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Low annual hospital volume of anterior cruciate ligament reconstruction is not associated with higher revision rates

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Abstract

Purpose Surgery performed in low-volume centres has been associated with longer operating time, longer hospital stays, lower functional outcomes, and higher rates of revision surgery, complications and mortality. This has been reported consistently in the arthroplasty literature, but there is a paucity of data regarding the relationship between surgical volume and outcome following anterior cruciate ligament (ACL) reconstruction. The purpose was to compare ACL reconstruction failure rates between hospitals performing different annual surgical volumes.

Methods All patients from the Norwegian Knee Ligament Register having primary autograft ACL reconstruction between 2004 and 2016 were included. Hospital volume was divided into quintiles based on the number of ACL reconstructions performed annually, defined arbitrarily as: 1–12 (V1), 13–24 (V2), 25–49 (V3), 50–99 (V4) and ≥ 100 (V5) annual procedures. Kaplan–Meier estimated survival curves and survival percentages were calculated with revision ACL reconstruction as the end point. Secondary outcome measures included (1) mean change in Knee Injury and Osteoarthritis Outcome Score (KOOS) Quality of Life (QoL) and Sport subsections from pre-operative to 5-year follow-up and (2) subjective failure defined as KOOS QoL < 44.

Results Twenty thousand eight hundred and fifty patients met the inclusion criteria and 1195 (5.7%) underwent subsequent revision ACL reconstruction over the study period. Revision rates were lower in the lower volume hospitals compared with the higher volume hospitals ($p < 0.001$). There was no clinically significant difference in improvement between pre-operative and 5-year follow-up KOOS scores between hospital volume categories, but a higher proportion of patients having surgery at lower volume hospitals reported a subjective failure. Patients in the lower volume categories (V1-3) were more often male and older compared to the higher volume hospitals (V4-5). Concomitant meniscal injuries and participation in pivoting sports were most common in V5 compared with V1 ($p < 0.001$). Median operative time decreased as hospital volume increased, ranging from 90 min at V1 hospitals to 56 min at V5 hospitals ($p < 0.001$).

Conclusion Patients having ACL reconstruction at lower volume hospitals had a lower rate of subsequent revision surgery relative to higher volume hospitals. However, complications occurred more frequently, operative duration was longer, and the number of patients reporting a subjective failure of ACL reconstruction was highest at these lower volume hospitals.

Level of evidence Level III

Introduction

Anterior Cruciate Ligament (ACL) reconstruction is a commonly performed orthopaedic procedure and surgery rates are increasing [59]. Extensive research has focussed on optimising outcomes for this procedure through surgical technique and implant innovations. This has led to improved outcomes; however, return to pre-injury level of sports participation after ACL reconstruction as low as 63% at 2 years [3] and revision rates of 4.1–13.3% at 5 years have been reported [14]. In light of these shortcomings, there is a need to improve outcomes after surgery, and identification of factors that can influence outcomes after ACL reconstruction has been made possible through large national register databases. Since their inception, several register-based studies have improved our understanding of factors affecting surgical outcome [16, 17, 51]. Register studies have demonstrated that graft type, graft diameter, fixation method, age, sports

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type, concomitant meniscal and chondral injuries are all associated with the outcome after ACL reconstruction [1, 2, 16, 39, 49–51].

Surgical volume has been identified as a factor influencing surgical outcomes and complications following orthopaedic surgery. Specifically, procedures performed in low-volume centres have been associated with longer operating time, longer hospital stays, lower functional outcomes, and higher rates of revision surgery, complications and mortality [5, 20, 22, 25, 27–29, 33–35, 37, 38, 47, 52, 57]. This effect has not been shown consistently across all studies, however, and the majority of these studies are found in the arthroplasty literature [4, 19, 53]. There is a paucity of information regarding the effect of surgical volume on the outcome and complication rate following ACL reconstruction. It is unknown if low-volume centres have inferior outcomes relative to high-volume hospitals. Working under the assumption that this is the case, the centralization of these procedures to regional centres with high volumes to improve outcomes and minimise complication rates has been posited.

The purpose of this study was to evaluate and compare the results of ACL reconstruction in relation to the annual procedural volume of the hospital. The hypothesis was that patient outcome following ACL reconstruction would be related to hospital volume, with higher revision rates and higher rates of subjective failure associated with low-volume hospitals. With many hospitals performing a low volume of ACL reconstructions per year, this study may inform discussions and policy related to the distribution of patient care throughout a national hospital system.

Materials and methods

All patients participating in the NKLR have provided informed consent. Based on this consent, the NKLR has permission from the Norwegian Data Inspectorate to collect, analyse and publish on health data. The registration of data and the present study were performed confidentially and according to Norwegian and EU data protection rules, with all data de-identified prior to retrieval from the NKLR. The Regional Ethics Committee (REK) has previously determined that it is not necessary to obtain further ethical approval for Norwegian register-based studies [12].

This manuscript was written in accordance with the REporting of studies Conducted using Observational Routinely collected health Data (RECORD) statement [6]. In this level-II prospective cohort study, all patients from the Norwegian Knee Ligament Register (NKLR) that underwent primary autograft ACL reconstruction between 2004 and 2016 were eligible for inclusion. The NKLR was established in 2004, and was the world's first ACL register [12]. The aim is to collect information prospectively on all cruciate ligament reconstructions in Norway and to monitor the outcomes. Patients undergoing cruciate ligament surgery sign an informed consent and are asked to complete the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire pre-operatively and at 2-, 5-, and 10-year follow-ups. The KOOS score has been validated for measuring knee function in patients with osteoarthritis and for other knee injuries, including ACL injuries, meniscal injuries and cartilage injuries [45].The surgeon completes a knee ligament surgery form immediately post-operatively, with detailed information regarding the procedure, graft utilised, intra-operative findings, injury mechanism, date of injury and date of surgery. Any subsequent surgery to the ipsilateral knee is to be reported to the register and can be linked to the index surgery through every participant's personal identification number. The compliance of reporting primary reconstructions to the register was 78.1% from 2008 to 2012 [44] and 86.5% in 2017–2018 [43].

Patients with less than 2 years of follow-up ($n = 3985$) or concomitant ipsilateral knee ligament injuries ($n = 2039$) were excluded. The following patient-specific data was requested: patient demographic variables [age, sex, body mass index (BMI) and activity at primary ACL injury (pivoting sports; yes/no)] and surgical data including concomitant meniscal injuries (no meniscal injury, meniscal injury with partial resection, meniscal injury with repair, or meniscal injury with other procedure such as transplantation or trephination), cartilage injuries [no chondral injury, International Cartilage Regeneration & Joint Preservation Society (ICRS) grade 1–2, or ICRS grade 3–4], reconstruction graft type [bone-patellar tendon-bone (BTB) autograft, hamstring tendon autograft, quadriceps tendon autograft, or other graft], operation duration (minutes), intra-operative complications (yes/no), hospital that performed the primary surgery, and its ACL reconstruction volume in that calendar year.

Exposure of interest

Each patient was stratified based on the number of ACL reconstructions performed by their surgical location the year of surgery. The hospital volume variable was divided into quantiles and defined arbitrarily as: 1–12 (V1), 13–25 (V2), 26–50 (V3), 51–100 (V4) and > 100 (V5) annual procedures.

Endpoint variables

Primary outcome measure was failures, defined as ACL revision surgery. Revision surgery may have been performed at a different hospital than the primary ACL reconstruction, but the failure was attributed to the hospital performing the initial operation. A secondary outcome measure was a score < 44 on the KOOS Quality of Life (QoL) subscale. A KOOS QoL < 44 has been validated as a measure of inadequate knee function associated with prospective ACL reconstructed graft failure [13]. In addition, we compared the patient demographic and injury/surgical details across the five volume groups.

Statistical analysis

Descriptive analysis was used to assess patient characteristics for the different hospital volume categories. Differences between groups were tested with Chi-square for categorical variables and student *t* test and independent samples median test for continuous variables where applicable. Survival analyses was performed with revision of the ACL as the end point. Kaplan–Meier estimated survival curves were constructed for hospital volume categories, and the survival estimates with 95% confidence interval (CI) reported. Pre-operative along with 2-, 5- and 10-year post-operative patient-reported outcomes (KOOS) were reported for each hospital volume group.

Hazard ratios (HR) were calculated using the Cox regression model with 95% CI. Statistical significance was set to $p < 0.05$ and all tests were 2-sided. The multivariable Cox regression was adjusted for possible confounding factors [age, sex, BMI, pivoting/non-pivoting sports at primary injury, operative time, time from injury to surgery, hospital setting (public versus private), graft choice, cartilage injury and meniscal pathology and treatment]. The assumptions of the Cox regression were checked by Schoenfeld residual plot and found suitable. Multivariable logistic and linear regression models were used to examine the risk-adjusted association between outcomes and hospital volume.

During the study period, 573 (2.7%) patients were lost to follow-up due to death ($n = 106$) or emigration ($n = 467$) and were censored in the analyses at the time of event.

Results

In total, 20,850 patients met the inclusion criteria (Fig. 1). Median age was 26 (11–75) and 56% were male. Demographics and surgical details of patients distributed between hospital volume groups are presented in Tables 1 and 2,

Fig. 1 Patient inclusion flow-diagram

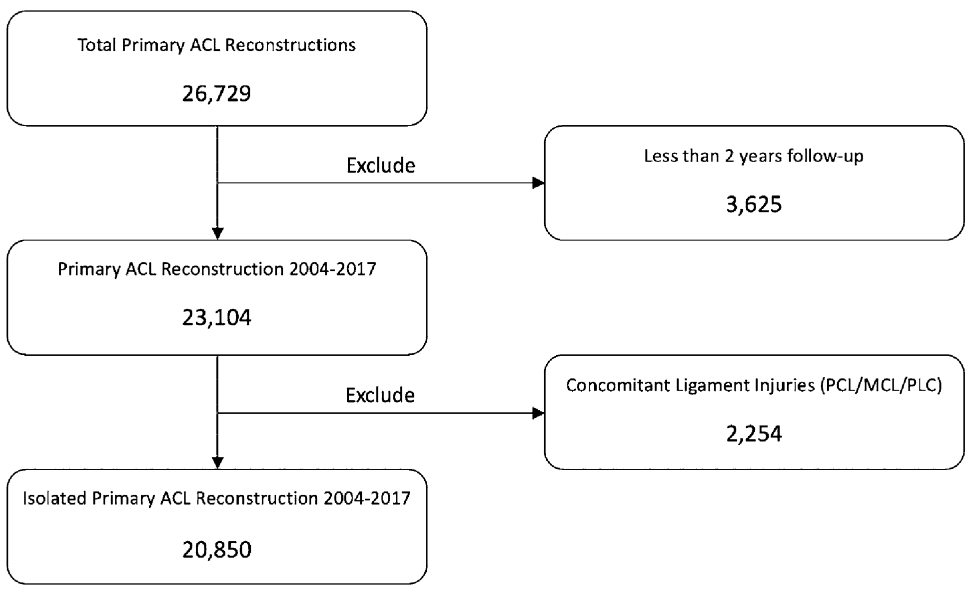

Table 1 Patient demographics across all five hospital volume categories

Hospital volume group	≤ 12	13–25	26–50	51–100	> 100	*p* value
Number of procedures; *n* (%)	1292 (6)	3291 (16)	6406 (31)	5532 (26)	4329 (21)	< 0.001
Median follow-up; years (IQR)	9.2 (7.8)	9.2 (6.9)	9.2 (6.0)	7.9 (6.0)	7.9 (7.1)	< 0.001
Sex; % male	57	59	57	55	54	< 0.001
Median age; years (range)	27 (13–66)	27 (11–67)	27 (12–75)	26 (11–69)	25 (11–65)	< 0.001
BMI ≥ 30; *n* (%)*	73 (13)	211 (12)	401 (11)	375 (9)	246 (7)	< 0.001
Pivoting sport participation; *n* (%)	715 (55)	1870 (57)	3582 (56)	3165 (57)	2681 (62)	< 0.001

*$n = 13{,}661$ [missing 7189 (34.5%)]

Table 2 Surgical details of ACL reconstruction at hospitals performing various annual volumes

Hospital volume group	≤ 12	13–25	26–50	51–100	> 100	*p* value
Time from injury to surgery < 6 months; *n* (%)	1039 (93)	2717 (92)	5224 (93)	4575 (94)	3488 (95)	< 0.001
Private hospital; *n* (%)	264 (20)	591 (18)	2000 (31)	1961 (35)	2559 (59)	< 0.001
No meniscus injury; *n* (%)	816 (63)	1841 (56)	3486 (54)	2948 (53)	2359 (54)	< 0.001
Meniscus injury without repair; *n* (%)	367 (29)	1057 (32)	2104 (33)	1553 (28)	1229 (29)	< 0.001
Meniscus injury with repair; *n* (%)	109 (8)	393 (12)	816 (13)	1013 (19)	741 (17)	< 0.001
No cartilage injury; *n* (%)	923 (71)	2417 (73)	4794 (75)	4446 (80)	3603 (83)	< 0.001
Cartilage injury grade 1–2; *n* (%)	290 (22)	567 (17)	1152 (18)	717 (13)	484 (11)	< 0.001
Cartilage injury grade 3–4; *n* (%)	72 (6)	291 (9)	440 (7)	355 (6)	236 (6)	< 0.001
Hamstring autograft; *n* (%)	835 (65)	2304 (70)	4212 (66)	3299 (60)	2578 (60)	< 0.001
BTB autograft; *n* (%)	455 (35)	953 (29)	2102 (33)	2165 (39)	1624 (37)	< 0.001
Other graft; *n* (%)	2 (–)	32 (1)	85 (1)	63 (1)	123 (3)	< 0.001
Median operative time; minutes (interquartile range)	90 (70–110)	83 (63–101)	75 (58–95)	70 (52–93)	56 (45–70)	< 0.001
Peri-operative complication; *n* (%)	50 (4)	128 (4)	203 (3)	165 (3)	83 (2)	< 0.001

Chi-square, independent samples median tests

Table 3 2-, 5- and 10-year revision rates with 95% confidence intervals

	2 years	5 years	10 years
≤ 12	1.7% (0.01%–2.5%)	3.3% (2.3%–4.3%)	4.7% (3.3%–6.1%)
13–25	2.0% (1.6%–2.4%)	4.3% (3.5%–5.1%)	6.0% (5.2%–6.8%)
26–50	1.7% (1.3%–2.1%)	4.2% (3.6%–4.8%)	5.8% (5.2%–6.4%)
51–100	2.8% (2.4%–3.2%)	5.4% (4.8%–6.0%)	7.1% (6.3%–7.9%)
> 100	3.2% (2.6%–3.8%)	6.0% (5.2%–6.8%)	7.7% (6.7%–8.7%)

respectively. Overall, 6.2% of patients had surgery at hospitals performing fewer than 12 procedures per year (5–8% per year consistently over the study period). In contrast, over 45% of patients had surgery at hospitals performing more than 50 ACL reconstructions annually. Patients having surgery at higher volume hospitals were younger, proportionally more female, more active in pivoting sport, and had a lower BMI ($p < 0.001$). These patients had concomitant meniscus tears more frequently and a higher proportion were treated at private hospitals ($p < 0.001$).

There were 1195 failed ACL reconstructions requiring revision (5.7%). Table 3 demonstrates the 2-, 5- and 10-year estimated survival rates and a Kaplan Meier survival curve is presented in Fig. 2. Multivariable Cox regression is presented in Table 4. Patients having surgery at lower volume hospitals experienced a higher complication rate and a longer average length of surgery.

Regarding patient-reported outcome measures, the change in KOOS QoL and Sport subscale scores from pre-operative to 5 years post-operative among all five hospital volume categories is presented in Table 5. While the differences between hospital groups reached statistical significance, they were small and did not reach minimal clinically significant difference [24]. A higher proportion of patients from lower volume hospitals reported KOOS QoL < 44 at 5-year follow-up (Table 5).

Discussion

The most important finding of this study was that hospitals performing a relatively low annual volume of ACL reconstruction (1–12 procedures annually) had a slightly lower revision rate than was observed at high-volume hospitals (greater than 50 procedures annually), refuting our hypothesis. Improvement in patient-reported outcome measures was similar between the low-volume and high-volume groups, but the proportion of patients reporting a subjective failure of ACL reconstruction (KOOS QoL < 44) was highest in the low-volume categories in keeping with our secondary hypothesis. In addition, surgery performed at these hospitals was associated with a higher rate of complications and longer operating time. Over the study period, only a minority of the patients underwent surgery at low-volume hospitals, with no significant trend towards centralization of these procedures from the low-volume hospitals over time.

The hazard ratio of undergoing revision surgery at high-volume hospitals (V4 and V5) compared with a low volume (V1) was 1.5 and 1.6, respectively. There are several possible explanations for these findings. First, the patient populations were heterogeneous between groups, with younger and more active patients opting for surgery at high-volume hospitals. These patients may be more likely to return to activities placing them at risk for re-injury such as pivoting sports. Previous studies have reported that the risk of revision surgery was higher in the young, active population returning to pivoting sports such as soccer, handball, rugby

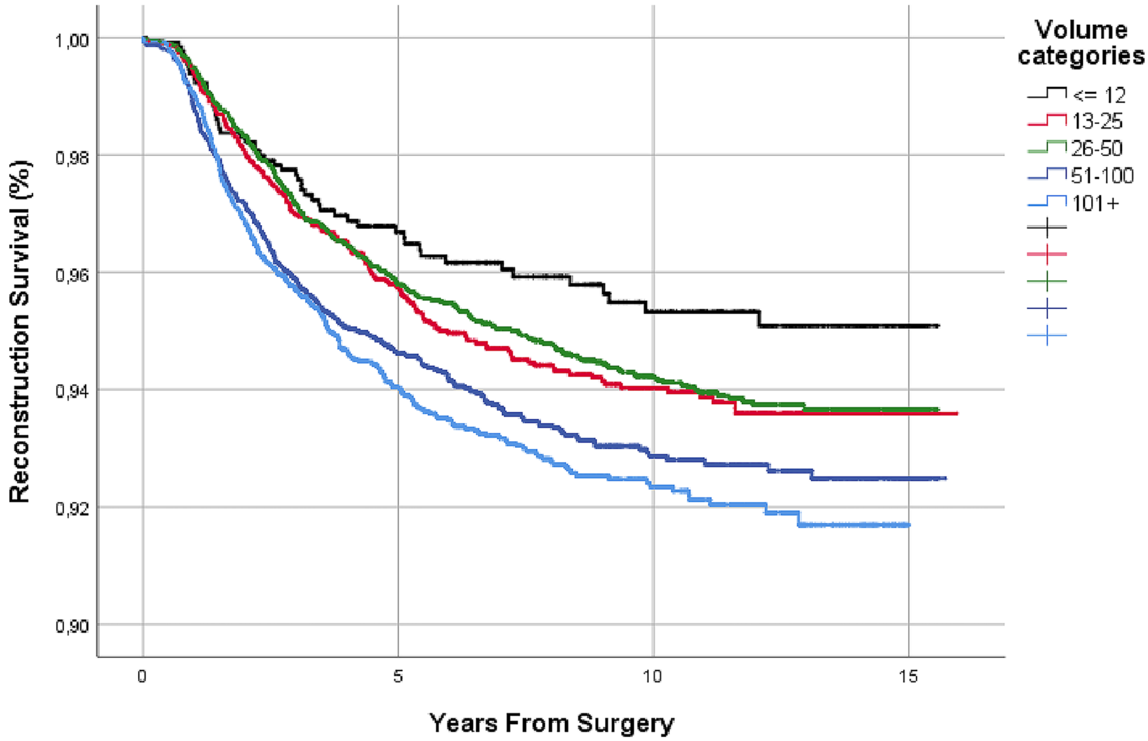

Fig. 2 Kaplan–Meier survival curve of ACL reconstruction performed at hospitals grouped into quintiles according to annual surgical volume. Log rank test of equality of survival distributions for the different volume quintiles gives a p value < < 0.001

and basketball [9, 54, 55], and younger patients have been found to more frequently proceed to revision surgery after clinical failure [41]. Time from injury to surgery was longer at lower volume hospitals which also suggests the patients may have been lower demand, as the typical trend in Scandinavia is to proceed with surgery earlier for younger and more active patients [21, 48]. Indications for ACL revision may also vary between surgeons at different hospitals, with higher volume surgeons potentially more comfortable proceeding surgically. The end point of revision surgery may not capture patients who have re-ruptured but do not undergo further surgery. Outcome may also be affected by post-operative rehabilitation data which may differ between hospitals and was not available. Finally, it has been reported that the NKLR response rate for smaller hospitals (less than 30 ACL reconstructions per year) is less than for the larger hospitals (69% versus 86%, respectively) [58], and this difference in compliance may influence the findings.

Surgical complexity might also have contributed to the observed higher failure rate. The highest volume hospitals include large academic centres and private clinics, both of which are responsible for managing complex clinical presentations and high-level athletes. Low-volume hospitals in Norway are often small and rural, where the surgeons may have less experience diagnosing and treating failed ACL reconstruction. There was also a higher rate of concomitant meniscus injury among patients treated at high-volume hospitals. If a meniscus tear was identified, surgeons at lower volume hospitals were more likely to perform a partial meniscectomy while higher volume hospital patients more often had repairs—a finding consistent with a previous study of meniscal treatment in the setting of ACL reconstruction [56].

Many studies have reported on the effects of surgeon and hospital volume on patient outcome. Higher hospital and/or surgeon volume has been associated with lower mortality, fewer complications, and shorter length of stay for procedures across various surgical specialties [7, 8, 10, 11, 18, 23, 26, 36]. Relative to the other surgical specialties, the association between high volume and better outcomes is generally weaker for orthopaedic procedures, and much of the data comes from the arthroplasty literature [15]. Few studies have focussed on the volume-outcome association of orthopaedic sports medicine procedures.

The relationship between ACL reconstruction annual volume and patient outcome has been reported previously. ACL reconstruction performed at higher volume hospitals has been associated with shorter operating time, more discharges directly home, and lower readmission and revision rates [25, 32]. In addition, ACL reconstruction performed

Table 4 Multivariable Cox regression analysis

Cox regression	Adjusted*	
	HR (95% CI)	*p* value
Volume		
≤12	1 (ref.)	
13–25	1.3 (0.9–1.7)	n.s.
26–50	1.2 (0.9–1.6)	n.s.
51–100	1.5 (1.1–2.0)	0.008
100+	1.6 (1.2–2.1)	0.003
Sex		
Female	1 (ref.)	
Male	1.1 (0.9–1.2)	n.s.
Age (cont.)	0.9 (0.9–0.9)	< 0.001
Pivoting sport		
Yes	1 (ref.)	
No	0.9 (0.8–1.1)	n.s.
Cartilage injury		
No injury	1 (ref.)	
ICR 1–2	1.0 (0.8–1.2)	n.s.
ICR 3–4	1.0 (0.8–1.3)	n.s.
Graft		
Hamstring	1 (ref.)	
BPTB	0.5 (0.5–0.6)	< 0.001
Other	0.9 (0.5–1.4)	0.562
Time injury/op		
≤6 months	1 (ref.)	
> 6 months	0.8 (0.7–0.9)	< < 0.001

*Adjusted (full model) includes: sex, age, pivoting sport, graft, cartilage injury, time between injury and surgery

by low-volume surgeons has been associated with increased risk of readmission and subsequent knee surgery [32], and a high risk of early conversion to TKA [30]. The risk of infection following revision ACL reconstruction has also been linked to surgeon volume, with higher infection rates associated with lower volume [31]. Finally, the economic effect of surgeon volume has been quantified, with potentially substantial cost savings possible with centralization of ACL reconstructions to high-volume surgeons [46]. While other studies reporting higher volume as associated with shorter operative duration is in line with our study, the reported lower revision rates may be related to differences in study design and patient populations.

In Norway, most patients undergo ACL reconstruction at higher volume hospitals with only 6% choosing hospitals performing fewer than one procedure per month. Despite this apparent centralization, in 2019, there were 24 hospitals in Norway that performed 12 or fewer ACL reconstructions [42]. The impetus for the present study was to compare the surgical outcome between these hospitals and those performing a high volume of annual procedures to clarify the implications of the current model.

There are limitations to the present study. First, only the annual hospital volume of ACL reconstruction could be assessed, and the number of surgeons at each hospital performing these procedures is unknown. The NKLR does not track surgeon-specific volume to protect confidentiality and encourage compliance with the register. Another limitation is the aforementioned patient heterogeneity between hospital volume categories. This makes direct comparison of revision rate difficult, but we feel that it provides a useful real-world evaluation of the outcome these patients experience. Outcome may also be affected by post-operative rehabilitation data which may differ between hospitals and was not available. In addition, the register does not have complete capture of subsequent surgery to the index knee, which could give us another definition of failure compared with revision surgery. Finally, we consider the risk of misclassification bias to be low, as the surgical details reported are well known to the average ACL surgeon. With this study design, there is always a risk of unmeasured confounding that can affect the results. Trends in surgical technique during the study period, for instance usage of femoral drilling technique (anteromedial versus trans-tibial drilling technique), may be unequally distributed in the groups and affect our results. Although patient characteristics and injury patterns are similar in comparison between countries, subtle differences in management approaches may exist and the results may, therefore, have limited validity outside of Norway [40].

Based on the findings of this study, it is not necessary to restrict the provision of ACL reconstruction to high-volume hospitals based on revision rate alone. The centralization of ACL reconstructions may also pose geographic challenges for those in rural areas who would have to travel

Table 5 Post-operative improvement in patient-reported outcome and proportion of patients reporting a subjective failure of ACL reconstruction according to annual hospital volume

	≤12	13–25	26–50	51–100	> 100	*p* value
5-year KOOS sport and recreation improvement	23.3	24.0	28.9	26.1	24.3	n.s.
5-year KOOS quality of life improvement	31.6	31.6	35.7	35.5	34.2	< 0.001
Percentage of responders reporting 5-year KOOS quality of life < 44	22.4%	24.0%	18.3%	17.2%	16.5%	< 0.001
Percentage of total eligible patients reporting 5-year KOOS quality of life < 44	10.1%	11.2%	8.4%	6.8%	6.7%	< 0.001

long distances for their care. This should be weighed against the higher complication rate and longer operative duration observed at low-volume hospitals, however, as these are important factors that may influence patient satisfaction and economic decisions based on operative room utilisation and resource allocation. In addition, while patient-reported outcome measures improved to a similar degree across all hospital volume groups the proportion of patients reporting a KOOS QoL < 44 was highest in the lowest volume hospitals suggesting an inferior subjective outcome.

Conclusion

Patients having ACL reconstruction at higher volume hospitals had a slightly higher rate of subsequent revision surgery relative to lower volume hospitals. However, lower volume hospitals were associated with more patients reporting a subjective failure of ACL reconstruction without proceeding to revision surgery. Complications also occurred more frequently, and operative duration was longer at lower volume hospitals. Based on these findings, it is not necessary to restrict ACL reconstruction to high-volume hospitals.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All patients participating in the Norwegian Knee Ligament Register (NKLR) have provided informed consent. Based on this consent, the NKLR her permission from the Norwegian Data Inspectorate to collect, analyze, and publish on health data. The registration of data and the present study were performed confidentially and according to Norwegian and EU data protection rules, with all data de-identified prior to retrieval from the NKLR. The Regional Ethics Committee (REK) has previously determined that it is not necessary to obtain further ethical approval for Norwegian register-based studies.

Informed consent All patients participating in the NKLR have provided informed consent.

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