Original Articles

Subjective Outcomes After Allograft Reconstruction and Nonoperative Treatment of Anterior Cruciate Ligament Ruptures Are Similar in Patients Aged 40 Years and Older: A 2:1 Propensity Score–Matched Analysis

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Purpose: To compare subjective outcomes and rates of subsequent operations for patients aged 40 years and older with anterior cruciate ligament (ACL) ruptures who elected nonoperative management or allograft ACL reconstruction (ACLR). **Methods:** This was a retrospective study comparing 2-year minimum results of nonoperative treatment and primary allograft ACLR among patients aged 40 years and older presenting to a single institution between the years 2005 and 2016. Patients who elected nonoperative management were 2:1 propensity score (PS)-matched to patients who elected ACLR based on age, sex, body mass index, sports-related mechanism of injury, Outerbridge grade III or IV chondral lesions, and medial or lateral meniscus tears. Univariate analysis was performed to compare subjective outcome measures of International Knee Documentation Committee and Marx activity level scores, subsequent operations, and satisfaction rates. **Results:** After 2:1 PS matching, 40 ACLR and 20 nonoperative patients with mean ages of 52.2 years and 54.5 years, respectively, were included with a mean follow-up of 5.7 years (SD 2.1 years, range 2.3-10.6 years). There were no significant differences between the groups in any of the matching variables. There were no significant differences in International Knee Documentation Committee scores (81.9 ± 14.1, CI 77.4-86.5 vs 84.3 ± 12.8, CI 78.3-90.3, $P = .53$), Marx activity level scores (5.8 ± 4.8, CI 4.2-7.3 vs 5.7 ± 5.1, CI 3.3-8.1, $P = .96$), or satisfaction rates (100% vs 90%, $P = .11$) between the ACLR and nonoperative groups. Four (10%) patients who underwent ACLR sustained a graft treated with revision ACLR. 7 (17.5%) ACLR and 0 nonoperative patients subsequently received further ipsilateral knee surgeries ($P = .08$), including 2 total knee arthroplasties. **Conclusions:** In this PS-matched analysis of patients aged 40 years and older with ACL ruptures, patients who elected nonoperative management had similar subjective outcomes compared with those who elected allograft ACLR. Patients who elected allograft ACLR did not have fewer subsequent operations than those who elected nonoperative treatment. **Study Design:** Level III, retrospective cohort study.

Anterior cruciate ligament (ACL) injuries have been increasing in patients aged 40 years and older as participation in physical activities in this population has increased.[1,2] However, there is less consensus on the optimal management of ACL injuries in this patient population as compared with pediatric and young adult populations.[3] Historically, many patients aged 40 years and older were managed nonoperatively as the result of decreased patient activity levels and increased comorbidities compared with younger patients. Although anterior cruciate ligament reconstruction (ACLR) in this age group has an increased incidence of medical complications, there are many patients in which surgery is indicated.[4,5] Although the American Academy of Orthopaedic Surgeons has guidelines recommending ACLR for patients

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between the ages of 18 and 35 years, there are no guidelines for patients aged 40 years and older.[6] Regardless of the lack of guidelines for this patient population, the incidence of ACLR in patients aged 40 years and older has been increasing with multiple studies suggesting promising outcomes.[7-18]

There have been limited comparative studies investigating the outcomes of operative and nonoperative treatment of ACL injuries in patients aged 40 years and older. A study of patients between the ages of 40 and 59 years who underwent primary repair with or without augmentation of their ACL found significantly better KT-1000 measurements, OAK, and Lysholm scores when compared with patients who underwent nonoperative treatment.[9] A multicenter study found that patients older the age of 50 years had significantly better International Knee Documentation Committee (IKDC), Tegner, and Knee injury and Osteoarthritis Outcome Score (KOOS) quality of life scores if surgical treatment was pursued rather than conservative nonoperative management.[12] In addition, a systematic review concluded that patient-reported outcomes scores (PROs) were improved in the operative treatment group when compared with the nonoperative treatment group; however, it was noted that only one nonoperative study was included in the analysis.[10] Further studies have found that if there is a delay to ACLR, the incidence of meniscal tears, arthritis, and total knee arthroplasty is increased, which is an important factor to consider, as patients aged 40 years and older often have increased degenerative changes compared with a younger patient population.[19-24] Overall, this paucity of data makes it difficult for clinicians to counsel patients regarding the optimal treatment of ACL injuries in this population.

The purpose of this study was to compare the subjective outcomes and rates of subsequent operations for patients aged 40 years and older with ACL ruptures who elected nonoperative management or primary allograft ACLR. We hypothesized that patients who undergo ACLR will have significantly superior outcomes and fewer subsequent operations than matched patients who underwent nonoperative management.

Methods

This study was approved by the institutional review boards of New England Baptist Hospital (IRBNet#: 890506-9) and Tufts Medical Center (IRBNet#: 12868). Patients aged 40 years and older presenting to a single institution with an ACL rupture between the years of 2005 and 2016 were retrospectively identified. Patients were included if they received allograft ACLR performed by 1 of 4 sports medicine fellowship-trained surgeons, or if they were treated nonoperatively, with a minimum of 2-year follow-up. All patients with suspected ACL tears on clinical examination received magnetic resonance imaging (MRI) to confirm the diagnosis. The exclusion criteria for this study were concomitant multiligament knee reconstruction, incomplete operative report or MRI data, previous ipsilateral ACLR, receipt of an ACL autograft, and receipt of a transtibial drilled femoral tunnel (Fig 1).

Data Collection

Demographic information, MRI results, preoperative clinical examination findings, findings from operative reports, concomitant pathology, and surgical techniques were recorded from patient charts. Articular cartilage defects were assessed on MRI and confirmed intraoperatively at the time of the index surgery in the ACLR group, using the Outerbridge Classification scheme. For the ACLR group, postoperative outcomes were obtained via telephone calls, emails, or mail correspondence by a medical student (M.H.-L.), at a minimum of 2 years from the date of surgery. Outcome assessments were compiled into a survey questionnaire that included satisfaction with the surgery (yes/no), subsequent ipsilateral knee surgeries, as well as standard IKDC Subjective Knee Evaluation and Marx activity score forms. Results from patients in the ACLR group have been analyzed in a previous study without comparison to patients managed nonoperatively.[14] For the nonoperative group, patients were sent a survey questionnaire including satisfaction (yes/no), subsequent ipsilateral knee surgeries, IKDC and Marx activity scores forms, months of physical therapy, and knee brace use. Surveys were sent via e-mail and mail correspondence by a medical student (M.H.-L.), at a minimum of 2 years after injury.

Treatment

For the ACLR group, all patients received tibial-tunnel independent femoral drilling via an anteromedial portal or outside-in technique using exclusively ACL allografts. Femoral-sided fixation was performed with an interference screw, cortical button, or cross-pin, whereas tibial fixation was performed with an interference screw or screw and washer. All patients received a standardized postoperative rehabilitation treatment that included immediate weight-bearing as tolerated in a hinged knee brace with a goal of 0-90° of knee flexion by the first postoperative clinic visit. Quadriceps sets and heel slides were implemented immediately, closed-chain leg press at 2-4 weeks, stationary bike at 4 weeks, open chain knee extension at 6 weeks, light running at 12-16 weeks, and sports-specific training at 16-20 weeks. For the nonoperative group, patients were offered physical therapy with progression of activity as tolerated.

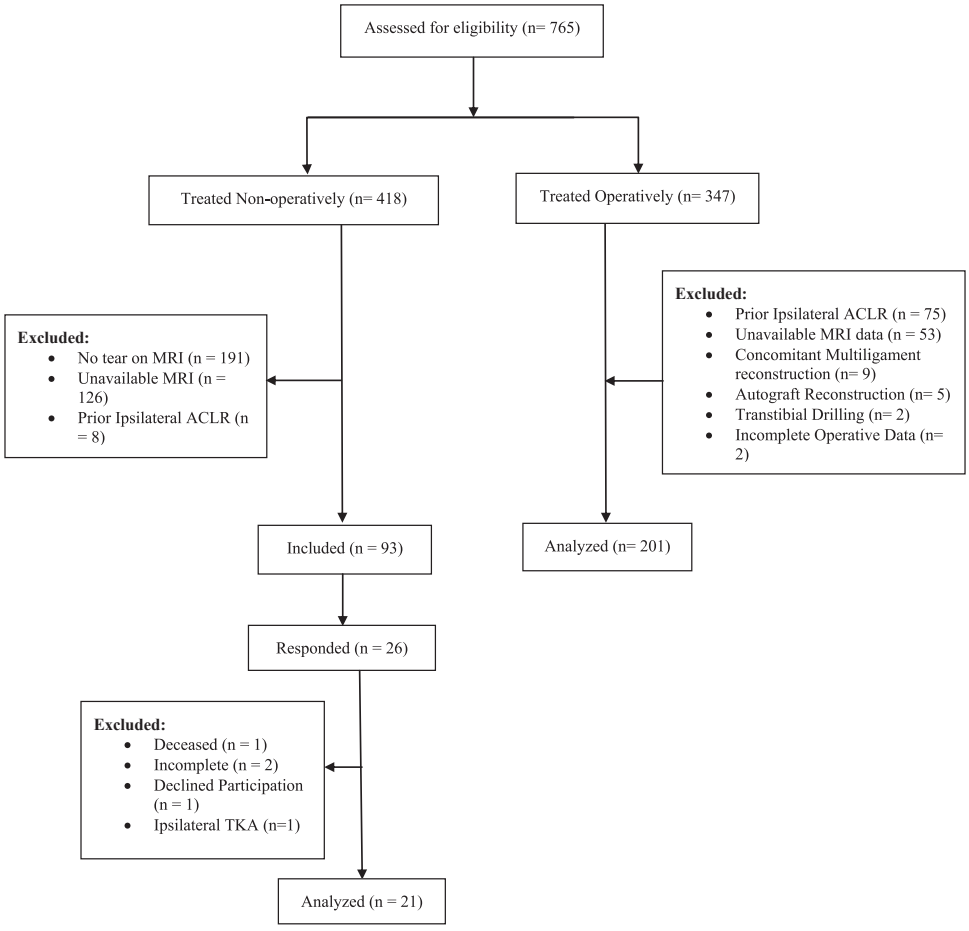

Figure 1. CONSORT Flow Diagram

Data Analysis

Recognizing there was likely a treatment selection bias and baseline differences between the groups, patients who met inclusion and exclusion criteria were 2:1 (operative: nonoperative) propensity score (PS) matched to reduce potential biases and confounders. The PSs were generated using a logistic regression model method, incorporating age at the time of the diagnostic MRI; sex; BMI; sport-related mechanism of injury; presence of any Outerbridge grade III or IV chondral lesion in the medial, lateral, or patellofemoral compartments; and presence of medial or lateral meniscal tear. The matching process was executed using a greedy, nearest-neighbor matching algorithm, without replacement. A caliper was specified for acceptable matches, to eliminate the risk of making bad matches if the closest eligible neighbor was far away. The caliper was set as 0.3 times the standard deviation of the logit of the propensity scores among the entire population.

Among the final 2:1 PS matched cohort, patients treated with an ACLR were compared with those treated nonoperatively. The outcomes of interest included IKDC scores, Marx activity level scores, satisfaction, and subsequent ipsilateral knee surgeries. Baseline demographic and clinical characteristics as well as outcomes were reported in terms of means with standard deviations and frequencies. Univariate analysis was performed using Student's *t*-, χ^2, and Fisher exact tests as indicated. All analyses were performed using SPSS statistical software, version 25 (IBM Corp., Armonk, NY).

Propensity Scoring Exclusion

Experimentally, 0.2 to 0.5 times the standard deviation of the logit of the PS has been recommended as an appropriate caliper to effectively control for variance, with lower values having increased prevision in matching. Patients that were not matched were excluded from final analysis.

Results

After application of study inclusion and exclusion criteria, 201 patients were identified who received a primary allograft ACLR, and 21 who underwent nonoperative management. After 2:1 PS matching, 40 ACLR and 20 nonoperative patients with a mean follow-up of 5.7 years (SD 2.1 years, range 2.3-10.6

Table 1. Comparison of Patient Characteristics Between 2:1 Propensity Score Matched Groups

Parameter	ACLR n = 40	Nonoperative n = 20	*P* Value
Age, y* mean (SD)	52.2 (5.4)	54.5 (7.7)	.19
Sex*			
Female, n (%)	24 (60)	14 (70)	.45
Male, n (%)	16 (40)	6 (30)	
BMI,* mean (SD)	25.7 (4.2)	25.8 (4.4)	.97
Sports-related injury,* n (%)	27 (67.5)	13 (65)	.85
Cartilage damage,*† n (%)	9 (22.5)	4 (20)	.83
Medial compartment	4 (11.4)	1 (5.9)	.99
Lateral compartment	3 (8.1)	1 (5.9)	.99
Patella	2 (6.1)	2 (11.8)	.6
Trochlea	2 (7.7)	1 (7.1)	.99
Meniscal tear			
Medial,* n (%)	12 (30)	8 (40)	.44
Lateral,* n (%)	9 (22.5)	6 (30)	.53
MCL injury, n (%)	7 (17.5)	8 (44.4)	.03‡
Additional injury,§ n (%)	6 (15)	6 (30)	.11

ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; MCL, medial collateral ligament; SD, standard deviation.

*Variables included in the propensity score matching.

†Outerbridge grade III or IV.

‡Statistically significant at $P < .05$.

§Posterior cruciate ligament, Posterolateral corner, patellar tendon, of lateral collateral ligament.

years), were included for final analysis. There was a significant difference in follow-up time between the ACLR and nonoperative groups (6.11 ± 2.18 vs 4.86 ± 1.6 years, $P = .03$). There were no significant differences between the ACLR and nonoperative groups in age (52.2 ± 5.4 vs 54.5 ± 7.7, $P = .19$), sex (60% female vs 70% female, $P = .45$), BMI (25.7 ± 4.2 vs 25.8 ± 4.4, $P = .97$), sports-related mechanism of injury (67.5% vs 65%, $P = 85$), presence of Outerbridge grade 3 or 4 chondral lesions (22.5% vs 20%, $P = .83$), lateral meniscus tear (22.5% vs 30%, P=0.53), or medial meniscus tears (30% vs 40%, $P = .44$).

PS-matched ACLR and nonoperative groups were then compared for presence of other ipsilateral knee injuries. There was a significantly higher proportion of patients with MCL injuries in the nonoperative group (17.5% vs 44.4%, $P = .03$), but no difference in other additional ligamentous injuries (15% vs 30%, $P = .11$) (Table 1). Regarding concomitant procedures in the ACLR group, there was 1 (2.5%) lateral meniscus repair, 22 (55%) medial meniscectomies, 15 (37.5%) lateral meniscectomies, and 1 (2.5%) microfracture of a medial femoral condyle chondral lesion.

At the time of follow-up, there were no significant differences in postoperative IKDC scores (81.9 ± 14.1, confidence interval [CI] 77.4-86.5 vs 84.3 ± 12.8, CI 78.3-90.3, $P = .53$), Marx activity level scores (5.8 ± 4.8, CI 4.2-7.3 vs 5.7 ± 5.1, CI 3.3-8.1, $P = .96$), or proportion of patients satisfied with the state of their knee (100% vs 90%, $P = .11$) between the ACLR and nonoperative groups (Table 2). 95.4 % of nonoperative patients reported attending physical therapy after ACL injury for an average of 3.8 months (SD 2.0, range 1.5-8 months). Ten (47.6%) of the 21 nonoperative patients before PS matching indicated that they now wear a knee brace for physical activity. Four (10%) patients who underwent ACLR had received a revision ACLR for graft re-rupture. In addition, 7 (17.5%) ACLR and 0 nonoperative patients had received further ipsilateral knee surgeries ($P = .08$) (Table 2). Two patients in the ACLR group received multiple subsequent surgeries (one revision ACLR converted to a TKA, and one revision meniscectomy converted to a TKA).

Discussion

In this study, patients aged 40 years and older who elected nonoperative treatment of ACL tears demonstrated similar subjective measures of satisfaction to patients who elected ACLR. Both groups had high patient satisfaction rates of ≥90% and no significant differences between IKDC and Marx activity level scores at a minimum follow-up of 2 years. Therefore, patients aged 40 years and older with ACL ruptures may be counseled that both operative and nonoperative management results in satisfactory outcomes. Individual

Table 2. Comparison of Outcomes Between 2:1 Propensity Score–Matched Groups

Parameter	ACLR n = 40	Nonoperative n = 20	*P* Value
IKDC score, mean (SD)	81.9 (14.1)	84.3 (12.8)	.53
Marx activity score, mean (SD)	5.78 (4.8)	5.7 (5.1)	.96
Satisfied, n (%)	40 (100)	18 (90)	.11
Subsequent ipsilateral knee surgeries, n (%)	7 (17.5)	0	.08
TKA or UKA	2 (5)	0	.55
Meniscectomy	4 (10)	0	.29
Other Arthroscopic Procedure	3 (7.5)	0	.99
Subsequent revision ACLR	4 (10)	N/A	N/A

ACLR, anterior cruciate ligament reconstruction, IKDC, International Knee Documentation Committee; TKA, total knee arthroplasty; N/A, not available; SD, standard deviation; UKA, unicompartmental knee arthroplasty.

patient demographics and goals should be considered when making recommendations.

Previous studies suggest that patients aged 40 years and older can achieve high satisfaction rates after nonoperative treatment of ACL tears. One case series followed 11 recreational Alpine skiers with a median age of 43 after nonoperative management of complete ACL tears.[25] At 2-year follow-up, no patients in the study complained of instability at 2-year follow-up, 10 had low-grade Lachman tests, 8 had returned to skiing, and 2 demonstrated healing on subsequent MRIs. Importantly, these subjects were selected based on the presence of low-grade Lachman tests at 6-12 weeks postinjury, likely contributing to their success with conservative management.

Few studies directly compare PROs and satisfaction between ACLR and nonoperative treatment of ACL tears in patients aged 40 years and older. Zysk and Refior[9] evaluated the outcomes of nonoperative treatment of torn ACLs in patients 40 to 59 years old and compared them with outcomes of surgical intervention consisting of either primary suture or primary suture and semitendinosus tendon augmentation. Their study found that the primary repair with augmentation group showed significantly better results according to OAK and Lysholm scores, Lachman test, pivot-shift test, and KT-1000 arthrometer measurements than the primary repair and conservative treatment groups. Physical activity level was also significantly higher in the primary repair with augmentation group. Similarly, in a 2021 prospective study, Ehlinger et al[12] compared results between surgical vs non-surgical treatment of ACL tears in 320 over-50-year-old patients. The authors found that at follow-up, patients in the surgical group showed improved Lachman tests, had a less frequent marked pivot-shift, better differential laxity, and more stable knees. Surgical patients also demonstrated higher IKDC scores, Tegner scores, and KOOS quality of life subscores at follow-up. However, they also found that Global KOOS and ACL-RSI scores were comparable and improved in both groups. This may suggest that despite the comparable satisfaction and activity levels found in the study, objective measures of knee stability may be favorable in patients who undergo ACLR. Nonoperative management may be more reasonable in patients participating in only light and moderative activities that don't necessitate more objective knee stability.

Several systematic reviews on the management of ACL injuries in older populations conclude that patients older 40 years can have satisfactory outcomes from ACLR.[10,15,16,26] However, all have also found that there are not enough direct comparison studies between operative and nonoperative management to support one treatment option over another.

Limitations

It should be noted that patients in the present study self-selected their treatment option, which may influence patients' satisfaction and impart selection bias. Patients who self-select for nonoperative management of ACL tears may be less likely to desire further knee surgeries, which may account for the difference in subsequent ipsilateral knee surgeries between groups. Another limitation is the lack of pretreatment, baseline PROs, which precluded analysis of treatment effects on PROs and satisfaction and could have influenced treatment decision. The study additionally lacks pretreatment range of motion, stability testing, or Kellgren-Lawrence scores: all measurements with possible effects on the treatment selected by patients. Further limitations include the small number of patients included in the study, the low response rate in the nonoperative group, possible recall bias as with any survey study, the measurement of PROs at one time point instead of multiple designated time points, and the lack of matching by activity level. Finally, the study is limited by its lack of posttreatment objective data such as measures of knee laxity or radiographic evidence of further chondral or meniscal lesions.

Conclusions

In this PS-matched analysis of patients aged 40 years and older with ACL ruptures, patients who elected nonoperative management had similar subjective outcomes compared with those who elected allograft ACLR. Patients who elected allograft ACLR did not have fewer subsequent operations than those who elected nonoperative treatment.

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