 to 1.0)	NS	1.8 (–0.4 to 3.9)	NS
Adjusted	5753	0.1 (–1.4 to 1.6)	NS	0.2 (–0.7 to 1.1)	NS	2.8 (0.8 to 4.8)	.006
Sport/Rec							
Unadjusted	5794	–0.5 (–3.5 to 2.6)	NS	–0.9 (–2.7 to 0.9)	NS	–0.6 (–4.6 to 3.3)	NS
Adjusted	5507	–1.0 (–3.9 to 2.0)	NS	–0.3 (–2.0 to 1.5)	NS	0.3 (–3.6 to 4.1)	NS
QoL							
Unadjusted	5953	–1.8 (–4.7 to 1.0)	NS	–0.5 (–1.7 to 1.6)	NS	0.1 (–3.5 to 3.8)	NS
Adjusted	5692	–1.8 (–4.6 to 0.9)	NS	0.0 (–1.6 to 1.7)	NS	2.3 (–1.3 to 5.9)	NS

[a]Adjusted for sex, age, previous ipsilateral knee surgery, time from injury to surgery, concomitant ligament injury, concomitant cartilage lesions (International Cartilage Regeneration & Joint Preservation Society grade 3 or 4), type of ACL graft, and preoperative KOOS values. ACL, anterior cruciate ligament; ADL, Activities of Daily Living; KOOS, Knee injury and Osteoarthritis Outcome Score; NS, not significant; QoL, knee-related Quality of Life; Sport/Rec, Sport and Recreation.
[b]Reference variable: no meniscal lesion.

5-year follow-up.[2,7] Of those, 781 (42%) had a concomitant meniscal lesion and 1069 (58%) had no concomitant meniscal lesions. Of the 6467 (78%) patients dichotomized as not having treatment failure, 2813 (43%) had a concomitant meniscal lesion and 3654 (57%) had no concomitant meniscal lesions. Having a concomitant meniscal lesion at the time of ACLR did not affect the odds of treatment failure at follow-up (OR, 0.95; 95% CI, 0.85-1.05). Analogous to this, having a concomitant medial (OR, 1.03; 95% CI, 0.90-1.18) or a concomitant lateral (OR, 0.88; 95% CI, 0.75-1.03) meniscal lesion did not affect the odds of treatment failure.

DISCUSSION

The main finding of the present study was that a concomitant meniscal lesion at the time of ACLR did not predict inferior outcome, as measured by KOOS, 5 years after surgery. Indeed, patients with a concomitant meniscal lesion reported equal or better outcomes than patients without such concomitant lesions. Moreover, compared with patients without meniscal lesions, patients with concomitant meniscal lesions improved significantly during follow-up in several KOOS domains. Although medial meniscal repair was associated with worse 5-year outcomes in KOOS

Symptoms, Sport/Rec, and QoL in the unadjusted analyses, lateral meniscal repair was associated with equal or better ADL outcome compared with patients without concomitant meniscal lesions. As population mean scores and mean changes are difficult to apply to individuals in clinical practice, we performed a responder analysis in which the continuous outcome measure was dichotomized into treatment failure (KOOS QoL <44) or nontreatment failure (KOOS QoL ≥44). In these responder analyses, concomitant meniscal lesions at the time of ACLR did not increase the odds of reporting treatment failure at the 5-year follow-up.

In light of the increased focus on concomitant meniscal lesions, these findings might seem controversial; however, they are supported by similar findings in other large cohort studies.[2,5,16] In a large multivariable model with 6-year follow-up, Cox et al[5] found that concomitant medial meniscal repair predicted worse KOOS at the 6-year follow-up as compared with patients without meniscal lesions. The authors also identified that lateral meniscal lesions left untreated, partially resected, or repaired fared significantly better than not having concomitant meniscal lesions at all. In line with those findings, we observed that lateral meniscal repair predicted better outcome in KOOS ADL and equal outcome in the remaining subscales as compared with patients without concomitant meniscal lesions. In contrast, we found that lateral meniscal resection was associated with inferior KOOS Symptoms in the unadjusted regression analyses. Apart from that, lateral meniscal lesions left untreated or resected predicted equal KOOS outcome to patients without concomitant meniscal lesions. However, the finding that lateral meniscal repair, but not medial meniscal repair, improved outcome should be interpreted in light of the results from both the unadjusted and the adjusted analyses. In the adjusted analyses, no negative effect of medial meniscal repair was evident, indicating that factors other than the repair itself, such as preoperative KOOS, concomitant cartilage lesions, and concomitant ligament injury (other than ACL), modifies the effect on the 5-year KOOS. Cox et al suggested that, because of decreased mobility and vascularity, medial meniscal repair is subject to greater biomechanical loads than lateral repair in the setting of ACLR.

In line with the findings from the current study, in a retrospective 2-year follow-up from the Swedish Knee Ligament Register, Barenius et al[2] did not find concomitant meniscal injury at the time of ACLR to be a predictor for outcome. However, by dichotomizing their outcomes into treatment failure and functional recovery as determined by prespecified cutoffs in KOOS, medial meniscal resection and repair were significantly associated with higher risk of treatment failure.

In the current study, having adjusted for variables known to be associated with outcome, such as full-thickness cartilage lesions, sex, age, time from injury to surgery, preoperative KOOS, and others, and regardless of anatomic localization and treatment, no significant negative effects of concomitant meniscal lesions were identified in any of the KOOS subscales.

Based on these observations, one may suggest that concomitant meniscal lesions play a relatively minor role in dictating the patient-reported prognosis 5 years after ACLR. In former reports from the longitudinal follow-up of the present cohort, concomitant cartilage lesions were identified as having significant negative effects on KOOS at selected time points.[22,27] One could speculate that injury to the ACL itself along with other concomitant injuries, such as cartilage lesions, overshadow the effect of meniscal injuries on PROMs during the first 5 years.

The current study has several limitations. An obvious limitation is the rate of loss to follow-up (46%), with the potential of introducing attrition bias, as discussed in detail in previous publications from this cohort.[26,27] Even though the baseline characteristics of the study cohort and those lost to follow-up were comparable, the proportion of younger men was higher among patients lost to follow-up. Hence, there is a possibility that those patients lost to follow-up affected the results. Nevertheless, in a validation study of the Danish Ligament Reconstruction Register, the KOOS values from nonresponders were found to be comparable with those of responders, indicating that registry data could be valid despite a high rate of loss to follow-up.[20] In addition, a selection bias has been introduced, as not all ACLRs (85%) are reported to the national registries at the time of surgery. Another limitation is that information on potential confounders, or effect modifiers, such as activity level, body mass index, surgical techniques used in ACLR and meniscal repair, postoperative rehabilitation, or a more precise classification of the meniscal pathomorphological characteristics were not available, as these variables are not recorded in the 2 registries. These variables, together with other unknown factors, could be a potential source of confounding, or at least be a source of modification of the measured lack of effects on the present 5-year results. In addition, the current study design makes it difficult to establish any causal inference. Furthermore, direct comparison between the different surgical treatment options (no treatment, resection, and repair) is challenging because reparable/repaired lesions are not comparable with irreparable/resected lesions, or with minor/untreated lesions, because the indications are generally different. Finally, using KOOS, with its inherent risk of ceiling effects, as the sole PROM might leave the analyses insensitive to true differences between groups.[12]

The results from the present study are based on ACLRs performed during a period when meniscal repairs were quite infrequent (11%-19%). Considering the more recent focus on meniscal preservation[19] and steadily increasing rates of meniscal repairs,[10] future studies should investigate whether such a transition in surgical management actually results in better PROMs. The findings in the present study could be used as a benchmark for future studies looking into the effect of the subsequent years increasing rates of meniscal repair and preservation in the setting of ACLR.

Nevertheless, PROMs at 5-year follow-up are not the only form of outcome assessment. Premature OA, even though not linked to PROMs,[25] is known to be linked closely to concomitant meniscal lesions, particularly meniscal resection.[3,15,17] In the present study, the length of follow-up is probably too short to fully evaluate the long-term

effects of meniscal lesions and treatment in relation to OA. Consequently, there is still reason for advocating for meniscal preservation, at least in terms of OA prevention.

CONCLUSION

Concomitant meniscal lesions at the time of ACLR conferred no negative effect on patient-reported outcome 5 years after ACLR. The improvement in selected KOOS subscales from preoperatively to the 5-year follow-up was significantly greater for patients with concomitant meniscal lesions than for patients without such lesions. The odds of treatment failure were not increased for patients with a concomitant meniscal lesion as compared with patients without such lesions.

ACKNOWLEDGMENT

The authors thank the Norwegian and Swedish national knee ligament registries for providing data for the current study and the Oslo Sports Trauma Research Center for its advisory and economic support.

REFERENCES

1. Ahldén M, Samuelsson K, Sernert N, Forssblad M, Karlsson J, Kartus J. The Swedish National Anterior Cruciate Ligament Register: a report on baseline variables and outcomes of surgery for almost 18,000 patients. *Am J Sports Med*. 2012;40(10): 2230-2235.
2. Barenius B, Forssblad M, Engström B, Eriksson K. Functional recovery after anterior cruciate ligament reconstruction, a study of health-related quality of life based on the Swedish National Knee Ligament Register. *Knee Surg Sports Traumatol Arthrosc*. 2013; 21(4):914-927.
3. Barenius B, Ponzer S, Shalabi A, Bujak R, Norlen L, Eriksson K. Increased risk of osteoarthritis after anterior cruciate ligament reconstruction: a 14-year follow-up study of a randomized controlled trial. *Am J Sports Med*. 2014;42(5):1049-1057.
4. Claes S, Hermie L, Verdonk R, Bellemans J, Verdonk P. Is osteoarthritis an inevitable consequence of anterior cruciate ligament reconstruction? A meta-analysis. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(9):1967-1976.
5. Cox CL, Huston LJ, Dunn WR, et al. Are articular cartilage lesions and meniscus tears predictive of IKDC, KOOS, and Marx activity level outcomes after anterior cruciate ligament reconstruction? A 6-year multicenter cohort study. *Am J Sports Med*. 2014;42(5): 1058-1067.
6. Filbay SR, Roos EM, Frobell RB, Roemer F, Ranstam J, Lohmander LS. Delaying ACL reconstruction and treating with exercise therapy alone may alter prognostic factors for 5-year outcome: an exploratory analysis of the KANON trial. *Br J Sports Med*. 2017;51: 1622-1629.
7. Frobell RB, Roos EM, Roos HP, Ranstam J, Lohmander LS. A randomized trial of treatment for acute anterior cruciate ligament tears. *N Engl J Med*. 2010;363(4):331-342.
8. 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.
9. Granan LP, Forssblad M, Lind M, Engebretsen L. The Scandinavian ACL registries 2004-2007: baseline epidemiology. *Acta Orthop*. 2009; 80(5):563-567.
10. Annual Report from the Norwegian Knee Ligament Registry (2019). Accessed February 1, 2020. nrlweb.ihelse.net
11. Hamrin Senorski E, Svantesson E, Beischer S, et al. Factors affecting the achievement of a patient-acceptable symptom state 1 year after anterior cruciate ligament reconstruction: a cohort study of 343 patients from 2 registries. *Orthop J Sports Med*. 2018;6(4): 2325967118764317.
12. Ingelsrud LH, Granan LP, Terwee CB, Engebretsen L, Roos EM. Proportion of patients reporting acceptable symptoms or treatment failure and their associated KOOS values at 6 to 24 months after anterior cruciate ligament reconstruction: a study from the Norwegian Knee Ligament Registry. *Am J Sports Med*. 2015; 43(8):1902-1907.
13. Ingelsrud LH, Terwee CB, Terluin B, et al. Meaningful change scores in the Knee injury and Osteoarthritis Outcome Score in patients undergoing anterior cruciate ligament reconstruction. *Am J Sports Med*. 2018;46(5):1120-1128.
14. Janssen RP, du Mee AW, van Valkenburg J, Sala HA, Tseng CM. Anterior cruciate ligament reconstruction with 4-strand hamstring autograft and accelerated rehabilitation: a 10-year prospective study on clinical results, knee osteoarthritis and its predictors. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(9):1977-1988.
15. Keays SL, Newcombe PA, Bullock-Saxton JE, Bullock MI, Keays AC. Factors involved in the development of osteoarthritis after anterior cruciate ligament surgery. *Am J Sports Med*. 2010;38(3): 455-463.
16. LaPrade CM, Dornan JG, Granan LP, LaPrade RF, Engebretsen L. Outcomes after anterior cruciate ligament reconstruction using the Norwegian Knee Ligament Registry of 4691 patients: how does meniscal repair or resection affect short-term outcomes? *Am J Sports Med*. 2015;43(7):1591-1597.
17. Oiestad BE, Holm I, Aune AK, et al. Knee function and prevalence of knee osteoarthritis after anterior cruciate ligament reconstruction: a prospective study with 10 to 15 years of follow-up. *Am J Sports Med*. 2010;38(11):2201-2210.
18. Pedersen M, Johnson JL, Grindem H, Magnusson K, Snyder-Mackler L, Risberg MA. Meniscus or cartilage injury at the time of anterior cruciate ligament tear is associated with worse prognosis for patient-reported outcome 2 to 10 years after anterior cruciate ligament injury: a systematic review. *J Orthop Sports Phys Ther*. 2020; 50(9):490-502.
19. Pujol N, Beaufils P. Save the meniscus again! *Knee Surg Sports Traumatol Arthrosc*. 2019;27:341-342.
20. 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.
21. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee injury and Osteoarthritis Outcome Score (KOOS)—development of a self-administered outcome measure. *J Orthop Sports Phys Ther*. 1998;28(2):88-96.
22. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Aroen A. Effect of meniscal and focal cartilage lesions on patient-reported outcome after anterior cruciate ligament reconstruction: a nationwide cohort study from Norway and Sweden of 8476 patients with 2-year follow-up. *Am J Sports Med*. 2013;41(3):535-543.
23. Røtterud JH, Sivertsen EA, Forssblad M, Engebretsen L, Årøen A. Effect of gender and sports on the risk of full-thickness articular cartilage lesions in anterior cruciate ligament-injured knees: a nationwide cohort study from Sweden and Norway of 15,783 patients. *Am J Sports Med*. 2011;39(7):1387-1394.
24. Smoak JB MJ, Vinod AV, Kluczynski MA, Bisson LJ. An up-to-date review of the meniscus literature: a systematic summary of systematic reviews and meta-analyses. *Orthop J Sports Med*. 2020;8(9): 2325967120950306.
25. Son KM, Hong JI, Kim DH, Jang DG, Crema MD, Kim HA. Absence of pain in subjects with advanced radiographic knee osteoarthritis. *BMC Musculoskelet Disord*. 2020;21:640.

26. Spindler KP, Huston LJ, Wright RW, et al. The prognosis and predictors of sports function and activity at minimum 6 years after anterior cruciate ligament reconstruction: a population cohort study. *Am J Sports Med*. 2011;39(2):348-359.
27. Ulstein S, Aroen A, Engebretsen L, Forssblad M, Lygre SHL, Rotterud JH. A controlled comparison of microfracture, debridement, and no treatment of concomitant full-thickness cartilage lesions in anterior cruciate ligament-reconstructed knees: a nationwide prospective cohort study from Norway and Sweden of 368 patients with 5-year follow-up. *Orthop J Sports Med*. 2018;6(8):2325967118787767.
28. Ulstein S, Aroen A, Engebretsen L, Forssblad M, Lygre SHL, Rotterud JH. Effect of concomitant cartilage lesions on patient-reported outcomes after anterior cruciate ligament reconstruction: a nationwide cohort study From Norway and Sweden of 8470 patients with 5-year follow-up. *Orthop J Sports Med*. 2018;6(7):2325967118786219.