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The Effect of Aging on Outcomes after Posterior Cruciate Ligament Reconstruction: Older (≥ 50 Years) Versus Younger (< 50 Years) Patients

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Background: This study aimed to evaluate the clinical and radiological outcomes after posterior cruciate ligament (PCL) reconstruction in ≥ 50-year-old patients.

Methods: This retrospective case-control study reviewed 28 patients (age, ≥ 50 years) who underwent PCL reconstruction from 2004 to 2018. These patients were 1 : 1 matched to < 50-year-old patients by sex. Clinical, radiological, and survivorship outcomes of the patients were assessed at the final follow-up. Failure of PCL reconstruction was defined as the requirement for additional surgery (revision PCL reconstruction, high tibial osteotomy, or arthroplasty) due to unrelieved symptoms or grade III instability on stress radiographs.

Results: The mean follow-up periods (± standard deviation) in < 50- and ≥ 50-year-old patients were 3.9 ± 1.0 years and 3.6 ± 1.9 years, respectively (p = 0.583). In < 50- and ≥ 50-year-old patients, the mean International Knee Documentation Committee scores were 64.1 ± 10.3 and 53.5 ± 17.3; mean Lysholm scores were 81.4 ± 13.0 and 66.3 ± 21.5; and mean Tegner activity scores were 6.1 ± 1.4 and 4.8 ± 1.7, respectively (p = 0.032, p = 0.018, and p = 0.016, respectively). Side-to-side differences in posterior translation on Telos stress radiographs at the final follow-up were 4.4 ± 1.4 mm and 6.9 ± 3.0 mm in < 50- and ≥ 50-year-old patients, respectively (p < 0.001). According to Kaplan-Meier analysis, the failure-free survival rates of both groups were significantly different in the follow-up period (p = 0.014). The failure-free survival rates for < 50- and ≥ 50-year-old patients were 100% and 78.6%, respectively.

Conclusions: Clinical, radiological, and survivorship outcomes were inferior among ≥ 50-year-old patients after PCL reconstruction. Thus, surgeons should be careful when deciding and performing PCL reconstruction in patients 50 years old or over.

Keywords: *Posterior cruciate ligament reconstruction, Reconstruction, Age*

Historically, acute isolated posterior cruciate ligament (PCL) injury has been managed with nonoperative treatment.[1] In chronic PCL injuries, PCL reconstruction is indicated for grade III instability in patients of appropriate age and activity level.[1] According to our knowledge, no study has precisely indicated the definition of "appropriate age."

According to recent United Nations data, the aged population is expected to double by the year 2050.[2] The demand for physical and sports activity in the aged population is increasing. Restricted activity level associated

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with instability after chronic PCL injury is not well tolerated, even in the aged group. The incidence of PCL reconstruction has been increasing steadily in South Korea. The number of PCL reconstruction in older age has also shown an increasing trend in South Korea.[3] Although the requirement for PCL reconstruction is increasing in the aged group, no studies have investigated the surgical outcomes after PCL reconstruction in the aged group.

There are some concerns regarding ligament reconstruction in the aged population. First, bone quality and healing response in the aged population, which may affect fixation and incorporation of the graft, are a concern in anterior cruciate ligament (ACL) reconstruction.[4,5] Age-dependent differences in healing potential after ACL reconstruction have been reported previously.[6,7] In addition, rehabilitation is known to play a crucial role in determining patient outcomes after PCL reconstruction.[8] The quadriceps muscle is a key factor in rehabilitation after PCL reconstruction, and age-related muscle loss may negatively affect the outcomes after PCL reconstruction.[9]

Therefore, this study aimed to compare the clinical, radiological, and survivorship outcomes between ≥ 50- and < 50-year-old patients after PCL reconstruction. It was hypothesized that compared with < 50-year-old patients, ≥ 50-year-old patients would have inferior clinical and radiological but superior survivorship outcomes after PCL reconstruction.

METHODS

Patient Selection and Study Design

This retrospective study was approved by Institutional Review Board of Kyung Hee University Hospital (No. KHUH 2020-05-074). Informed consent was waived because of the nature of the study. All patients who underwent isolated primary PCL reconstruction in a single center from 2004 to 2018 were reviewed. Among them, those who were followed up for a minimum of 2 years were included in this study. Indications for PCL reconstruction were grade III instability (side-to-side difference [STSD], > 10 mm) and grade II instability (STSD, 5–10 mm) with discomfort after at least 6 weeks of nonoperative treatment during the acute stage.[10] Patients with bilateral knee injury, concomitant ipsilateral fracture around the knee, and multiligamentous injury requiring combined ligament surgery were excluded. Thereafter, patients were divided according to age (< 50 or ≥ 50 years old). Thus, 28 patients (age, ≥ 50 years) were enrolled (Fig. 1). The enrolled patients and < 50-year-old patients who underwent PCL reconstruction were 1 : 1 matched by sex.

Surgical Technique and Rehabilitation

All arthroscopic procedures were performed by a single surgeon (KHY) using the previously described surgical technique for PCL reconstruction.[11] Achilles allografts were used for all cases. The bony portion for the tibial tunnel was fashioned in a cylinder shape (length, 25 mm; diameter, 10 mm). The tibial tunnel was created through the posterior transseptal portal under arthroscopic visualization. It was made sure the bone block was tight press fit with the tibial tunnel after the grafts were passed from the tibia to the femur. An 8-mm metal interference screw was used to secure this bone block. Femoral fixation was performed with staples, as well as with bioabsorbable interference screws, for double fixation. Fixation was performed with the knee flexed to 90° and with maximal anterior tibial translation.[12]

Postoperative Rehabilitation

Knee joint motion was limited owing to cast immobilization for 6 weeks, which was followed by brace application for 6 weeks.[13] Long-leg casts were applied, with the patient

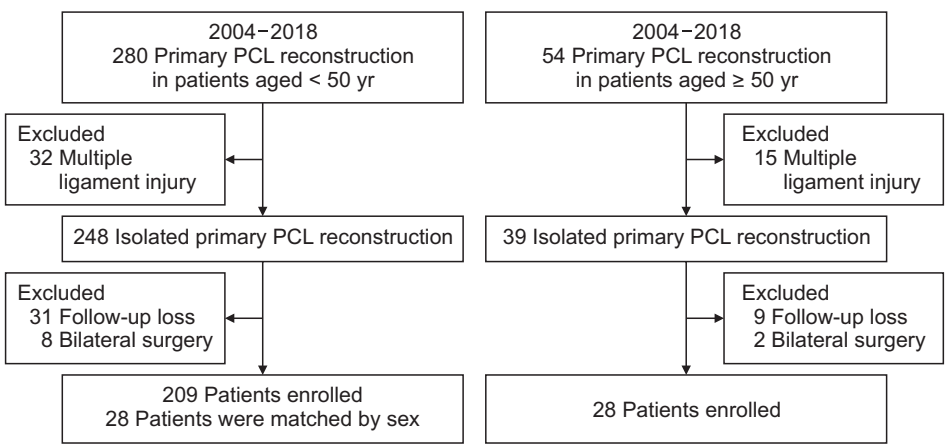


Fig. 1. Flowchart of patient enrollment. PCL: posterior cruciate ligament.

in prone position, to fix the femur and place the tibia under gravity force. The toes were placed on the surface to avoid posterior tibial translation owing to tensioning of the hamstring muscle. To avoid excessive knee extension, casts were applied with the knee flexed at 5°. Quadriceps strengthening and straight leg-raising exercises, as well as full weight-bearing ambulation, were encouraged immediately after cast application. After 6 weeks of cast application, the cast was removed and a 0° locking brace was applied for 6 additional weeks. After cast removal, range-of-motion exercises (closed kinetic chain squats) were performed in an effort to attain 90° of flexion by 9 weeks, 120° by 3 months, and full flexion by 6 months.

Clinical and Radiological Assessments

A questionnaire for clinical scores was completed and radiographs were obtained during the outpatient visit after PCL reconstruction. The clinical and radiological outcomes at the final follow-up were assessed. A senior resident blinded to the group assignment (HSL) examined clinical results using the International Knee Documentation Committee (IKDC) subjective score, Lysholm score, and Tegner activity score. Radiological outcomes were assessed in terms of STSD on Telos stress radiographs and osteoarthritis (OA) progression. Anteroposterior, lateral, and axial images, as well as Telos stress radiographs, were taken of both knee joints. Telos stress radiographs were obtained at approximately 90° of knee flexion with 134 N posterior load applied to the proximal tibia. OA progression was defined as a more progressive arthritic change in the tibiofemoral or patellofemoral joint than that in the contralateral knee on the last follow-up radiograph. Arthritic change was qualitatively evaluated using the Kellgren-Lawrence (K-L) classification. Two orthopedic surgeons blinded to the group allocation (JYP and HSL) independently measured the posterior tibial translation and K-L grade twice, and the inter- and intraobserver reliabilities were evaluated.

Graft Failure

Failure of PCL reconstruction was defined as the requirement for additional surgery (revision PCL reconstruction, high tibial osteotomy, or arthroplasty) due to unrelieved symptoms or grade III instability on stress radiographs (STSD, > 10 mm).[12]

Statistical Analysis

All statistical analyses were performed using IBM SPSS ver. 21.0 (IBM Corp., Armonk, NY, USA). Quantitative variables are presented as mean ± standard deviation or median and interquartile range. The chi-square and Fisher exact tests were used to compare qualitative variables. The independent *t*-test and Mann-Whitney *U*-test were used to compare normally and non-normally distributed continuous variables, respectively. The paired-sample t-test was used for comparison of pre- and postoperative STSD on stress radiographs. The Kaplan-Meier method was used to compare the failure-free survival rates of the two PCL reconstruction groups (< 50 years vs. ≥ 50 years). The log-rank test was performed to determine whether a statistical difference existed between the two groups. A *p*-value of < 0.05 was considered statistically significant. Intra- and interobserver reliabilities were determined by calculating the intraclass correlation coefficient (ICC) for posterior tibial displacement measurements. An ICC of < 0.40 was considered poor, whereas ICCs of 0.40–0.59, 0.60–0.74, and 0.75–1 were considered fair, good, and excellent, respectively. This study had a power of 98.1% to detect 19 points of difference in the Lysholm scores at the final follow-up between the two groups at the 0.05 significance level through use of the *t*-test.

Table 1. Preoperative Data of Both PCL Reconstruction Groups

Variable	PCL reconstruction group		*p*-value
	Age < 50 yr (n = 28)	Age ≥ 50 yr (n = 28)	
Age at surgery (yr)	25.6 ± 6.6	55.8 ± 6.8	< 0.001
Male : female	19 : 9	19 : 9	1.000
Body mass index (kg/m^2)	24.5 ± 3.4	24.7 ± 2	0.760
Injured side (right : left)	14 : 14	14 : 14	1.000
Duration from injury to surgery (mo)	10.6 (10.9–34.6)	4.3 (3.1–11.7)	0.018
Preoperative STSD (mm)	10.6 ± 1.7	11.1 ± 2.2	0.385
Combined chondral injury	2 (7)	11 (39)	0.004
Combined meniscus injury	0	16 (57)	< 0.001
Follow-up period (yr)	3.9 ± 1.0	3.6 ± 1.9	0.583

Values are presented as mean ± standard deviation, median (interquartile range), or number (%).
PCL: posterior cruciate ligament, STSD: side-to-side difference.

Table 2. Clinical and Radiological Outcomes

Variable	Age < 50 yr (n = 28)	Age ≥ 50 yr (n = 28)	*p*-value
IKDC subjective score			
Preoperative	49.5 ± 14.4	40.8 ± 14.4	0.074
Postoperative 2 yr	64.1 ± 10.3	53.5 ± 17.3	0.032
p-value	< 0.001	0.028	
Lysholm score			
Preoperative	59.1 ± 15.6	55.2 ± 16.1	0.483
Postoperative 2 yr	81.4 ± 13.0	66.3 ± 21.5	0.018
p-value	< 0.001	0.111	
Tegner activity score			
Preoperative	4.3 ± 6.3	3.8 ± 9.3	0.326
Postoperative 2 yr	6.1 ± 1.4	4.8 ± 1.7	0.016
p-value	0.001	0.105	
STSD (mm)			
Preoperative	10.6 ± 1.7	11.1 ± 2.2	0.385
Postoperative 2 yr	4.4 ± 1.4	6.9 ± 3.0	< 0.001
p-value	< 0.001	< 0.001	

Values are presented as mean ± standard deviation.
IKDC: International Knee Documentation Committee, STSD: side-to-side difference.

Table 3. Characteristics of Failed PCL Reconstruction

Variable	PCL reconstruction group	
	Age < 50 yr (n = 28)	Age ≥ 50 yr (n = 28)
Failure	0	6
Need for additional surgery	NA	NA
STSD > 10 mm	NA	6 (100)

Values are presented as number (%).
PCL: posterior cruciate ligament, NA: not applicable, STSD: side-to-side difference.

RESULTS

Patient Baseline Characteristics

Preoperative patient characteristics are described in Table 1. The mean ages of < 50- and ≥ 50-year-old patients were 25.6 ± 6.6 years and 55.8 ± 6.8 years, respectively ($p < 0.001$). Both groups had a higher proportion of men (men : women = 19 : 9). The injured side was evenly distributed in both groups. The duration from the injury to surgery was significantly longer in < 50-year-old patients than in ≥ 50-year-old patients (10.6 vs. 4.3 months, $p = 0.018$). Combined chondral injury (39% vs. 7%, $p = 0.004$) and combined meniscus injury (57% vs. 0%, $p = 0.004$) occurred more frequently among ≥ 50-year-old patients than among < 50-year-old patients. The mean follow-up period was longer than 3 years in both groups.

Clinical and Radiological Outcomes

At the final follow-up, all clinical scores of ≥ 50-year-old patients were inferior to those of < 50-year-old patients. The mean IKDC subjective scores of < 50- and ≥ 50-year-old patients were 64.1 and 53.5, respectively ($p = 0.032$). Similarly, the mean Lysholm score and Tegner activity score of < 50-year-old patients were higher than those of ≥ 50-year-old patients (mean Lysholm score: 81.4 vs. 66.3, $p = 0.018$ and Tegner activity score: 6.1 ± 1.4 vs 4.8 ± 1.7, $p = 0.016$).

The mean postoperative STSD on Telos stress radiographs was significantly longer in ≥ 50-year-old patients than in < 50-year-old patients (6.9 mm vs. 4.4 mm, $p < 0.001$) (Table 2). OA progression was observed in 2 patients aged < 50 years (7%) and 11 patients aged ≥ 50 years (39%). A significant difference was noted between the two groups ($p = 0.004$). All ICC values for intra- and interobserver reliabilities were > 0.8.

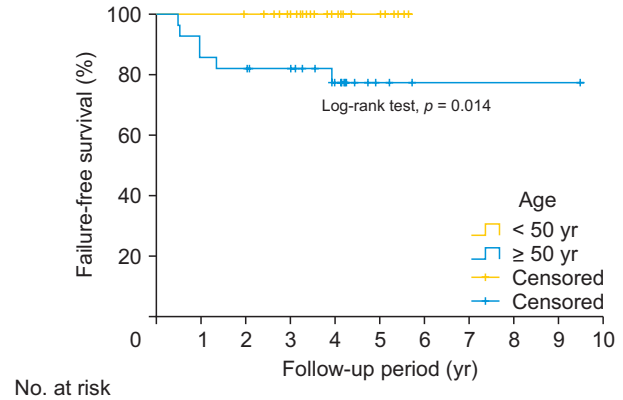
Failure Rate

Six cases (21.4%) of failure were noted among ≥ 50-year-old patients. However, none of the < 50-year-old patients experienced graft failure (Table 3). The relative risk of graft failure was 1.27 (≥ 50 vs. < 50 years old; 95% confidence interval, 1.05–1.54; $p = 0.01$). Further, the failure-free survival in both groups during the follow-up period was estimated using the Kaplan–Meier method and compared using the log-rank test. A significant difference was noted between the Kaplan-Meier survival curves of both groups ($p = 0.014$). The 5-year failure-free survival rates of < 50- and ≥ 50-year-old patients were 100% and 78.6%, respectively (Fig. 2).

DISCUSSION

The most important finding of this study is that compared with < 50-year-old patients, ≥ 50-year-old patients had inferior clinical, radiological, and survivorship outcomes after PCL reconstruction. However, the absolute difference of pain degree was only visual analog scale 1.

Several studies have demonstrated the effect of old age on ACL reconstruction.[14-16] In a recent systematic review by Costa et al.,[16] outcomes of ACL reconstruction in >



No. at risk

Age < 50 yr	28	27	27	23	12	7	0	0	0	0	0
Age ≥ 50 yr	28	24	23	21	14	3	1	1	1	1	0

Fig. 2. Kaplan-Meier analysis with failure as the endpoint. The failure-free survival rates of the two groups were significantly different during the follow-up period (p = 0.014). The 5-year failure-free survival rates of < 50- and ≥ 50-year-old patients were 100% and 78.6%, respectively.

50-year-old patients were reported to be good and comparable to those in younger patients of our study. However, unlike the outcomes after ACL reconstruction, outcomes after PCL reconstruction in aged population of the present study were inferior. It is important to take into account age-related changes in the ligament healing process, such as diminished healing potential, declining mesenchymal stem cell function, and diminished structural organization.[17]

Quadriceps strengthening is particularly important after PCL reconstruction because the quadriceps act as a secondary anteroposterior stabilizer with the PCL.[18] Inferior clinical and radiological outcomes in ≥ 50-year-old patients may be attributed to poor rehabilitation owing to age-related loss of muscle mass and strength.[19] A previous study demonstrated that muscle apoptosis increased in approximately 50-year-old patients compared with younger patients.[9] Higher rates of chondral and meniscal injury and OA progression in patients older than 50 years may have contributed to the inferior clinical outcomes.

Ligamentization refers to a process in which every graft undergoes necrosis and degenerative changes, followed by revascularization, cellular repopulation, and remodeling in both ACL and PCL reconstruction.[20,21] Ligamentization process is known to occur over a 12-month period.[21] Six cases of failure were noted among ≥ 50-year-old patients. Five out of 6 failure cases occurred within 1 year. A possible explanation for the high number of failures in the first year may be failure in incorporation of the graft. Failure in incorporation of graft at older age can be explained by previous studies demonstrating age-dependent differences in healing potential after ACL reconstruction. Hasegawa et al analyzed ACLs of 80 donors and revealed that ACL aging was characterized by a decrease in cell density and proliferation potential.[6] Nakano et al.[7] demonstrated that ACL-derived cells from younger patients resulted in enhanced early bone–tendon healing in an immunodeficient rat model of ACL reconstruction. Increased age has been known to negatively affect the cellular and molecular processes throughout the different stages of the bone fracture healing process.[22]

In a systematic review by Devitt et al,[23] the outcomes after isolated PCL reconstruction were assessed and found to be as follows: postoperative STSD, 3.5 mm; mean postoperative IKDC score, 73.5; Lysholm score, 87.8; and Tegner score, 5.7. These outcomes are comparable to those in < 50-year-old patients after PCL reconstruction in the present study. The clinical relevance is that age is not a contraindication to PCL reconstruction in patients over 50 years. However, inferior results compared to PCL reconstruction in patients below 50 years should be acknowledged by the physician and the patients. The strength of the study is that it is the only study that explored the outcomes of PCL reconstruction in patients over 50 years old.

The main limitations of the present study are its retrospective design and small study population, which is because PCL reconstruction is not commonly performed in patients over 50 years. A cutoff value could not be achieved due to the small number of patients. Further studies with a larger number of patients are warranted to confirm the results of the present study. Second, patients with intra-articular pathologies were included in the study and may have affected the clinical results. Third, the patients were matched only by sex but not body mass index. Fourth, muscle strength was not measured in the patients. Future studies with data on muscle strength need to be investigated.

Clinical, radiological, and survivorship outcomes were inferior among ≥ 50-year-old patients after PCL reconstruction. Thus, surgeons should be careful when deciding and performing PCL reconstruction in patients 50 years old or over.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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