Original Article

Reconstruction of chronic anterior cruciate ligament rupture using the ligament advanced reinforcement system artificial ligament—comparisons between patients over 50 years and under 50 years

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Background: With the increasing physical activity level in elderly population, anterior cruciate ligament (ACL) injuries are becoming more frequent. Due to the possible surgery complications, treatment for ACL rupture in patients with advanced age is still controversial. The purpose of this study was to compare the therapeutic effects of reconstruction using the ligament advanced reinforcement system (LARS) artificial ligament in patients older than 50 and patients younger than 50 with chronic ACL rupture.

Methods: Indications included: (I) concurrent history of subjective symptomatic anterior knee instability despite nonoperative rehabilitation for least 3 months, (II) positive preoperative Lachman and pivot shift tests, (III) ACL stump still connecting the femur with the tibia as demonstrated by Magnetic Resonance Imaging (MRI), and (IV) some residual ligament fibers still connecting the femur with the tibia as demonstrated by arthroscopy. Participants were divided into groups based on their age. Participants were divided into groups based on their age. A total of 37 patients who underwent reconstruction of chronic ACL rupture using the LARS artificial ligament were divided into group A (≥50 years, n=16) and group B (<50 years, n=21).

Results: The outcome measures were compared between the 2 groups. These included the baseline clinical data, the International Knee Documentation Committee (IKDC) scoring system, Pivot shift test, Lachman test, Kneelax arthrometer measurements, Tegner activity scale, Lysholm knee scoring scale, and Kellgren-Lawrence radiographic classification of arthritis and complications. Postoperative knee laxity and the functional examination were significantly improved compared to preoperative measurements for both groups (all $P<0.01$). No significant differences were found in postoperative knee laxity and functional examination between the 2 groups (all $P>0.05$). The level of osteoarthritis did not statistically increase in either group during follow-up (all $P>0.05$). No complications associated with the arthroscopic surgery were found in either group.

Conclusions: The reconstruction of chronic ACL rupture using the LARS artificial ligament showed similar therapeutic effects in patients over the age of 50 and those under the age of 50.

Keywords: Anterior cruciate ligament (ACL); reconstruction; arthroscopy; LARS artificial ligament; fifty-year-old patients

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Introduction

Arthroscopic reconstruction is the golden standard of therapy for anterior cruciate ligament (ACL) rupture. However, in patients with advanced age, the treatment for ACL rupture remains controversial. Due to an increase in the general level of health and improvements in medical technology, the mean life expectancy for humans is increasing worldwide. For example, in 2016 (1), the current life expectancy in Switzerland increased to 81.2 years for men and 85.2 years for women. With an increase in the elderly population, accidental injuries to the ACL are becoming more common, especially in those over the age of 50. In addition, the recommended level of physical activity for the elderly population has increased. As a result, the treatment of ACL injuries in elderly patients has been gradually receiving more attention (2-15). Ciccotti *et al.* (3) carried out conservative treatment in 52 patients with ACL rupture between the ages of 40 and 60. Researchers followed up with these patients for an average of 7 years and found that 83% of patients acquired satisfactory outcomes based on patient self-ratings; however, 97% of patients had a grade 2 or 3 Lachman test and 83% had a positive pivot shift test. Moreover, 37% of patients reported a reinjury throughout the follow-up period. Due to unsteadiness and possible reinjury of the injured joint, some elderly patients have had to change their habits and give up more demanding physical activities such as sports (16-18). Many elderly patients struggle to accept these limitations, so orthopedic surgeons have begun to selectively perform arthroscopic reconstruction on patients over the age of 50.

Highlight box

Key findings

- The reconstruction of chronic ACL rupture using LARS artificial ligament shows similar therapeutic effects in those over the age of 50 and those under the age of 50.

What is known and what is new?

- In young patients, reconstruction of chronic ACL rupture using LARS artificial ligament showed satisfied therapeutic effects.
- In patients over the age of 50, reconstruction of chronic ACL rupture using LARS artificial ligament showed similar therapeutic effects with younger patients.

What is the implication, and what should change now?

- In clinical practice, to achieve satisfied therapeutic effects, reconstruction using LARS artificial ligament could be undertaken in elderly patients with chronic ACL rupture.

Elderly patients who underwent these procedures achieved similar results as young patients (7-10). However, some orthopedic surgeons are concerned about the range of complications associated with ACL reconstruction on the elderly, which include arthrofibrosis, stiffness, infections, wound healing problems, and thromboembolic disease. In addition, many providers believe that latent degenerative knee osteoarthritis may lead to a poor prognosis (17,19-21). At the same time, there are also doubts about the choice of grafts for reconstruction of ACL rupture in elderly patients.

In patients over the age of 50, bone-patellar tendon-bone autograft, hamstring tendon autograft, and quadriceps allograft are typically used in the reconstruction of ACL rupture (2,3,5-14,22-25). Details on the application of these artificial grafts have not yet been reported; however, autologous grafts have a number of well-documented drawbacks, including donor site morbidity and a delayed recovery to preinjury levels (26-28). Allograft tendons are associated with infection and disease transfer, and sterilization may result in tissue weakness, although these have reportedly produced excellent clinical outcomes (28). In addition, biological grafts require a process of ligament remodeling to completely replace the ACL, which is associated with ingrowth and proliferation of host cells around grafts. The activity of ACL-derived fibroblasts is significantly weaker in elderly patients than in young patients (29). Kinugasa *et al.* (8) performed arthroscopy on 11 patients over the age of 50 at 2 years after their ACL reconstruction and found that graft coverage was more than 80% in only 5 patients, which was significantly lower compared to the younger control group. This suggested that orthopedic surgeons' concern about repeated rupture of the ACL after reconstruction in elderly patients is because biological grafts require a longer healing process.

The ligament advanced reinforcement system (LARS, Surgical Implants and Devices, Arc-sur-Tille, France), an artificial ligament, has been used frequently over the past 20 years. In theory, LARS is suitable for elderly patients because it can allow the injured knee to rapidly return to better function due to its good biocompatibility and high strength (29-33). However, the LARS ligament, like other synthetic grafts, has a risk of failure once spontaneous rupture occurs due to wear (34,35). It is necessary for the injured ACL to retain enough stump tissue to provide growth of sufficient fibroblasts into these artificial ligaments to help maintain the long-term mechanical properties of artificial ligaments (29-33).

Crain *et al.* (36) reported that in some patients with ACL

rupture, the residual bundle is still connecting the femur with the tibia, contributing to forward steadiness of the affected knee. These researchers also found that in some patients with ACL rupture, especially elderly patients, while the residual bundle still connected the femur with the tibia, it had lost mechanical strength due to long-term stress and repeated accumulation of injuries. There is no report on the effect of the LARS artificial ligament on ACL reconstruction in those patients whose residual bundles still connecting the femur with tibia lose mechanical strength. In this study, we compared LARS ligament reconstruction in chronic ACL injuried patients over 50 years of age [51–72] with those under 50 years of age [21–46]. Although further evidence is needed for the efficacy of reconstruction in patients at a higher age, this study proves to a certain extent that LARS reconstruction in patients over 50 years old with appropriate indications can achieve similar clinical efficacy under 50 years old. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-6330/rc).

Methods

Patient data

The population for this study included data from 45 patients with chronic ACL injury who underwent ACL reconstruction using the LARS artificial ligament in Shengjing Hospital between July 2009 and November 2017. The surgical indications included: (I) concurrent history of subjective symptomatic anterior knee instability despite nonoperative rehabilitation for least 3 months, (II) positive preoperative Lachman and pivot shift tests, (III) ACL stump still connecting the femur with the tibia as demonstrated by Magnetic Resonance Imaging (MRI), and (IV) some residual ligament fibers still connecting the femur with the tibia as demonstrated by arthroscopy. The exclusion criteria were as follows: (I) multiligament lesions in the affected knee, (II) contralateral knee injuries, (III) an interval between injury and surgery of fewer than 3 months, (IV) follow-up of fewer than 2 years, and (V) radiographic changes indicating Kellgren-Lawrence grade IV knee osteoarthritis (37). Of the 45 patients, 4 had a medial collateral ligament injury, 3 had a ligament injury or surgical history of the contralateral knee, and 1 had Kellgren-Lawrence grade IV knee osteoarthritis. In total, 37 patients satisfied the inclusion criteria and were eligible to be included in this retrospective study. We divided these 37 patients into 2 groups: over 50 years of age, or group A (n=16); and under 50 years of age, or group B (n=21). Patients were grouped according to their age at the time of surgical treatment. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of Shengjing Hospital of China Medical University (No. 2015PS99K) and all patients signed informed consent prior to participation.

Table 1 Associated injuries

Lesions	Group A (≥50 years) (n=16)	Group B (<50 years) (n=21)
Meniscal injuries		
Medial	7	9
Lateral	3	4
Both	5	5
Cartilage lesions (Outerbridge score)		
Grade I	5	6
Grade II	4	5
Grade III	3	2
Grade IV	1	0

Surgical technique

Initial diagnostic arthroscopy was conducted after anesthesia via the standard anterior and posterior anteromedial access portals to assess the status of all crucial anatomical structures and to determine the degree of ligament damage and any associated meniscal or cartilage lesions. Meniscus lesions were treated with meniscal suture or partial meniscectomy. Cartilage lesions were debrided using a radiofrequency probe (outer bridge grade 1–2) or treated with microfractures (outer bridge grade 3–4) (37). The distributions of meniscal lesions and cartilage lesions are shown in *Table 1*.

ACL reconstruction was carried out using LARS in line with previously mentioned isometric surgical concepts (38). A shaver was used to debride the partial ACL stump, primarily the femoral side. The ACL stump with masked synovium was retained as much as feasible if the region of view or manipulation was not affected. A 7.5-mm cannulated reamer was utilized to build a tibial

tunnel alongside the first tendon excision incision after the implantation of an orthopedic guide frame with an inner portal placed on the anteromedial side of the ACL footprint on the tibia. The intraarticular point of the femoral tunnel was located at a relative position of 10:30–11:00 in the right knee or 1:00–1:30 in the left knee. The 7.5-mm diameter bit was drilled into the femur from the anterolateral thigh into the knee joint with the use of a Kirschner wire as a guide. From the extraarticular entrance of the tibial tunnel, the LARS artificial ligament with a diameter of 7.5 mm was implanted. Wire-guided tibial and femoral tunnels as well as the lateral thigh were punctured throughout the procedure. It was confirmed that the knee had a complete range of motion and that no impingement existed between the LARS artificial ligament, notch, or posterior cruciate ligament (PCL). At a knee flexion angle of 30 degrees, both the tibial and femoral sides of the LARS artificial ligament were fixed using titanium interference-fit nails (Surgical Implants and Devices) with an 8-mm diameter on one side and 9 mm on the other.

All surgical procedures described above were carried out by one senior surgeon (Dr. Li).

Postoperative rehabilitation

On the first day after surgery, knee flexion exercises, straight-leg raises, and quadriceps isometric exercises were carried out. Knee flexion increased gradually from 45° to complete flexion and extension within 4 weeks of surgery. Beginning at 3 days after surgery, the affected legs could bear partial body weight. This progressed to bearing entire body weight within 6 weeks. The crutch was removed at 6 weeks following operation. Two months following reconstruction, patients were able to resume light sports activity. Three to 4 months after surgery, full preinjury sports activities could be resumed.

Evaluation

Baseline clinical data including gender, age, interval between injury and surgery and the median follow-up were collected and compared. All preoperative evaluations were carried out in the operating room on the day of operation. Postoperative evaluations were done at 6 months and 1 year after surgery and then once a year for 2 years. This study investigated the follow-up data. The Tegner activity score, Lysholm questionnaire, and objective International Knee Documentation Committee (IKDC) ligament evaluation form were used to evaluate the patients' functional outcomes. The pivot-shift and Lachman test were used to measure anterior and rotatory instability. The IKDC Standard Evaluation Form was used to qualify these results, including grades 0, 1+, 2+, and 3+ (39). Additionally, a Kneelax arthrometer was used to measure the degree of anterior tibial translation (30° flexion and 132 N). The difference in the degree of anterior translation between the nonaffected side and the affected side was reported in millimeters. Lateral and anteroposterior (AP) weight-bearing radiographs were taken for Kellgren-Lawrence osteoarthritis grading (39). Each evaluation was carried out by the same investigator. This investigator did not participate in the surgery in order to minimize latent bias.

Statistical analysis

A power analysis was carried out to identify the number of patients necessary to distinguish significant differences in the knee laxity arthrometer measurements that were recorded during the follow-up period. Samples from both groups were hypothesized to have equal population average differences and overall standard deviations, all of which were 2 mm. For each group, 16 samples were required to detect the difference with a 95% confidence level and 80% power. SPSS software (Version 25.0; SPSS Inc., Chicago, IL, USA) was used to analyze the data. Continuous statistics with Gaussian distribution are described as mean (± standard deviation) and abnormal distribution as median (range). Nominal data were compared using a chi-square test and continuous data using an unpaired Student's *t*-test when normally distributed. Statistics with abnormal distribution were compared using the Wilcoxon signed rank test. Statistical significance was confirmed at $P<0.05$.

Results

All patients in both groups attended the last follow-up. General patient data are shown in *Table 2*. There were no significant differences in gender or the median follow-up between the 2 groups (all $P>0.05$). No patients reported the occurrence of graft failure, infection, deep thrombosis, neurovascular injury, or any other complication.

Table 3 summarizes the functional evaluations of the injured knees. Postoperative IKDC rating results, Tegner activity level, and Lysholm score were all significantly

Table 2 General data of patients in the 2 groups

General data	Group A (≥50 years) (n=16)	Group B (<50 years) (n=21)	P values
Male/Female	10/6	12/9	c^2=0.108, P=0.724
Mean age (years), [range]	57 [51–72]	30 [21–46]	Z=−4.638, P<0.001
IBIS (month), median [range]	43 [9–214]	13 [7–60]	Z=−4.112, P=0.001
Follow-up (month), median [range]	26 [24–27]	25 [24–29]	Z=−1.238, P=0.125

IBIS, interval between injury and surgery.

Table 3 Functional examination of the knee in group A and group B

Functional examination	Group A (≥50 years) (n=16)		Group B (<50 years) (n=21)	
	Preoperative	Postoperative	Preoperative	Postoperative
ROM (°), mean ± SD	108.4±21.7	112.4±23.6	116.7±26.5	117.4±27.2
Lysholm score, median [range]	65 [35–96]	86 [43–98]	66 [32–95]	85 [49–99]
Tegner activity level, median [range]	3 [1–7]	5 [2–8]	3 [1–7]	5 [2–8]
IKDC objective score				
Normal	0	6	0	8
Nearly normal	3	9	1	11
Abnormal	9	1	11	2
Severely abnormal	4	0	9	0

ROM, range of motion; SD, standard deviation; IKDC, International Knee Documentation Committee.

improved in both groups compared with preoperative data (all P<0.01). However, there were no significant differences between the 2 groups in the postoperative Lysholm score, Tegner activity level, or IKDC rating results (all P>0.05). Postoperative range of motion (ROM) did not show significant improvement compared with preoperative ROM in both groups (all P>0.05), and no significant differences were found in postoperative ROM between the 2 groups (P>0.05).

Table 4 summarizes the knee stability measurements of the injured knees. No significant differences were observed between the 2 groups in the preoperative Lachman test, Pivot shift test, or Kneelax arthrometer examination (all P>0.05). Both groups significantly improved in terms of the 3 knee stability measurements (all P<0.001) between the preoperative and postoperative assessments. Meanwhile, no significant differences were observed in the postoperative Lachman test, Pivot shift test, or Kneelax arthrometer examination results between groups (all P>0.05).

Radiographic findings regarding the degree of arthrosis according to the Kellgren-Lawrence radiographic classification of arthritis (37) are summarized in *Table 5*. In group A, preoperative radiographs showed 14 patients with normal or mild degeneration (87.5%) and 2 patients with marked arthritis (12.5%). Postoperative radiographs displayed 13 patients with normal or mild degeneration (81.25%) and 3 patients with marked arthritis (18.75%), with no significant difference between before and after operation (P>0.05). In group B, preoperative radiographs showed 21 patients with normal or mild degeneration (100%). Postoperative radiographs showed 20 patients with normal or mild degeneration (65.24%) and 1 patient with marked arthritis (4.76%), with no significant difference between before and after operation (P>0.05). Meniscus or cartilage injuries were found during the operation in all patients, with postoperative marked arthritis in both groups.

Discussion

The main findings of this study showed that stability and function of the injured knees were significantly improved for chronic ACL injury using the LARS artificial ligament.

Table 4 Assessment of anterior and rotatory instability before and after reconstruction

Instability assessment	Group A (≥50 years) (n=16)		Group B (<50 years) (n=21)	
	Preoperative	Postoperative	Preoperative	Postoperative
Lachman test				
Grade 0	0	12	0	16
Grade 1	1	3	2	4
Grade 2	13	1	17	1
Grade 3	2	0	2	0
Pivot shift test				
Grade 0	0	11	0	16
Grade 1	3	4	5	4
Grade 2	11	1	15	1
Grade 3	2	0	1	0
Kneelax arthrometer (mm), mean ± SD	6.5±1.7	1.9±1.3	6.2±2.3	3.0±1.9

Table 5 Radiographic findings of degree of arthrosis (number)

Grade	Group A (≥50 years) (n=16)		Group B (<50 years) (n=21)	
	Preoperative	Postoperative	Preoperative	Postoperative
Grade 0	2	0	9	7
Grade I	7	6	7	6
Grade II	5	7	5	7
Grade III	2	2	0	1
Grade IV	0	1	0	0

SD, standard deviation.

No significant differences were observed in the stability and function of the affected knees of those patients over the age of 50 and those patients under the age of 50 after 2 years of follow up. In addition, patients did not report any complications such as joint stiffness, graft rupture, or infection.

There is no final conclusion on the best course of treatment of ACL injuries in the elderly population (2-14,22,40). With the increase in life expectancy and the development of arthroscopic surgery, many doctors believe that ACL reconstruction can be accomplished in some elderly patients. *Table 6* reviews 15 clinical studies on ACL reconstruction in patients over the age of 50. These studies all indicated that significant improvement was observed in postoperative stability and function. In this study, side-to-side arthrometer difference-related data measured in patients over the age of 50 were comparable with that in other studies (*Table 6*) (2,4-13,20,41-43). In this study, ACL achieved excellent or good postoperative IKDC scores in 93.75% of patients, which is similar to what has been reported by other studies (8,12). Graft failures did occur in some patients in 2 different studies (2,3,11,12). Results varied due to differences in patient data, surgical methods, graft types, and postoperative rehabilitation programs. It is worth noting the consistent result that all affected knees achieved satisfactory functional recovery.

Some orthopedic surgeons are worried about a high incidence of complications after ACL reconstruction in

Table 6 Review of studies on ACL reconstruction in patients aged 50 years or older

Study	Year	Level of evidence	Injured knees (n)	Mean age (year) [range]	TTS (month) median [range]	Graft type	Follow-up (month), median [range]	Functional assessment	Arthrometer (side-to-side difference)	Complications
Blyth *et al.* (2)	2003	IV	31	54.5 [50–66]	88 [2–396]	10 BPTB autograft; 21 HS autograft	46 [24–95]	IKDC 81% A + B; Lysholm 93; Tegner 5.2	93% <5 mm	3 graft failure because of trauma; 2 symptomatic tibial hardware
Stein *et al.* (10)	2006	IV	19	54 [49–64]	NA	BPTB or AT allograft	24 [9–48]	Lysholm 92	18 (95%)	No
Dahm *et al.* (4)	2008	IV	35	57 [50–66]	24 [1–156]	23 BPTB allograft; 12 BPTB autograft	72 [25–173]	IKDC 92 [28–100]; Lysholm 90 [33–100]; Tegner 4.3 [2–7]	NA	3 graft failure because of trauma; 2 symptomatic tibial hardware
Trojani *et al.* (11)	2009	IV	18	57 [51–66]	11 [3–72]	HS autograft	30 [12–59]	IKDC 83% A + B	NA	3 hypoesthesia of the medial saphenous nerve territory; 1 posterior knee pain
Kinugasa *et al.* (8)	2011	II	11	58.5 [50–71]	27.4 [1–158]	HS autograft	15.5 [12–20]	IKDC 100% A + B; Lysholm 98 [95–100]; Tegner 3.7 [1–6]	−0.2±1.0 mm	No
Osti *et al.* (9)	2011	III	20	56 [50–62]	2.87 [2.4–3.33]	NA	32 [24–49]	IKDC 91 [80–100]; Lysholm 89 [41–100]	15 (75%)	1 graft failure
Ventura *et al.* (12)	2012	IV	50	54.4 [50–65]	32.6 [3–125]	HS autograft	52.8 [24–84]	IKDC 94% A + B; Lysholm 90±6.4; Tegner 5 [2–8]	2.7±0.8 mm; 96% <5 mm	No
Figueroa *et al.* (5)	2014	IV	50	52.15 [50–64]	8.4 [4–12]	45 HS autograft; 5 AT allografts	53.17 [36–68]	IKDC 90.96 [57.5–100]; Lysholm 93.7 [60–100]; Tegner 4.3 [2–7]	NA	2 ACL re-ruptures; 1 infection
Wolfson *et al.* (13)	2014	IV	32	58.4 [51–65]	NA	26 allografts [16 TA, 8 BPTB, 1 TP, 1 AT]; 6 autograft [4 BPTB, 2 HS]	60 [26.4–108]	IKDC 80.1 [33–100]; Lysholm 86.7 [45–95]; Tegner [0–3]	1.2 ± 1.3 mm (range: 0 to 4.5 mm)	2 symptomatic tibial hardware; 3 knee stiffness; 1 graft failure
Toanen *et al.* (20)	2017	IV	12	61.0 [59–64]	49.6 [21–91]	HS autograft	11.5 [6–18]	IKDC 83.8 [60.9–94.3]	1.9±4.3 mm	5 hypoesthesia of the medial saphenous nerve territory
Iorio *et al.* (6)	2018	III	36	54.0 [50–62]	NA	HS autograft	64 [60–72]	IKDC 91.4±4.78; Lysholm 94.3±5.14; Tegner 5.4 [3–7]	97% <5 mm	No
Kim *et al.* (7)	2019	IV	40	52.0 [51–53]	23.8 [16.5–30.1]	HS autograft	12	IKDC 75.6 [70.1–79.3]; Lysholm 93.0 [85.0–95.0];	95% <5 mm	No
Ovigue (41)	2020	III	75	53.9 [50–65]		58 ST, 17 STG	28.3 [24–38]	IKDC 82.9±13.1; Tegner 5 [1–7]; Lysholm 90.4±12.1	NA	2% hematomas; 8% graft failure
Ehlinger *et al.* (42)	2021	II	228	54.8±4.3 [50–71.6]	23.6±59 [0.3–414]	197 BPTB autograft; 31 HS autograft	14.2 [3.5–30.5]	IKDC 79% A + B; Tegner 5.2±1.5	NA	1% meniscal lesion; 2% stiffness in extension; 2% stiffness in flexion; 3% global pain 1% residual laxity; 0.5% swelling; 1% CRPS; 1% femoral fixation site pain; 0.5% tibial fixation site pain; 3% patella syndrome
Arbuthnot and Brink (43)	2010	IV	14	60 [55–75]	NA	9 BPTB autograft; 5 HS autograft	114 [2–240]	Lysholm 79 [43–100]; Tegner 3 [1–5]	1.5±1.2 mm	1 graft failure

ACL, anterior cruciate ligament; BPTB, bone-patellar tendon-bone; HS, hamstring; AT, Achilles tendon; TA, tibialis anterior; TP, tibialis posterior; ST, semitendinosus graft; STG, semitendinosus and gracilis tendon; IKDC, International Knee Documentation Committee; TTS, time from injury to surgery; NA, not applicable; CRPS, complex regional pain syndrome.

elderly patients. These include joint fibrosis, joint stiffness, incision infection, and graft failure (19,20). *Table 6* shows that the most common complication in patients over the age of 50 is graft failure that occurs after ACL reconstruction. The rates of graft failure are as high as 9.67% (2,3) and 8.57% (11,12) and most are associated with re-trauma. Other articles reported 1 patient with graft failure (9,13,43).

According to a cytological investigation, fibroblast activity of ACL-derived fibroblasts was considerably reduced in older patients compared to young individuals (28). Arthroscopy also found that graft coverage was significantly lower in patients over the age of 50 than in younger patients at 2 years after ACL reconstruction (8). This suggests that elderly patients may experience a lengthier graft reconnection process and have a greater incidence of failure following ACL reconstruction than young patients. According to some reports (2,3,5-14,22), the overall rate of graft failure after ACL reconstruction is not high in those over the age of 50. Consequently, surgeons should not be afraid to perform ACL reconstruction on patients over the age of 50 due to concern about graft failure. In this study, we used LARS artificial ligaments to perform ACL reconstruction. Although there have been reports on the spontaneous rupture of the LARS artificial ligament (34,35,44), this condition did not occur in our study. As shown in *Table 6*, in patients over the age of 50, the second most common complication was symptomatic tibial hardware after ACL reconstruction. The incidences were 6.45% (2), 5.71% (4), and 6.25% (11), respectively. In some studies (2,4,13) where suture posts or staples were used, symptomatic tibial hardware disappeared after their removal. In this study, we used a metal interference screw fixation, and thus no symptomatic tibial hardware occurred. In addition, 1 study (11,12) reported sensory hypoesthesia in the region dominated by the knee medial saphenous nerve. This occurred in 3 patients (16.67%) who underwent ACL reconstruction using autologous hamstring tendon graft (12,14). Another study reported an incision infection in 1 patient (2%) (5,6). As for the complication of joint stiffness after ACL reconstruction in elderly patients, only 1 article reported joint stiffness (3 patients, 9.37%) (13,14), and no joint stiffness was reported in any other studies (2,4,5,8-12,43). In our study, no significant differences in ROM and no joint stiffness were found before or after knee surgery, and thus our results were similar to those reported in these studies (2,4,5,8-12,43). The graft used in this study was the LARS artificial ligament. Compared with biological grafts, LARS artificial ligaments do not require realignment, and its strong initial stability can ensure early functional exercise, preventing joint stiffness.

Another concern is that latent knee osteoarthritis may preclude a positive outcome (19,20). Blyth *et al.* (2) and Ventura *et al.* (12) followed patients for 46 months and 4.9 years, respectively, and found no significant difference in the degree of joint degeneration before and after knee surgery. Wolfson *et al.* (13) believed that the degree of arthrosis in the operative knee did not correlate with worse outcomes. Blyth *et al.* (2) and Dahm *et al.* (4) also reported that the postoperative degree of knee joint degeneration was not significantly correlated with clinical outcomes. In this study, we followed patients over the age of 50 who underwent ACL reconstruction for 2 years after their surgery and did not find significant change in knee joint degeneration. Our results are similar to those reports above (2,4,12,13).

To evaluate the value of ACL reconstruction in elderly patients, it is necessary to compare the therapeutic effect of ACL reconstruction in elderly patients with that in other age groups (9,10,45). Osti *et al.* (9) found no significant difference in the stability and function of the affected knee between the 2 groups after 2 years follow-up, but there was a significant improvement compared with preoperative evaluation. Kinugasa *et al.* (8) divided 102 patients with ACL reconstruction into 3 groups: below 30 years of age, 30–49 years of age, and over 50 years of age. Follow-up lasted for 2 years. Results found that except for sports activity, there was no significant difference observed in knee stability and function (IKDC subjective scores and Lysholm scores) among the 3 groups. In our study, we compared the therapeutic effect of ACL reconstruction using the LARS artificial ligament in patients over the age of 50 and under the age of 50. No significant differences were found in knee stability and function between the 2 groups, which was similar to the results reported by previous studies. Therefore, it can be concluded that for some elderly patients, ACL reconstruction may obtain similar therapeutic effects to younger patients. In the available literature, the oldest patient undergoing ACL reconstruction (46,47) received ACL reconstruction 10 weeks after ACL injury had occurred. The patient returned to normal ROM and IKDC score with arthrometry of –0.5 mm compared with healthy knee joint 6 months after surgery (46,47).

In the available literature, all the grafts used in ACL reconstruction for patients over the age of 50 have been biological grafts, including autogenous tendons and allogeneic tendon grafts. In this study, the LARS ligament was used. As an artificial graft, there are risks of graft rupture due to wear

and synovitis induced by worn particles (34,35).

Smith *et al.* (47) systematically reviewed 5 clinical studies including 129 patients undergoing PCL reconstruction using the LARS artificial ligament and found that 1 patient had ligament rupture and 1 patient had synovitis after follow-up of 10.5–44 months. In addition, therapeutic effects were better in the LARS artificial ligament than in the autograft, and thus the LARS ligament could be considered a safe and effective graft. Parchi *et al.* (31) and Jia *et al.* (29) followed patients who had undergone ACL reconstruction using the LARS artificial ligament for 8 and 7 years, respectively. They found that only 1 patient had ligament rupture and other patients obtained satisfactory therapeutic effects, confirming that the application of LARS in ACL reconstruction was safe and effective. Tiefenboeck *et al.* (48) followed 18 patients who had undergone ACL reconstruction using the LARS artificial ligament for 10 years and found that graft rupture occurred in 5 patients. Initially, it was believed that the LARS artificial ligament was not suitable for a first ACL reconstruction. These varied results from different studies may be due to the varying lengths of follow-up times. The follow-up time in Tiefenboeck *et al.* (48) was the longest, which increases the risk of artificial ligament rupture. It is also worth considering the variables in patients' basic data and surgical techniques. Both Parchi *et al.* (31) and Jia *et al.* (29) clearly indicated that the ligament stump was preserved during operation. However, Tiefenboeck *et al.* (48) did not mention this. Viateau *et al.* (35) developed an ACL rupture model using sheep. This was followed by ACL reconstruction using the LARS artificial ligament. Three and 12 months later, they took samples for observation and found that only in the contact region between the artificial ligament and host tissue did the artificial ligament play a supportive role. This was because of the rich blood supply of the tissue. Obvious wear was seen in the 40% of artificial ligaments without host tissue ingrowth. Therefore, using the LARS artificial ligament to reconstruct ACL is suitable for patients with the appropriate amount of stump tissue, and the stump tissue should be preserved as much as possible during the operation to ensure sufficient contact between the stump fiber and the artificial ligament, thereby reducing the risk of artificial ligament rupture. Crain *et al.* (36) reported that in some cases after ACL rupture, the stump still connecting the femur with the tibia would contribute to maintaining the anterior stability of the affected knee. In this study, all patients had better stump connecting the femur with the tibia, which provided sufficient fibroblast for growth into the artificial ligament. This helped to maintain long-term mechanical properties of the artificial ligament.

The first disadvantage of this study was the short follow-up time. Follow-up time for this study was a period of 2 years, while the incidence of complications such as artificial graft rupture due to wear and synovitis induced by worn particles gradually increase with the extension of postoperative time. The second disadvantage was that we did not set a conservative treatment group to accurately evaluate the therapeutic effects in patients over the age of 50. However, this study had definite surgical indications and exclusion criteria, and all patients had chronic ACL injuries with marked joint instability. Finally, there were significant differences in operation time between the 2 groups. The interval between injury and surgery (IBIS) in patients over the age of 50 was longer than those under the age of 50, likely because elderly patients are more likely to select conservative treatment instead of surgery until apparent symptoms appear. In addition, doctors are more concerned about reconstructing ACL in elderly patients than in young patients. However, in this study, surgical procedures were the same and were carried out by the same surgeon. The rehabilitation program was also the same. All patients were followed for a minimum of 2 years, which boosted the statistical power of the findings.

Conclusions

In summary, patients over the age of 50 with chronic ACL injury could achieve similar stability and function as younger patients with the surgical technique of ACL reconstruction using LARS artificial ligaments.

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Footnote

Reporting Checklist: The authors have completed the STROBE checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-6330/rc

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ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-6330/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). All patients who participated in this study signed an informed consent form, and this study was approved by the Ethics Committee of Shengjing Hospital of China Medical University (No. 2015PS99K).

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