Patient demographic and surgical characteristics in anterior cruciate ligament reconstruction: a description of registries from six countries

Heather A Prentice,[1] Martin Lind,[2] Caroline Mouton,[3] Andreas Persson,[4,5] Henrik Magnusson,[6] Ayman Gabr,[7] Romain Seil,[3] Lars Engebretsen,[4,5] Kristian Samuelsson,[8] Jon Karlsson,[8] Magnus Forssblad,[9] Fares S Haddad,[10] Tim Spalding,[11] Tadashi T Funahashi,[12] Liz W Paxton,[1] Gregory B Maletis[13]

For numbered affiliations see end of article.

Correspondence to
Dr Heather A Prentice, Surgical Outcomes and Analysis, Kaiser Permanente, San Diego, CA 92108, USA; heather.prentice@kp.org

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ABSTRACT

Objective Findings from individual anterior cruciate ligament reconstruction (ACLR) registry studies are impactful, but how various registries from different countries compare with different patient populations and surgical techniques has not been described. We sought to describe six ACLR registry cohorts to understand variation across countries.

Methods Five European registries and one US registry participated. For each registry, all primary ACLR registered between registry establishment through 31December 2014 were identified. Descriptive statistics included frequencies, proportions, medians and IQRs. Revision incidence rates following primary ACLR were computed.

Results 101 125 ACLR were included: 21 820 in Denmark, 300 in Luxembourg, 17 556 in Norway, 30 422 in Sweden, 2972 in the UK and 28 055 in the US. In all six cohorts, males (range: 56.8%–72.4%) and soccer injuries (range: 14.1%–42.3%) were most common. European countries mostly used autografts (range: 93.7%–99.7%); allograft was most common in the US (39.9%). Interference screw was the most frequent femoral fixation in Luxembourg and the US (84.8% and 42.9%), and suspensory fixation was more frequent in the other countries (range: 43.9%–75.5%). Interference was the most frequent tibial fixation type in all six cohorts (range: 64.8%–98.2%). Three-year cumulative revision probabilities ranged from 2.8% to 3.7%.

Conclusions Similarities in patient demographics and injury activity were observed between all cohorts of ACLR. However, graft and fixation choices differed. Revision rates were low. This work, including >100 000 ACLR, is the most comprehensive international description of contemporary practice to date.

INTRODUCTION

Anterior cruciate ligament (ACL) tears are a common orthopaedic injury. Though the ideal treatment for an ACL tear has yet to be fully elucidated,[1 2] and some studies suggest only 65% patients who undergo surgical reconstruction return to the same level of activity,[3] the incidence of ACL reconstruction (ACLR) continues to increase.[4 5] Research continues to investigate ACLR procedure optimisation, postoperative care and minimising adverse outcomes. Evidence in many areas is insufficient to guide clinical practice, particularly for multiligament injuries, graft selection and fixation method.[6]

ACL registries provide a mechanism for prospective surveillance of a well-defined patient population, providing long-term follow-up of patients and continuous feedback to surgeons for patient safety and quality improvement. Registries also allow for identification of early failures and best clinical practices,[7] and trends in clinical practice over time. Individual ACL registries from across the world have evaluated patient characteristics, surgical technique, graft selection and fixation devices on risk affecting short-term clinical outcomes following ACLR (ie, infection and venous thromboembolism),[8] as well as long-term outcomes requiring surgical intervention (ie, reoperation and revision).[9–23] The generalisability of findings from single registries to other populations throughout the world where patient and surgical factors differ is unclear.

A cross-registry appraisal provides an opportunity to evaluate clinical practices and outcomes globally. While some international ACLR studies have been previously reported,[24–30] these investigations focused on Scandinavian and US registries only and are limited in the level of detail provided. Therefore, we sought to provide the most comprehensive description of ACLR to date through the largest collaboration of registries, each with unique population bases, surgeon preferences and healthcare structures. The purpose of this descriptive study is to characterise each cohort with respect to case volume, patient characteristics and demographics, activity at the time of injury, concurrent injuries at the time of surgery, ACL graft type, femoral and tibial fixation devices, and outcomes requiring subsequent surgical intervention.

MATERIALS AND METHODS

Study sample

We conducted a descriptive study of six national, regional and hospital-based ACL registries. For each registry, all primary ACLR registered between the start of the given registry through 31 December 2014 were identified. Patient characteristics, demographics and surgical characteristics were summarised by each registry. Subsequent surgical outcomes following primary ACLR included ipsilateral reoperation, contralateral operation and revision surgery. Each participating registry reported

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results using summary-level statistics to protect individual patient health information.

Danish cruciate ligament register

The national Danish registry is a prospective, web-based clinical database, initiated in 2005 and included >23 000 total patients by the end of 2014 with 93% participation. The registry contains data on epidemiology and surgical techniques for primary and revision ACL and posterior cruciate ligament (PCL) procedures.[31] Both public and private hospitals supply data to the Danish registry, and submission in this official clinical database is mandatory. Preoperative (patient characteristics, demographics and activity injury), intraoperative (concomitant injuries, graft type and device choice) and 1-year surgical outcome (revisions and reoperations) data are recorded by surgeons and linked to the primary by the registry.

Luxembourg ligament register

The Luxembourg registry is a hospital-based registry started in March 2011, with >300 ACLR registered by the end of 2014 and 90%–95% participation. This registry includes all patients with a clinically documented ACL injury and MRI scan regardless of operative or non-operative treatment.[32] The Luxembourg registry prospectively collects demographic, patient characteristic and injury information using questionnaires completed by the patient and operative data using paper forms filled in by surgeons. One-year postoperative outcomes, including revision and reoperation, depend on the patient reporting back to a participating hospital for either ACL or other knee pathologies. All data are saved using software specific to the follow-up of patients with an ACL injury and checked daily with the help of a scientific coordinator.

Norwegian knee ligament register

The Norwegian registry, the first national cruciate ligament registry, was started in June 2004. This registry includes primary and revision ACL and PCL reconstructions, with almost 20 000 patients by the end of 2014. Although initially voluntary, reporting to the registry is now mandatory to all public and private hospitals, with a report rate of 86% in 2008–2009.[33] The registry collects patient-specific data, surgical detail and intraoperative findings through forms filled out by the surgeon. Subsequent surgical outcomes are surgeon-reported and linked to the primary by the registry.[34]

Swedish national ACL register

The Swedish registry was initiated in January 2005 by Sweden ACL surgeons with the goal of allowing all surgeons to access the registry database and results online. Protocol for the Swedish registry is nearly identical to Denmark and Norway. The registry included >30 000 patients with ACLR by the end of 2014, and voluntary reporting to the registry by both public and private surgeons was >90%.[35] Surgeons report on patient characteristics, intraoperative findings, and graft and implant selection via standardised web-based forms; demographic information is then linked using Swedish social security numbers. Revisions are surgeon-reported and linked to the primary by the registry.[36]

UK national ligament register

The UK registry was established in March 2013 and modelled on the Scandinavian registries. Entry is voluntary for surgeons, involving a fully online web-based data collection system. At the time of this study the number of patients was low compared with most other established registries (<3000 patients), including public and private-funded patients.[37] Participation rates for the UK registry are not currently available. In the UK registry, patients and surgeons enter data via an online portal. Patients enter demographic, injury and outcome data. Surgeons enter operative detail and any postoperative adverse events. Revisions depend on surgeons declaring a further procedure was performed or the patient reporting a revision at one of the follow-up time points. Revisions are not currently linked to any national system documenting operations performed.

Kaiser Permanente ALCR registry

This US-based registry includes patients from Kaiser Permanente (KP), a large, integrated healthcare system serving >11.2 million members in eight geographical regions of the US (Colorado, Georgia, Hawaii, Mid-Atlantic, Northern California, Northwest, Southern California and Washington). The registry was established in February 2005 and registered >30 000 cases by the end of 2014, and voluntary participation was 93% in 2011.[38] The KP ACLR registry collects operative data, including intraoperative findings, graft type and fixation devices, using forms completed by the surgeon. These data are supplemented with demographic, patient, surgeon and healthcare centre information collected via the electronic health record (EHR), administrative claims, membership files and mortality records. Subsequent surgical outcomes are prospectively monitored by the registry and validated by trained clinical content experts using the EHR.[38 39] At the end of the study period, 20.5% of patients were lost to follow-up due to death or leaving KP membership.

Variable definitions

Ipsilateral operations included any non-revision procedure on the index knee, while contralateral operations included any procedure or ACLR performed in the contralateral knee at a date following the primary ACLR. Cartilage injury included any injury, regardless of the grade. Revisions were defined as any procedure in the index knee in which the graft was replaced.

Statistical analysis

Frequencies, proportions, medians and IQRs were used to describe each registries' population. Cumulative revision probabilities were calculated as one minus the Kaplan-Meier estimator and revision densities as the proportion of revisions over person-years follow-up, reported per 100 years of follow-up. For calculations, follow-up was defined as the time from the date of the primary ACLR to the date of revision, loss to follow-up or study end date (31 December 2014), whichever came first. Loss to follow-up was defined as death, emigration or membership termination.

RESULTS

The study consisted of 101 125 primary ACLR: 21 820 from Denmark, 300 from Luxembourg, 17 556 from Norway, 30 422 from Sweden, 2972 from the UK and 28 055 from the US. Median follow-up was 4.6 years in Denmark, 0.4 years in Luxembourg, 5.0 years in Norway, 4.4 years in Sweden, 1 year in the UK and 2.8 years in the US (table 1).

Patient characteristics were similar across cohorts (table 1). The most common age group at the time of surgery was 15–19 years in all countries except the UK where 25–29 years was more common. Male patients were more frequently observed in all six cohorts (range: 56.8%–72.4%). Characteristics related to the reconstructed knee did vary slightly. Of US patients, 4.3% had a

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Table 1 Procedure description and patient characteristics

Characteristic, n (%)	Denmark*	Luxembourg†	Norway‡	Sweden§	UK¶	US**
Established/start date	July 2005	March 2011	June 2004	January 2005	March 2013	February 2005
Primary procedures	21 820	300	17 556	30 422	2972	28 055
Age (at time of surgery) (years)						
<15	635 (2.9)	10 (3.3)	374 (2.1)	788 (2.6)	45 (1.5)	948 (3.4)
15–19	4635 (21.2)	61 (20.3)	4219 (24.0)	7982 (26.2)	452 (15.3)	7506 (26.7)
20–24	4271 (19.6)	55 (18.3)	3135 (17.9)	6570 (21.6)	602 (20.4)	4178 (14.9)
25–29	3195 (14.6)	57 (19.0)	2484 (14.1)	4652 (15.3)	612 (20.7)	3673 (13.1)
30–34	2721 (12.5)	42 (14.0)	2143 (12.2)	3223 (10.6)	379 (12.8)	3310 (11.8)
35–39	2522 (11.6)	27 (9.0)	2074 (11.8)	2800 (9.2)	281 (9.5)	2851 (10.2)
≥40	3841 (17.6)	48 (16.0)	3127 (17.8)	4407 (14.5)	586 (19.8)	5589 (19.9)
Gender						
Male	13 244 (60.7)	215 (71.7)	9975 (56.8)	17 548 (57.7)	2153 (72.4)	17 618 (62.8)
Female	8576 (39.3)	85 (28.3)	7581 (43.2)	12 874 (42.3)	819 (27.6)	10 437 (37.2)
BMI (kg/m^2)						
<25	–	176 (58.7)	2983 (56.4)	8452 (62.5)	525 (51.0)	10 890 (39.3)
25–29	–	101 (33.7)	1773 (33.5)	4246 (31.4)	377 (36.6)	10 381 (37.4)
≥30	–	23 (7.6)	537 (10.1)	834 (6.2)	128 (12.4)	6455 (23.3)
Prior procedure to the index knee	–	22 (7.3)	3427 (19.5)	–	–	1193 (4.3)
No injury to the contralateral ACL	19 682 (92.1)	248 (82.7)	13 958 (92.0)	23 107 (91.7)	–	12 876 (93.5)
Operative side						
Right	10 926 (50.9)	166 (55.3)	8941 (50.9)	15 729 (51.7)	1357 (51.0)	13 793 (49.2)
Left	10 525 (49.1)	134 (44.7)	8615 (49.1)	14 684 (48.3)	1303 (49.0)	14 262 (50.8)
Time to reconstruction (months)††						
0–3	4665 (22.3)	107 (35.8)	3383 (24.0)	3825 (13.8)	249 (40.9)	7002 (43.8)
4–6	4772 (22.8)	74 (24.7)	3120 (22.1)	6347 (22.9)	155 (25.5)	3739 (23.4)
7–12	4633 (22.1)	52 (17.4)	3263 (23.1)	8060 (29.1)	120 (19.7)	2260 (14.1)
>12	6875 (32.8)	66 (22.1)	4346 (30.8)	9428 (34.1)	85 (14.0)	2980 (18.6)
Follow-up time (years)‡‡, median (IQR)	4.6 (2.3–6.8)	0.4 (0.2–0.9)	5.0 (2.6–7.6)	4.4 (2.2–6.9)	1 (–)	2.8 (1.3–4.8)

*Missing data: no contralateral injury: 439 (2.0); operative side: 369 (1.7%); time to reconstruction: 875 (4.0%).
†Missing data: time to reconstruction: 1 (0.3%).
‡Missing data: BMI: 12 263 (69.8%); no contralateral injury: 2391 (13.6); time to reconstruction: 3444 (19.6%).
§Missing data: BMI: 16 890 (55.5%); no contralateral injury: 5235 (17.2); operative side: 9 (0.0%); time to reconstruction: 2762 (9.1%).
¶Missing data: age: 15 (0.5%); BMI: 1942 (65.3%); operative side: 312 (10.5%); time to reconstruction: 2363 (79.5%).
**Missing data: BMI: 329 (1.2%); no contralateral injury: 14 285 (50.9%); time to reconstruction: 12 074 (43.0%).
††Calculated as the difference between the date of surgery and date of injury.
‡‡Calculated as the difference between the censoring date and the date for surgery. The censoring date is the last date of follow-up or the study end date (31 December 2014), whichever came first.
§§Loss to follow-up defined as death, emigration or membership termination (for KP) prior to the study end date.
–, not reported; ACL, anterior cruciate ligament; BMI, body mass index; KP, Kaiser Permanente.

history of a prior procedure in the index knee and 93.5% had an uninjured contralateral ACL. Corresponding results were 7.3% and 82.7% in Luxembourg and 19.5% and 92.0% in Norway. An uninjured contralateral ACL was also reported for 92.1% and 91.7% of Danish and Swedish patients, respectively. Operative side was evenly distributed across all cohorts. Of those where the time to reconstruction was known, ACLR were generally performed within the first six months for Luxembourg, the UK and US patients. Conversely, most reconstructions occurred >6 months following the injury date in Scandinavian countries.

Activities at the time of injury

Soccer was the most commonly reported activity at the time of injury in primary ACLR for all six cohorts (range: 14.1%–42.3%) (table 2). Winter sports (skiing and snowboarding) and handball followed as leading activities at the time of injury in Denmark, Luxembourg and Norway; while winter sports and other sport followed as other activities at the time of injury in Sweden and American football/rugby and other sport in the UK. Basketball/netball and other sport additionally led as activities at the time of injury in the US-based cohort.

Intraoperative concomitant injuries

ACL tears with intraoperative concomitant injuries were more common in all cohorts except the UK where isolated ACL tears were more common (table 3). Medial meniscal tears were more frequent than or of similar frequency to lateral meniscal tears in all cohorts except in Luxembourg. Articular cartilage lesions reported at the time of ACLR varied widely from 27.6% in the US to 3.6% in the UK. In the US, 15.7% had both menisci torn and 20.6% had both meniscal and cartilage injuries. Respective percentages were 13.3% and 24.0% in Luxembourg, 9.8% and 16.0% in Norway, 6.8% and 15.0% in Sweden, and 5.0% and 1.7% in the UK.

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Table 2 Activity at the time of injury/aetiology for primary anterior cruciate ligament reconstructions

Characteristic, n (%)	Denmark*	Luxembourg†	Norway‡	Sweden§	UK¶	US**
Total N	21 820	300	17 556	30 422	2972	28 055
American football/rugby	–	9 (3.1)	–	244 (0.8)	147 (14.5)	2348 (11.9)
Basketball/netball	240 (1.2)	28 (9.6)	230 (1.3)	622 (2.1)	40 (3.9)	3525 (17.9)
Fall	–	5 (1.7)	–	268 (0.9)	34 (3.4)	1098 (5.6)
Floor ball	–	1 (0.3)	–	2641 (8.7)	–	0 (0.0)
Football	8946 (43.2)	124 (42.6)	7045 (40.5)	12 876 (42.6)	419 (41.4)	5262 (26.7)
Handball	3513 (17.0)	28 (9.6)	2505 (14.4)	1632 (5.4)	0 (0.0)	2 (0.0)
Hiking/jogging/running/walking	–	1 (0.3)	1185 (6.8)	31 (0.1)	8 (0.8)	321 (1.6)
Martial arts/wrestling	196 (0.9)	5 (1.7)	330 (1.9)	840 (2.8)	17 (1.7)	671 (3.4)
Motorsports/motor vehicle accident	–	3 (1.0)	184 (1.1)	1330 (4.4)	13 (1.3)	824 (4.2)
Winter sports (skiing/snowboard)	2740 (13.2)	44 (15.1)	3033 (17.4)	4236 (14.0)	142 (14.0)	1509 (7.6)
Work injury	1266 (6.1)	9 (3.1)	437 (2.5)	512 (1.7)	9 (0.9)	320 (1.6)
Other	1811 (8.7)	14 (4.8)	1595 (9.2)	1824 (6.0)	41 (4.0)	599 (3.0)
Other sport	1997 (9.6)	20 (6.9)	864 (5.0)	3162 (10.5)	143 (14.1)	3261 (16.5)

*Missing data: 1111 (5.1).
†Missing data: 9 (3.0%).
‡Missing data: 148 (0.8%).
§Missing data: 204 (0.7%).
¶Missing data: 1959 (65.9%).
**Missing data: 8315 (29.6%).
– , not reported.

Graft selection and fixation devices

Differences existed in ACL graft selection and femoral fixation devices (table 4). Hamstrings and bone–patellar tendon–bone (BPTB) autografts dominated as the primary graft choices in the European cohorts (range: 92.3%–99.4%). Graft choice was more diverse in the US-based cohort with almost 40% of ACLR using allograft. Suspensory fixation was the most frequently used method of femoral fixation in Scandinavian countries and the UK; while interference fixation was more common in Luxembourg and the US (table 4). Metal was the most common femoral fixation material used in all cohorts except in Luxembourg where bioabsorbable material was more common. Interference fixation was the most frequent type of tibial fixation used in all cohorts. Bioabsorbable was the predominant tibial fixation material in Denmark, Luxembourg and the US; metal was primary choice in Norway, Sweden and the UK.

Subsequent surgical outcomes

Subsequent surgical outcomes following primary ACLR were available for Denmark, Luxembourg, Norway, Sweden and the US (table 5). The frequency of ipsilateral reoperations and contralateral operations was low. The 1-year and 3-year cumulative revision probabilities were 0.9% and 3.6% in Norway, 0.6% and 2.8% in Sweden and 1.0% and 3.7% in the US.

DISCUSSION

This is the largest collaboration of ACL registries describing each registries' ACLR cohort. These data can allow surgeons to compare

Table 3 Concurrent injuries and intraoperative findings for primary anterior cruciate ligament (ACL) reconstructions

Characteristic, n (%)	Denmark	Luxembourg*	Norway	Sweden	UK	US
Total N	21 820	300	17 556	30 422	2972	28 055
None—isolated ACL tear	10 015 (45.9)	80 (26.7)	6589 (37.5)	13 551 (44.5)	1862 (62.7)	8446 (30.1)
ALL	–	–	–	–	5 (0.2)	–
LCL	310 (1.4)	3 (1.0)	283 (1.7)	468 (1.5)	32 (1.1)	–
MCL	320 (1.5)	2 (0.7)	1248 (7.1)	1289 (4.2)	–	515 (1.8)
PCL	254 (1.2)	1 (0.3)	285 (1.6)	522 (1.7)	6 (0.2)	195 (0.7)
PLRI	277 (1.3)	–	–	–	16 (0.5)	157 (0.6)
Other	235 (1.1)	–	172 (1.0)	–	–	182 (0.6)
Meniscus pathology						
Lateral meniscus tear only	4561 (20.9)	126 (42.0)	2800 (15.9)	5151 (16.9)	336 (11.3)	6341 (22.6)
Medial meniscus tear only	5390 (24.7)	101 (33.7)	4004 (22.8)	5765 (19.0)	448 (15.1)	6593 (23.5)
Both menisci injured	–	40 (13.3)	1718 (9.8)	2077 (6.8)	150 (5.0)	4415 (15.7)
Articular cartilage injury	4364 (20.0)	99 (33.0)	4175 (23.8)	8088 (26.6)	106 (3.6)	7733 (27.6)
Meniscus† and cartilage injury	–	72 (24.0)	2813 (16.0)	4554 (15.0)	51 (1.7)	5772 (20.6)

*Missing data: isolated ACL tear=4 (1.3%), lateral meniscal tear only=8 (2.7%), medial meniscal tear only=9 (3.0%), both menisci injured=15 (5.0%), articular cartilage injury=18 (6.0%), and meniscal and cartilage injury=3 (1.0%).
†Lateral or medial meniscus injuries included.
–, not reported; ALL, anterolateral ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament; PLRI, posterolateral rotatory instability.

Table 4 Graft selection and fixation for primary anterior cruciate ligament reconstructions

Characteristic, n (%)	Denmark*	Luxembourg†	Norway‡	Sweden§	UK¶	US**
Total N	21 820	300	17 556	30 422	2972	28 055
Graft type						
Autograft						
Hamstrings	17 758 (81.4)	140 (46.8)	12 078 (68.9)	27 700 (92.7)	1923 (91.0)	9078 (32.6)
Quadriceps	303 (1.4)	3 (1.0)	51 (0.3)	183 (0.6)	2 (0.1)	17 (0.1)
Patellar tendon	2376 (10.9)	155 (51.8)	5339 (30.5)	1782 (6.0)	157 (7.4)	6956 (25.0)
Allograft	44 (0.2)	0 (0.0)	39 (0.2)	120 (0.4)	22 (1.0)	11 089 (39.9)
Other graft	1339 (6.1)	1 (0.3)	24 (0.1)	90 (0.3)	9 (0.4)	683 (2.5)
Fixation devices						
Femoral fixation						
Combination	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1653 (6.6)
Crosspin	8030 (38.1)	0 (0.0)	2552 (14.7)	7690 (25.6)	74 (4.1)	3580 (14.3)
Interference	3775 (17.9)	246 (84.8)	4928 (28.4)	5064 (16.8)	367 (20.4)	10 717 (42.9)
Suspensory	9251 (43.9)	44 (15.2)	9847 (56.8)	17 314 (57.6)	1359 (75.5)	9010 (36.1)
Femoral fixation material						
Bioabsorbable	8990 (42.8)	246 (84.8)	1008 (5.8)	0 (0.0)	72 (4.0)	8547 (34.2)
Metal	11 651 (55.4)	44 (15.2)	16 233 (93.7)	30 068 (100.0)	1724 (95.8)	15 583 (62.4)
Polyetheretherketone	371 (1.8)	0 (0.0)	86 (0.5)	0 (0.0)	4 (0.2)	830 (3.3)
Femoral tunnel location						
Extrachannel	8607 (40.5)	246 (84.8)	9847 (56.8)	17 340 (57.7)	1359 (75.5)	9639 (38.6)
Intrachannel	12 650 (59.5)	44 (15.2)	7480 (43.2)	12 728 (42.3)	441 (24.5)	15 321 (61.4)
Tibial fixation						
Combination	0 (0.0)	0 (0.0)	4042 (23.5)	3235 (10.8)	0 (0.0)	4095 (16.6)
Crosspin	0 (0.0)	0 (0.0)	159 (0.9)	936 (3.1)	14 (0.8)	51 (0.2)
Interference	21 427 (98.2)	249 (85.0)	12 883 (74.8)	19 346 (64.8)	1771 (95.0)	19 769 (80.1)
Suspensory	393 (1.8)	44 (15.0)	146 (0.8)	6325 (21.2)	80 (4.3)	765 (3.1)
Tibial fixation material						
Bioabsorbable	16 575 (76.6)	246 (84.0)	3809 (22.1)	6164 (20.7)	761 (40.8)	16 844 (68.2)
Metal	2051 (9.5)	47 (16.0)	12 814 (74.4)	23 685 (79.3)	1060 (56.8)	4833 (19.6)
Polyetheretherketone	3011 (13.9)	0 (0.0)	607 (3.5)	0 (0.0)	44 (2.4)	3003 (12.2)
Tibial tunnel location						
Extrachannel	162 (0.8)	249 (85.0)	146 (0.8)	9057 (30.9)	80 (4.3)	1272 (5.2)
Intrachannel	21 382 (99.2)	44 (15.0)	17 084 (99.2)	20 282 (69.1)	1785 (95.7)	23 408 (94.8)

*Missing data: femoral fixation: 764 (3.5%); femoral fixation material: 808 (3.7%); femoral tunnel location: 563 (2.6%); tibial fixation material: 183 (0.8%); tibial tunnel location: 276 (1.3%).

†Missing data: graft type: 1 (0.3%); femoral fixation, femoral fixation material and femoral tunnel location: 10 (3.3%); tibial fixation, tibial fixation material and tibial tunnel location: 7 (2.3%).

‡Missing data: graft type: 25 (0.1%); femoral fixation, femoral fixation material and femoral tunnel location: 229 (1.3%); tibial fixation, tibial fixation material and tibial tunnel location: 326 (1.9%).

§Missing data: graft type: 547 (1.8%); femoral fixation, femoral fixation material and femoral tunnel location: 352 (1.2%); tibial fixation: 580 (1.9%); tibial fixation material: 573 (1.9%); tibial tunnel location: 1083 (3.6%).

¶Missing data: graft type: 859 (28.9%); femoral fixation, femoral fixation material and femoral tunnel location: 1172 (39.4%); tibial fixation, tibial fixation material and tibial tunnel location: 7 (37.2%).

**Missing data: graft type: 232 (0.8%); femoral fixation, femoral fixation material and femoral tunnel location: 3095 (11.0%); tibial fixation, tibial fixation material and tibial tunnel location: 3375 (12.0%).

their own practice against large cohorts throughout the world. While we found similarities in demographics and injury activity, variation observed in concomitant injuries, ACL graft and fixation selection between the registries suggests these factors may need to be considered when comparing across different populations. This study opens opportunities for future international collaborations. Total joint arthroplasty has benefited from international registry collaborations, leading to a greater understanding of surgical best practices and outcomes within this orthopaedic specialty.[40] The same successes can be made for ACLR.

ACLR patient characteristics were similar across six cohorts

Primary ACLR in all six cohorts were mostly male and <30 years of age. Characteristics related to the reconstructed knee varied. Almost 20% of knees in Norway had a prior procedure to the index knee; however, <5% were previously operated on in the US. While Luxembourg, the UK and the US tended to have a shorter duration from injury to reconstruction, most reconstructions for Denmark, Norway and Sweden occurred at least 6 months following the injury. This difference may be explained by a delay in diagnosis or that most patients in Scandinavia are recommended to complete 3–6 months of physical therapy prior to ACLR. The higher proportion of prior procedures in Norway may also be due to later timing of ACLR; other meniscal procedures may be performed during this time. Caution should be taken when interpreting results from the UK and US cohorts as large proportions of the data for time to reconstruction were missing. The Scandinavian countries and the US had median

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Table 5 Outcomes following primary anterior cruciate ligament (ACL) reconstructions

	Denmark	Luxembourg	Norway	Sweden	UK	US
Total N	21 820	300	17 556	30 422	2972	28 055
Ipsilateral knee reoperations*, n (%)	1419 (6.5)	–	657 (3.7)	–	–	1640 (5.8)
Contralateral knee operations†, n (%)	–	5 (1.7)	457 (2.6)	921 (3.0)	–	850 (3.0)
Revisions, n	1002	0	762	975	–	941
Cumulative revision probability (years), % (95% CI)						
1	–	0 (0.0–0.0)	0.9 (0.7–1.1)	0.6 (0.5–0.7)	–	1.0 (0.8–1.1)
3	–	–	3.6 (3.2–4.0)	2.8 (2.6–3.0)	–	3.7 (3.4–3.9)
7	–	–	5.6 (5.2–6.0)	4.1 (3.6–4.5)	–	6.1 (5.7–6.6)
Revision incidence density (years), 100 person-years						
1	–	0.0	0.9	0.6	–	0.9
3	–	–	1.2	1.0		1.2
7	–	–	0.9	0.8	–	1.1

*Non-revision operations in the index knee following the primary ACL reconstruction.
†Operations/reconstructions on the contralateral knee following the primary ACL reconstruction.
–, not reported.

follow-up times of >2 years, valuable for future collaborations evaluating risk factors for long-term outcomes.

Soccer is the leading activity at the time of injury

Soccer was the most commonly reported activity at the time of injury across all six cohorts. Other common activities appeared to align with popular activities within the countries. Unreported injury activity for the UK and US cannot be ignored as this could lead to a misinterpretation of the findings for these two registries.

Reporting on concomitant injuries is inconsistent across registries

Reporting on additional ligament injuries varied across cohorts. Future collaboration investigating these factors may not be feasible unless collection across registries becomes more consistent. PCL tears were the only additional injury collected by all six registries and were infrequent (<2%).

Autografts predominated in European cohorts while allografts were more common in the US

While autografts were the primary choice in all cohorts, the US had the highest utilisation of allografts. In comparison to the US, allograft usage was <1% for all European cohorts. Hamstring tendons were the preferred autograft choice for all European cohorts, except Luxembourg, where autograft selection was more evenly split between hamstring and BPTB. Caution should be taken when interpreting results from the UK cohort as 28.9% of grafts were unspecified.

Suspensory devices were more common for graft fixation to the femoral side while interference devices predominated on the tibial side

Suspensory fixation and metal materials were the most common femoral fixation methods in the Scandinavian countries and the UK, likely because the primary graft used in these countries was hamstring autograft. In contrast, interference fixation was most commonly used on the tibial side for all registries, more often metal in Norway, Sweden and the UK and bioabsorbable in the other cohorts. This is the first cross-registry description to include femoral and tibial fixation information, enhancing knowledge on surgical practices for ACLR internationally.

Subsequent surgical outcomes following primary ACLR were similar across countries

Even though variation was observed in certain patient and surgical characteristics, for registries with revision data available, the 1-year and 3-year cumulative revision probabilities were nearly identical between Norway and the US, with Sweden having slightly lower revision probabilities. The frequency of ipsilateral reoperations was similar between Denmark and the US, while reoperations were lower in Norway. Frequency of contralateral operations was also similar between Norway, Sweden and the US, with Luxembourg having a lower frequency.

Data elements need to be standardised for future analytic research studies

This study sought to describe six ACLR cohorts. However, we found discrepancies in definitions and data collection methodologies. For example, prior index knee procedures were defined as prior ACL (not including ACLR), meniscus repair, meniscus transplant, microfracture/drilling, osteochondral allograft, osteochondral autograft, partial or total meniscectomy abrasion, or other procedure. All or some of these procedures were captured depending on the registry. Also, this information was reported by the operating surgeon for the Norway and the US while it was reported by the patient in Luxembourg. Missing data were also a concern, primarily the result of inconsistencies in data collection methodologies across years. These factors can create bias and a misinterpretation of results. Global standardisation of data elements is necessary for future analytic studies evaluating risk factors of outcomes (aclreg.org).[7 41 42]

Strengths and limitations

Strengths of this study include the large sample size, use of prospective data collection methodologies and high participation rates. Each registry captures ACLR data and outcomes prospectively, using predetermined algorithms, to maintain high internal validity. High participation ensures study samples are representative of target populations.

There are limitations to this study. Not all participating registries track patients with ACL tears, regardless of operative treatment, therefore this description is limited to patients with a reconstructed ACL. This study is purely descriptive, inferences regarding risk factors for subsequent surgical outcomes cannot be made. Further, findings may be skewed for Luxembourg and the UK as these two registries were established more recently and currently include fewer reconstructions.[32 37] Participation rates were also unavailable for the UK registry, and loss to follow-up was unavailable for the Luxembourg registry. Loss to follow-up is a limitation with the KP registry as roughly 20% left healthcare membership during follow-up. However, our revision calculations accounted for this, patients only contributed as long as they were followed and censored at the time of membership termination. Additional non-surgical outcomes that can also represent failure including infection, patient-reported outcome measures, radiographic findings or functional performance tests were not reported for this descriptive study.

CONCLUSIONS

ACL registries offer a real-world clinical perspective with the goal of improving quality and patient safety through research focused on understanding factors associated with subsequent surgical outcomes. Cross-registry variation observed in this work can serve as an international point of reference of patients with ACLR and contemporary practice. This work also forms the foundation for future analytic investigations. Sharing of summary information between registries will also allow for improvement and standardisation in data collection systems internationally, data collection rates and facilitate future multi-register data analysis.

What are the findings?

- ► Across six national, regional and hospital-based anterior cruciate ligament (ACL) registry cohorts, we observed similarities in demographics, patient characteristics and activities at the time of injury.
- ► Differences were observed in time to reconstruction, concomitant injuries, graft selection and fixation devices. These differences should be considered when generalising findings from single registry studies to other cohorts and may be avenues for future collaborative research studies.
- ► Even though differences in some patient and surgical characteristics were observed across countries, revisions following the primary ACL reconstruction were rare in all reporting cohorts, ranging from 2.8% to 3.7% at 3 years postoperative. Incidence of surgical outcomes across registries was similar.
- ► Discrepancies in data collection methodologies need to be addressed and data element should be standardised prior to commencement of future international collaborations.

Author affiliations
[1]Surgical Outcomes and Analysis, Kaiser Permanente, San Diego, California, USA
[2]Division of Sports Surgery, Department of Orthopaedics, Aarhus University Hospital, Aarhus, Denmark
[3]Department of Orthopaedic Surgery, Clinique d'Eich-Centre Hospitalier de Luxembourg, Luxembourg, Luxembourg
[4]Department of Orthopaedic Surgery, Oslo University Hospital, Oslo, Norway
[5]Norwegian Knee Ligament Registry, Orthopaedic Department, Haukeland University Hospital, Bergen, Norway
[6]Division of Physiotherapy, Department of Medical and Health Sciences, Linköping University, Linköping, Sweden
[7]Trauma and Orthopaedic Department, University College London Hospitals, NHS Foundation Trust, London, UK
[8]Department of Orthopaedic Surgery, Sahlgrenska Academy, University of Gothenburg, Sahlgrenska University Hospital, Mölndal, Sweden
[9]Stockholm Sports Trauma Research Center, Karolinska Institutet, Stockholm, Sweden
[10]Department of Trauma and Orthopaedics, University College London Hospitals, London, UK
[11]University Hospitals Coventry and Warwickshire (UHCW), Coventry, UK
[12]Department of Orthopaedics, Southern California Permanente Medical Group, Irvine, California, USA
[13]Department of Orthopaedics, Southern California Permanente Medical Group, Baldwin Park, California, USA

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