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Both isolated and multi-ligament posterior cruciate ligament reconstruction results in improved subjective outcome: results from the Danish Knee Ligament Reconstruction Registry

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Abstract
Purpose There are few descriptions of outcomes after posterior cruciate ligament (PCL) reconstruction in the literature due to the rarity of this type of knee injury. Since 2005, the Danish Knee Ligament Reconstruction Registry (DKRR) has monitored outcomes of PCL reconstructions. This study describes the epidemiology of PCL reconstruction and subsequent outcomes in a Danish population.
Methods Of 23,253 knee ligament reconstructions performed in 2005–2015, 581 were registered as PCL reconstructions in the DKRR. The types of reconstruction were classified as isolated ($n = 237$) or multi-ligament ($n = 344$), and the cause of injury and concomitant meniscus and cartilage injury data were extracted. The outcome at 1-year follow-up was based on the Knee Injury and Osteoarthritis Outcome Score (KOOS) and Tegner activity level. The outcome data were compared with data on 21.820 primary anterior cruciate ligament (ACL) reconstructions.
Results Isolated PCL reconstruction was performed in 43% of cases. Meniscus lesions and cartilage lesions were seen in 19 and 15% of cases, respectively. The main causes of PCL injuries were sports (43%) and traffic accidents (33%). The KOOS improved from pre-operative to 1-year follow-up for both isolated PCL reconstructions and multi-ligament PCL reconstructions but did not reach the levels of those recorded in ACL reconstructions. Multi-ligament reconstructions showed the highest improvement in KOOS. The Tegner activity levels for isolated and multi-ligament PCL reconstructions were 4 (0–7) and 4 (0–8), respectively.
Conclusions PCL reconstructions represented only 2.6% of all knee ligament reconstructions in Denmark. Sports and traffic accidents were the main causes of injury. Meniscus and cartilage injuries were less frequent in PCL injuries as compared to ACL injuries. Isolated PCL and multi-ligament PCL reconstructions showed significant improvements in subjective outcomes but did not reach those observed in ACL reconstructions. Patients should be counselled about expected outcomes after PCL reconstruction.
Level of evidence III.

Keywords Knee · Posterior cruciate ligament · Knee ligament · Epidemiology · Clinical registry

Introduction

Outcomes after posterior cruciate ligament (PCL) reconstruction have been poorly described in the literature due the rare incidence of PCL injury. PCL injuries account for only 2% of all knee injuries; they are mainly seen in males and are primarily caused by traffic accidents [12]. Since 2005, the Danish ACL Registry has monitored the incidence and outcome of PCL reconstruction. Other national registries for knee ligament reconstructions have provided an abundance of new knowledge concerning the epidemiology of anterior cruciate ligament (ACL) injuries, surgical treatment methods and clinical outcomes after ACL reconstruction [5, 14, 15, 17, 19, 20]. According to these registries, PCL reconstructions constitute only 2–3% of all cruciate ligament reconstructions [1, 15].

National registries, which include outcome data after surgical management of all knee ligament injuries, provide important information on rare conditions, such as PCL injuries, and treatment with PCL reconstruction. A

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national cohort represents the typical clinical scenario of different injury mechanisms and surgical techniques. A national registry also provides sufficient data to compare outcomes after isolated PCL reconstructions and PCL reconstructions performed in patients with multi-ligament-injuries. Recently, an epidemiological study of 1287 PCL reconstructions performed in Scandinavian countries demonstrated that two-thirds of PCL lesions were the result of multi-ligamentous injuries [17]. In that study, concomitant meniscus and cartilage injuries were reported in 21 and 26% of cases, respectively. The average age of the PCL reconstruction patients was 28 years, and the main causes of injury were road traffic accidents and pivoting sports (30 and 20%, respectively). Another study based on data from the Norwegian ACL registry compared subjective outcomes of 71 isolated PCL reconstructions with those of 9551 isolated ACL reconstructions [1]. The study found poorer subjective outcomes after PCL reconstruction, with scores 8–17 points lower on subscales of the Knee Injury and Osteoarthritis Outcome Score (KOOS).

Due to the low incidence of PCL injury and subsequent surgical management, the literature on outcomes after PCL reconstruction is sparse, with only case series presenting outcome data from typically less than 50 patients. Most of these small case series investigated outcomes after a specific surgical technique or graft type [2, 3, 11, 24, 25]. The literature on outcomes after isolated or combined PCL reconstructions is also very limited. A review paper on outcomes after isolated and combined PCL reconstructions reported graft failure rates of 10–12% for both reconstruction types, with no difference in functional and subjective outcomes [6, 12]. In a study of 39 patients with both isolated and combined PCL injuries, LaPrade et al. reported good post-operative clinical outcomes and knee stability using double-bundle PCL reconstruction [22].

The aim of the present study was to describe the epidemiology of PCL injuries and concomitant injuries, in addition to the surgical management and clinical outcomes after both isolated PCL reconstructions and PCL reconstructions in multi-ligament-injured patients based on a national cohort. Revision rates and patient-related outcomes were evaluated. The hypothesis of the present study was that fewer failures and better patient-related outcomes would be observed after isolated PCL injury and reconstruction compared to multi-ligament reconstruction.

Materials and methods

The study was based on the Danish Knee Ligament Reconstruction Registry (DKRR), which is a prospective, nationwide and web-based clinical database initiated in 2005. The register contains data on primary and revision ACL and PCL procedures, including concomitant collateral ligament procedures performed in Denmark. Both public and private hospitals supply data to this register [15]. More than 90% of performed procedures have been entered in the registry in recent years.

The operating surgeon records pre-operative, operative and 1-year follow-up data, using a standardized form and a secure Internet portal [15]. Furthermore, the patient independently reports on subjective knee function using self-assessed instruments, the KOOS [21] and Tegner functional score [23]. The patients enter relevant data into a web-based form before the surgery and 1 year post-surgery. The patient receives an automated reminder from the database when it is time to input the data in the database. The register records objective Lachman laxity at 1-year follow-up. However, as 70° posterior laxity was not included in the registry until 3 years ago, this parameter was not included in the present study.

No written consent is necessary in Denmark for studies based on data from national healthcare registries. However, this study was approved by the Regional Centre for Clinical Quality Development and the National Data Protection Agency (1-16-02-367-15).

Patients

In total, 23,253 knee ligament reconstructions were registered in the DKRR from July 1, 2005 to December 31, 2015, of which 581 were PCL reconstructions. Three study populations were identified: patients with isolated primary PCL reconstruction ($n = 237$); patients with multi-ligament PCL reconstruction, in combination with ACL or collateral ligament reconstruction ($n = 344$); and a comparison group of primary ACL reconstruction patients ($n = 21{,}820$).

The completeness of surgical registration was determined by correlating the registry data with data in a national registry of patients in which all public and private hospital contacts and procedures are registered. The completeness of PCL procedure registration in the ACL registry was 88%. The completeness of patient-reported outcome data was 35% pre-operatively and 27% at the 1-year follow-up. The epidemiological characteristics of the study groups are presented in Table 1, in addition to surgical data on meniscus and cartilage procedures, surgical techniques and graft types.

Outcomes

Patient-related outcome measures (PROMs) (i.e. KOOS and Tegner scores) were used to characterize subjective outcomes and knee functions. To calculate a single measure of the impact of PCL reconstruction based on KOOS data, a new parameter, KOOS4, was recently

Table 1 Epidemiological characteristics

	Isolated PCL	Multi-ligament PCL	ACL primary
N	237	344	21,820
Mean follow-up (years)	5.0 ± 2.9	5.7 ± 2.9	5.6 ± 2.4
Age (years)	31.8 ± 11.1	33.0 ± 11.1	29.9 ± 10.3
Sex (male %)	69	73	60
Cause of injury (%)			
Sports	49	39	81
Traffic	29	36	3
Other	22	25	16
Time since injury–surgery (months)	36 (3–250)	25 (0–297)	28 (0–394)
Joint pathology (%)			
Meniscus	14	23	46
Cartilage	14	16	63
Technique (%)			
Single bundle	97	99	98
Double bundle	3	1	2
Graft type (%)			
Autograft	78	46	99
Allograft	12	34	1

defined for young patients with ligament injury. KOOS4 is calculated as the mean of the scores in the four most responsive KOOS subscales: symptoms, pain, sports and quality of life (QoL) [4]. Failure rates are calculated as the rate of new PCL revision reconstruction. Both crude revision rates for the cohorts and 2-year revision rates are presented. A subjective failure rate was defined as a QoL score below 40 on the KOOS.

Statistical analyses

The sample size needed to detect a clinical relevant difference of 10 points in the KOOS QoL subscale, with a standard deviation of 20 points and a power of 0.9 was calculated. Sixty-nine patients were required per investigational group. More than 250 patients per subgroup provided a sufficient number of patients for the PROM subgroup analysis. KOOSs are presented as the mean, with standard deviations. Tegner activity levels are presented as median and range values. The characteristics of the patients in each study population are presented as proportions. A repeated Student's calculated changes from pre-operative to 1-year post-surgery PROM values *T* test based on mean cohort values and not changes within the individual patients. A repeated Student's *T*-test was also used for comparisons of 1-year KOOS values between study groups. For comparisons of Tegner activity level scores between the study groups, a nonparametric Mann–Whitney test was performed. Statistical significance was accepted at the 0.05 level.

Results

Epidemiology and surgery

PCL reconstructions constituted only 2.6% of all knee ligament reconstructions in the DKRR national cohort over 10 years. Isolated PCL reconstruction was performed in 41% of PCL reconstruction cases. In the study, 69 and 73% of patients who underwent isolated and multi-ligament PCL reconstructions, respectively, were males. For ACL reconstructions, the male proportion was smaller, at 60% (Table 1).

The main causes of PCL injuries were sports (43%) and traffic accidents (33%). For the PCL multi-ligament injuries, traffic accidents accounted for an even higher proportion of injuries (36%). The cause of injury was significantly different from that in ACL-injured patients, where sports and traffic accidents were responsible for 81% and 3% of injuries, respectively (Table 1).

At surgery, meniscus lesions and cartilage lesions were seen in 19 and 15% of cases, respectively. These percentages were lower than for primary ACL reconstructions, where meniscus lesions and cartilage lesions at surgery were observed in 46 and 61% of cases, respectively (Table 1).

For PCL reconstructions, the double-bundle technique was used in 3% of isolated PCL reconstructions and in 1% of multi-ligament PCL reconstructions. The surgical techniques were similar to those used in ACL reconstructions, where double-bundle reconstruction was also very

rarely used. Although allografts were frequently used in PCL reconstructions (12 and 34% for isolated and multi-ligament, respectively), such grafts were used in only 2% of ACL procedures.

Subjective outcomes

The KOOSs for four subscales [pain, activities of daily living (ADL), sports and QoL] improved significantly at the 1-year follow-up for both isolated PCL reconstructions and multi-ligament PCL reconstructions, as compared to the pre-operative scores. The greatest advances were made in sports and QoL subscales, with improvements of 13–21 points (Fig. 1).

When the improvements in the KOOSs between isolated PCL reconstructions and multi-ligament PCL reconstructions were compared, there were greater improvements after multi-ligament PCL reconstructions. However, the differences were not statistically significant across the subscales (Table 2).

Overall, the changes in the KOOS from pre-operative to the first post-operative year for the PCL reconstructions and ACL reconstructions were very similar, with no significant differences. However, overall, at follow-up, the scores for PCL reconstructions were poorer than those for ACL reconstructions in the following subscales: pain, ADL, sports and QoL, with differences of 10–24 points (Table 2).

The Tegner activity level improved significantly at the 1-year follow-up for isolated PCL reconstructions and multi-ligament PCL reconstructions compared to pre-operative values. There was no difference in the follow-up Tegner scores for isolated PCL reconstructions versus multi-ligament PCL reconstructions, but the Tegner scores for ACL reconstructions were significantly higher than those for PCL reconstructions.

Failures

During the follow-up period, 3.0% of patients who had undergone isolated PCL reconstructions and 3.4% of those who had undergone multi-ligament PCL reconstructions underwent revision surgery. The 2-year revision rates for both isolated PCL reconstructions and multi-ligament PCL reconstructions were 2.0%. In comparison, primary ACL reconstructions were revised in 4.5% of cases. At the 1-year follow-up, on the KOOS, a score of <40 was defined as a low QoL and indicative of subjective failure. Using this definition of failure, 83 (35%) of the isolated PCL reconstructions and 155 (45%) of the multi-ligament PCL reconstructions were subjective failures. For primary ACL reconstructions, the subjective failure rate was 21%.

Discussion

The most important finding of the present study was that the patients who underwent both isolated and multi-ligament PCL reconstructions reported significant improvements in several aspects of subjective outcomes, especially sports function and QoL. Another key finding was that at the 1-year follow-up, despite having lower absolute PROM scores, there were no statistically significant differences in the multi-ligament PROM scores of those who had undergone isolated PCL reconstruction. These results are novel because no previous studies have investigated clinical outcomes after both isolated and multi-ligament PCL

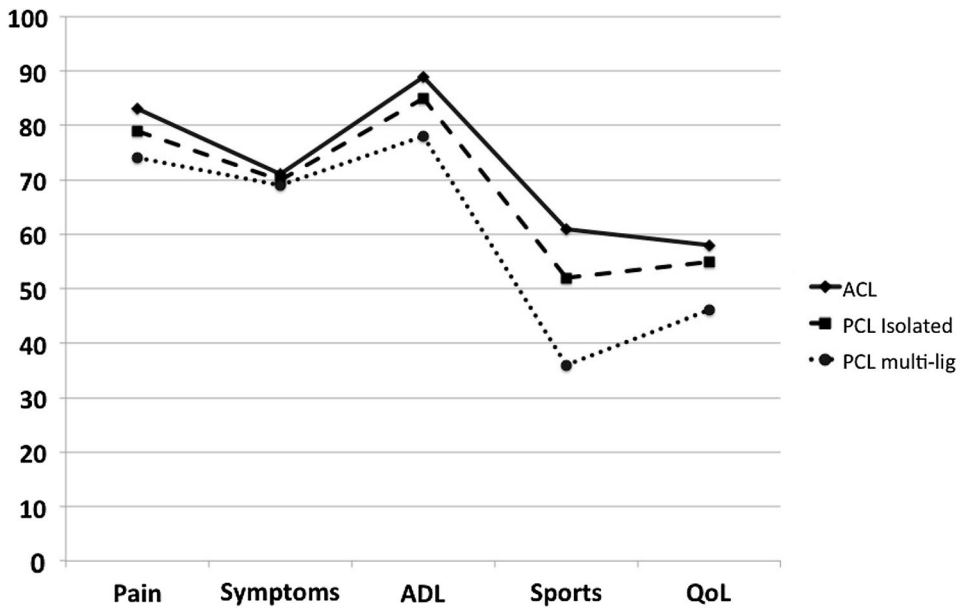

Fig. 1 KOOS profiles for isolated PCL reconstruction, multi-ligament PCL reconstruction and reference ACL reconstruction at 1-year follow-up

Table 2 Follow-up KOOS and Tegner scores for isolated and multi-ligament PCL reconstruction and those of a primary ACL control cohort

1-year follow-up KOOS	Isolated PCL Pre/1 year	Change (95% CI)	Multi-lig PCL Pre/1 year	Change (95% CI)	ACL primary Pre/1 year	Change (95% CI)
KOOS subscales[a]						
Pain	69/79[d,e]	9.6 (5.1 to 15.1)	66/74[d,e]	7.5 (−0.6 to 15.7)	71/83	10.6 (10.0 to 11.2)
Symptoms	71/70	−1.7 (−6.7 to 3.2)	69/69	−0.1 (−5.0 to 4.8)	71/71	−1.1 (−1.7 to −0.5)
ADL[b]	78/85[d,e]	7.4+ (4.2 to 10.6)	64/78[d,e]	13.2 (6.8 to 19.6)	79/89	9.1 (8.5 to 9.7)
Sports/recreation	36/52[d,e]	15.3 (7.2 to 23.4)	15/36[d,e]	21.4 (13.0 to 29.9)	38/61	21.5 (20.5 to 22.6)
QoL	41/55[d,e]	13.2 (6.4 to 20.0)	28/46[d,e]	18.4 (9.9 to 27.0)	39/58	18.5 (17.7 to 19.3)
KOOS4[c]	57/65[d,e]	8.5 (4.2 to 12.9)	44/57[d,e]	13.2 (7.4 to 19.0)	57/70	12.0 (11.4 to 12.6)
KOOS QoL <40	54/29%		82/44%		55/21%	
Tegner activity level	3(0 to 9)/4(0 to 7)[d,e]	1	2(0 to 9)/4(0 to 8)[d,e]	4	3(0 to 10)/5(0 to 10)[d]	2

Pre-operative (pre) and 1-year follow-up (1 year) values, as well as the changes in these values

[a] The KOOS subscale scores are presented as mean values, and the Tegner activity level scores are presented as median values

[b] ADL

[c] KOOS4 is a modified KOOS, defined as the average of the subscores for symptoms, pain, sports and QoL

[d] Significant difference in the pre-operative and 1-year follow-up scores

[e] Significant difference in the PCL and ACL primary reconstruction scores at 1-year follow-up

reconstructions based on large cohorts from a national clinical registry. Further, the results demonstrated that both subjective and functional outcomes after PCL reconstruction did not reach the same level as after primary ACL reconstruction.

Previous studies investigating outcomes after PCL reconstruction have typically been based on case series from a single surgeon at an academic centre [6, 12, 25]. The present data from a national cohort are potentially more representative of actual outcomes after PCL reconstruction, as the data are derived from several clinics and surgeons.

Only one previous study used data from a national registry (the Norwegian Registry) to investigate outcomes in isolated PCL reconstruction and compared the outcomes with those obtained in primary ACL reconstruction [1]. That study found significant improvements in subjective outcome measures after PCL reconstructions at a 2-year follow-up as compared to pre-operative scores, but the improvements were not as good as those reported for primary ACL reconstructions. The present study confirmed these results for isolated PCL reconstructions. The KOOSs found in the Norwegian Registry at the 2-year follow-up were almost identical to those reported in the 1-year follow-up in the present study.

The reasons for a poorer clinical outcome after PCL reconstruction than after ACL reconstruction are not understood, but several potential factors may play a role. First, the cause of injury in PCL and ACL injuries is different. As demonstrated in the present study and other studies, PCL injuries are more frequent in traffic injuries, whereas ACL injuries are typically sports related. Second, the PCL ligament is stronger than that of the ACL ligament, resulting in a higher injury trauma to results in ligament rupture, which could affect post-management symptoms negatively. Third, the muscle biomechanics around the knee make PCL reconstructions challenging. Hamstring activity subjects load to PCL grafts, which can result in post-operative laxity. Several studies have shown that normalization of knee laxity after PCL reconstruction is not as good as after ACL reconstruction [6, 8].

Interestingly, the present study found fewer meniscus and cartilage injuries intra-operatively during PCL reconstruction than during ACL reconstruction. As mentioned above, the cause of the trauma in PCL and ACL injuries is very different. PCL injuries typically occur from direct trauma to the proximal tibia or hyperextension, whereas ACL injuries occur from combined rotation and valgus loads during sports. The added rotatory injury mechanism in ACL injuries is potentially more likely to cause meniscus and cartilage lesions [16]. Previous studies also demonstrated that multi-ligament injuries were associated with fewer meniscus and cartilage injuries than isolated ACL injuries [9]. In another study of a PCL registry, Aroen

et al. also reported lower numbers of cartilage and meniscus injuries in PCL patients than ACL patients [1]. Due to higher rates of concomitant injuries, improvements in subjective outcome measures would have been expected to be poorer in ACL injuries than PCL injuries. However, the above-mentioned differences in the trauma mechanisms in PCL and ACL injuries and in the anatomy and biomechanics of the ligaments apparently override the impact of concomitant soft tissue injuries on subjective outcomes.

Failures after PCL reconstructions have been poorly investigated due to the rarity of such procedures and the resulting small size of clinical studies. In the present study, the 2-year revision rates for both isolated and multi-ligament PCL reconstruction were 2.0%. Revision rates after PCL reconstructions have not been described previously in registry studies. The rates after PCL reconstructions were lower than after primary ACL reconstruction. One potential reason for the low revision rate after PCL reconstruction is the higher threshold for advocating revision surgery. The latter is due to the extremely technically demanding nature of the procedures and the fact that no studies have defined surgical techniques that consistently provide improvements in knee stability and subjective outcomes in revision PCL settings.

With regard to the clinical impact of PCL reconstruction, the present study suggested that it resulted in consistent improvements in subjective and functional outcomes, even in a heterogeneous national patient cohort. The final outcome scores were lower than those reported after primary ACL reconstruction. However, functional levels at follow-up after PCL reconstruction were far from normal and poorer than after ACL reconstruction, and a significant proportion of patients had a poor QoL due to knee-related symptoms. To ensure realistic expectations, patients with PCL injuries should be informed about the predicted outcomes of PCL reconstruction. As mentioned above, there are numerous potential reasons for the differences in clinical outcomes following PCL and ACL reconstructions. In the present patient cohorts, single-bundle techniques were applied in the vast majority of surgeries. Previous research showed that single-bundle reconstructions could neither reconstruct the PCL anatomically nor recreate normal knee biomechanics [10, 12]. In contrast, clinical case studies demonstrated excellent post-operative knee stability and function after double-bundle PCL reconstruction [22]. However, thus far, no level 1 comparative study has investigated outcome after different surgical techniques for PCL reconstruction.

At present, discussions are ongoing about the potential role of non-operative management of PCL injuries due to the potential healing capacity of the partly extra-articular ligament. The recent introduction of PCL support braces has fuelled this discussion, but no studies have investigated the clinical efficacy of non-operative brace-based PCL injury management [7, 13]. Unfortunately, existing national registries do not include non-operative PCL injury management and can therefore not contribute to outcome studies of non-operative management.

Data from a national clinical registry have several limitations. These include data completeness and patient compliance with reporting PROM data. In the present study, the procedure registration completeness was 88%, which is considered acceptable for a national prospective cohort. Securing patient cooperation in reporting subjective scores over the Internet is very challenging. In this study, an average of 35 and 23% of patients reported data pre-operatively and at 1-year follow-up, respectively. This raises the possibility of selection bias in the evaluation of PROM data. However, a validation study demonstrated that there was no difference in the subjective outcomes of responders versus non-responders [18]. We are only able to present 1-year PROM data. After major surgical procedures, such as PCL reconstruction, with very long rehabilitation regimens, it would be of interest to examine subjective outcomes after a longer follow-up. Another limitation is the lack of objective data for PCL reconstruction outcomes, such as the quantitative posterior drawer test and functional tests. Such objective data are important for in-depth outcome evaluations. The strengths of the present study are the fact that the clinical registries are population based, with large sample sizes providing a high precision of estimates and ensuring generalization. Furthermore, the data collection was done prospectively and independently of future research aims, reducing both selection and information biases.

Conclusions

PCL reconstructions represented only 2.6% of all knee ligament reconstructions in Denmark. Sports and traffic accidents were the main causes of injury. Meniscus and cartilage injuries were seen less frequently in PCL injuries compared to ACL injuries. Isolated and multi-ligament PCL reconstructions showed significant improvements in subjective outcome measures following surgery, with no difference in those of isolated and multi-ligament PCL reconstructions. PCL reconstructions had poorer outcome than ACL reconstructions. Patients should be counselled about the expected outcomes after PCL reconstruction.

Compliance with ethical standards

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

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Ethical approval This study was approved by the Regional Centre for Clinical Quality Development and the National Data Protection Agency (1-16-02-367-15).

Informed consent No written consent is necessary in Denmark for studies based on data from national healthcare registries.

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