Systematic Review

Anterior Cruciate Ligament Reconstruction in Patients Over 40 Years Old Shows Low Failure Rates: A Systematic Review

John Roberts IV, B.A., Richard Puzzitiello, M.D., and Matthew Salzler, M.D.

Purpose: To review the literature reporting on complications and failure rates after primary anterior cruciate ligament reconstruction (ACLR) in patients ≥40 years. **Methods:** This was a secondary analysis from a prior systematic review of the MEDLINE, CINAHL, SportDiscus, Embase, Web of Science, and Cochrane databases on studies evaluating clinical outcomes in ACLR patients ≥40 years. Studies were included based on the following criteria: English-language studies reporting on postoperative complications and/or ACLR failure rates in patients ≥40 years. Case reports, technical notes, studies with duplicate reporting of patient cohorts, or studies using publicly available registry data were excluded. ACLR failure definitions, failure rates, graft rupture rates, revision ACLR and non-ACLR revision rates, and complication rates were recorded. **Results:** Twenty-one studies were included following full-text review. Autografts were used in 89.0% of cases. Definitions for ACLR failure varied, ranging from (1) revision ACLR, (2) graft rupture, (3) clinical examination of increased knee laxity, and (4) postoperative arthrofibrosis requiring an additional surgery. The median ACLR failure rate was 5.0% (range, 0%-12.1%) among the 9 studies reporting this outcome, with only 4 of the studies providing explicit definitions of failure. The median ACLR revision surgery, graft rupture, and non-ACLR revision surgery rates were 0% (range, 0%-7.7%), 2.7% (range, 0%-9.1%), and 7.2% (range 0%-34.4%), respectively. Commonly reported complications included pain (range, 0%-14.0%), stiffness (range, 0%-12.7%), hematoma (range, 2.5%-8.8%), neurovascular (range, 0%-41.7%), and undefined (range, 0%-13.8%). **Conclusions:** ACLR in patients over 40 years old shows low failure rates. **Level of Evidence:** Level IV, systematic review of Level II-IV studies.

Persistent controversy surrounds the treatment of anterior cruciate ligament (ACL) ruptures in individuals older than 40 years. There are reports that satisfactory outcomes can be achieved with nonoperative management of these injuries.[1,2] A recent retrospective study from Hayes-Lattin et al.[1] showed that both nonoperative and operative management of ACL rupture in patients ≥40 years had similarly high satisfaction rates at minimum 2-year follow-up. Likewise, Ciccotti et al.[2] reported an 83% overall satisfaction rate with nonoperative treatment for ACL rupture at a mean follow-up of 7 years. However, ACL reconstruction (ACLR) may be considered for older patients who intend to maintain active lifestyles, and there has been increasing evidence that this patient population can experience preoperative to postoperative improvements in outcome measures, including the subjective International Knee Documentation Committee (IKDC) score, the Knee Injury and Osteoarthritis Outcome Score, and knee laxity.[3] It has also been well established that compared to younger populations, those aged ≥40 years experience comparable symptomatic and functional improvements following ACLR[4] and that ACLR could be of benefit in this cohort.[5] However, despite these improvements following operative intervention, evidence regarding complications and failures following ACLR in this patient population is more limited.

Although uncommon, complications such as knee stiffness, objective knee laxity, ACL graft failure, and revision knee surgery may be encountered following ACLR. Previous systematic reviews and meta-analyses of studies comparing the outcomes of ACLR in older versus younger patients have concluded that older patients do not have significantly increased risks of such

From the Tufts University School of Medicine, Boston, Massachusetts, U.S.A. (J.R., M.S.) and Department of Orthopedic Surgery, Tufts Medical Center, Boston, Massachusetts, U.S.A. (R.P., M.S.).

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Address correspondence to John Roberts IV. E-mail: John.Roberts@tufts.edu

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complications.[6,7] In a recent analysis of a large insurance claims database, patients older than 50 years were found to have a significantly increased rate of experiencing short-term complications within 90 days, whereas younger patients experienced significantly higher rates of knee pain, stiffness, wound infections, and revision ACLR.[8] Additionally, differences in the definition of ACLR failure, which range from findings of knee laxity (as assessed by Lachman test, pivot shift, or side-to-side difference >5 mm)[9] to overt ACL graft rupture[10] or need for ACL revision surgery,[9] obscure our understanding of the incidence of ACLR failure. This is particularly relevant in older populations, who may be more inclined to elect for nonoperative management with activity modifications for ACLR graft rupture and thus would not be included in failure analyses based solely on need for revision ACLRs.[11] With such heterogeneity and limitations present in the current literature, the risk profile for ACLR in patients ≥40 years remains unclear.

The burgeoning demand and costs associated with ACLR in an aging population require concerted efforts to optimize the preoperative risk stratification and surgical indication processes. Improving the understanding of the risk profile of ACLR in older patients is a necessary step toward increasing the value proposition of this procedure. The purpose of this study was to review the literature reporting on complications and failure rates after primary ACLR in patients ≥40 years. We hypothesized that studies examining patients ≥40 years managed with ACLR would (1) report relatively low rates of complications and failures and (2) lack consistency in defining and/or reporting complications and failures.

Methods

Study Design

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were applied when conducting this systematic review. The study protocol was submitted for registration a priori to PROSPERO on May 14, 2021. This study is a secondary analysis of data reported in Roberts et al.[3] A research question was developed from PICOS methodology,[12] which represents population (patients over the age of 40 with ACL rupture), intervention (ACLR), comparison (nonoperative management), outcome (subjective and/or objective outcomes), and study design (randomized controlled trial, prospective cohort, retrospective cohort, case control, and case series). As this secondary analysis aimed solely to examine failures and complications associated with ACLR, nonoperative management will not be discussed further.

Search Strategy

A computerized search of electronic databases (MEDLINE, CINAHL, SportDiscus, Embase, Web of Science, and Cochrane databases) from database inception through June 1, 2021, was conducted by an experienced librarian. The Appendix details the search strategies, including the relevant search terms and keywords. The reference lists of included articles were reviewed to identify any additional publications not captured through the initial search. An extensive hand search of available literature was then conducted to identify any other potentially relevant studies.

Selection Criteria

Studies were included in this study based on the following criteria: English-language studies reporting on ACLR postoperative complications and/or failure rates in patients ≥40 years. Case reports, technical notes, studies with duplicate reporting of a patient cohort, studies using publicly available registry data, studies including revision ACLR, and studies that did not separately report outcomes for patients >40 years were excluded.

Study Selection and Data Collection

Using the Covidence platform, 2 authors (J.R., J.C.) independently screened titles and abstracts for study inclusion from the database search, while applying the a priori selection criteria during review of the articles. Full-text articles were obtained if (1) the abstract provided insufficient detail to establish eligibility or and (2) the article met criteria during the initial eligibility screening.

The 2 authors reviewed and discussed the article to reach a consensus for any instances of disagreement. For studies that passed the first eligibility screening, inclusion and exclusion criteria were again independently applied by the same 2 authors to the full text. Similarly, disagreements were resolved using a consensus method. If a consensus could not be reached, a third author (B.N.) provided consultation and conflicts were settled.

Quality Assessment

Two reviewers (J.R., A.W.), unblinded to study identifiers including "author" and "journal name," independently assessed the methodological quality of the included studies using the Methodological Index for Nonrandomized Studies (MINORS) criteria.[13] For this secondary analysis, as we sought only to evaluate complications of ACLR; there was no comparator group. Further, in assigning a MINORS score, we considered a follow-up period ≥2 years to be satisfactory for evaluation of failure rates, graft rupture, and additional long-term complications. Studies were not excluded based on their assigned MINORS score.

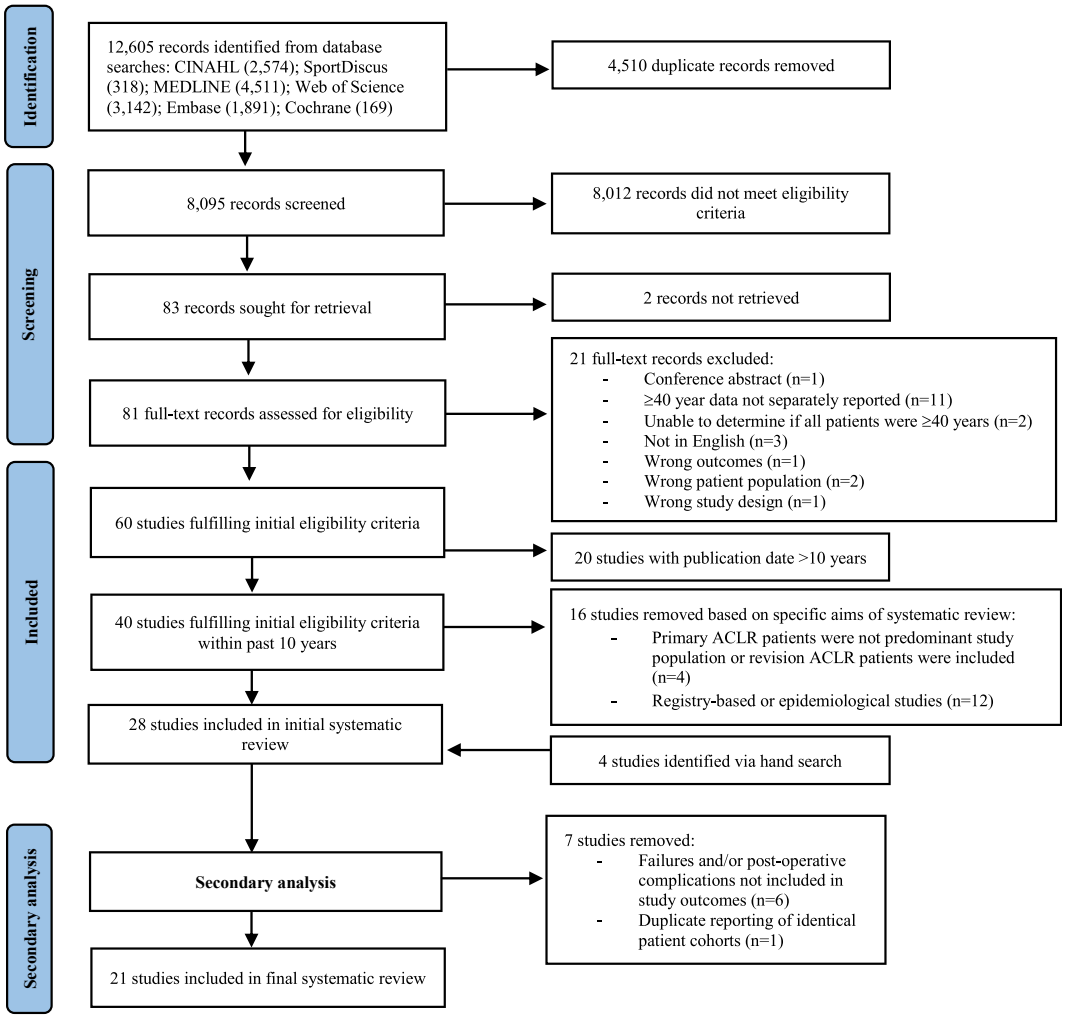

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram.

Data Extraction

Data were extracted independently for each study by 2 reviewers (J.R., M.M.), including author, year, study design, study population (age, sex), surgical descriptors, concomitant knee pathology and concomitant procedures at time of primary ACLR, definitions for ACLR failure, failure rates, graft rupture rates, revision ACR rates, revision non-ACLR rates, and complication rates. A consensus meeting was used to resolve any discrepancies. Two inferences were made during the data tabulation process to optimize and simplify the reporting of outcomes, including (1) if a patient received ACLR revision surgery, it was inferred that graft rupture necessarily occurred for that patient, even if not explicitly specified in the study, and (2) if a study explicitly reported that patients did not experience graft rupture and/or graft failure, it was inferred there were no ACLR revision surgeries as well, even if not explicitly specified in the study. In studies reporting the absence of major complications but without any explicit reference to failure, graft rupture, and/or revision surgery, we elected to make no inferences regarding these 3 postoperative complications. Further, to simplify the reporting of complication rates, we have created generalized categories, such as "neurovascular complication" and "pain," to encompass the wide range of different complications reported among the studies.

Results

In total, 12,605 citations were identified in the initial search. After removing duplicates and screening of titles and abstracts, 83 full-text studies were sought for retrieval, 2 of which were unavailable. Of those, 60 studies met the inclusion criteria upon review. Figure 1 outlines the reasons for exclusion. The number of included studies was reduced to those published within the past 10 years given prior publications from other systematic reviews.[14-16] A total of 44 studies were included. Inter-rater reliability for the title and abstract screening was k = 0.41, while full-text screening was k = 0.84.[3] This secondary analysis, which further

Table 1. Study Characteristics and Associated Meniscus Pathology

First Author, Year	Study Design (Level of Evidence)	Age Group, yr (n)	Graft (%)	Follow-up	Medial Meniscus Lesion, n (%)	Lateral Meniscus Lesion, n (%)	Bicompartmental/ Unspecified Meniscus Lesion, n (%)	Comments	MINORS
Weng, 2020[24]	Retrospective case series (IV)	≥50 (67)	Autologous: HT (100)	**30.2 mo (25-58)**	28 (41.8)	11 (16.4)	10 (14.9)/NR	Multiligament injuries excluded	11
Ovigue, 2020[19]	Retrospective case series (IV)	≥50 (75)	Autogenous: ST (77.3), STG (22.7)	**28.3 mo (24-38)**	NR	NR	NR/43 (57.3)	Multiligament injuries excluded	10
Dejour, 2021[25]	Retrospective cohort study (III)	≥50 (228)	Autograft: BPTB (13.6), HT (86.4)	**14.3 mo (6-30)**	83 (36.4)	25 (11)	46 (20.2)/NR	Concomitant grade 3 ligament injuries excluded	13
Fayard, 2019[26]	Retrospective case series (IV)	≥50 (398)	HT (68), PT (32)*	42.2 mo (19.9)	180 (45.2)	31 (7.8)	63 (15.8)/NR	Multiligament injuries excluded	7
Iorio, 2018[31]	Prospective cohort study (II)	≥50 (36)	Autograft: SGT (100)	**64 mo (60-72)**	NR	NR	NR	Severe associated ligamentous injuries excluded	13
Tay, 2018[27]	Retrospective cohort study (III)	>40 (22)	Autograft: SGT (100)	2-y follow-up (mean not reported)	NR	NR	NR/(63.6)	Multiligament injuries excluded	12
Nishio, 2018[47]	Retrospective cohort study (III)	≥40 (40)	Autograft: ST (100)	2-y follow-up (mean not reported)	NR	NR	NR/24 (60)	Combined ligament injury of PCL and LCL, posterolateral corner structures of the knee, and MCL (grade 3) excluded	10
Cinque, 2017[17]	Retrospective cohort study (III)	50-75 (33)	Autograft: BPTB (45.5) Allograft: BPTB (54.5)	**3.1 y (2-5.8)**	NR	NR	NR/31 (93.9)	Concomitant PCL injuries excluded	10
Wierer, 2017[48]	Retrospective cohort study (III)	40-60 (20)	Autograft: ST (80), STG (20)	2-y follow-up (mean not reported)	NR	NR	NR	Concomitant injuries (unspecified) excluded	10

(continued)

Table 1. Continued

First Author, Year	Study Design (Level of Evidence)	Age Group, yr (n)	Graft (%)	Follow-up	Medial Meniscus Lesion, n (%)	Lateral Meniscus Lesion, n (%)	Bicompartmental/ Unspecified Meniscus Lesion, n (%)	Comments	MINORS
Toanen, 2017[20]	Retrospective case series (IV)	≥60 (12)	Autologous: HT (100)	49.6 mo (24.0)	8 (66.7)	0 (0)	0 (0)/NR	Multiligament injuries excluded	10
Bali, 2015[21]	Retrospective case series (IV)	≥50 (55)	Autograft: BPTB (40), HT (60)	**46.2 mo (24-72)**	14 (25.5)	5 (9.1)	7 (12.7)/NR	Concomitant PCL injuries excluded	8
Figueroa, 2014[28]	Prospective case series (IV)	≥50 (50)	Autograft: HT (90) Allograft: Achilles tendon (10)	**53.17 mo (36-68)**	13 (26)	15 (30)	10 (20)/NR	Multiligament injuries excluded	10
El-Sallakh, 2014[49]	Retrospective case series (IV)	≥40 (16)	Autograft: HT (100)	NR	NR	NR	NR	Multiligament injuries, advanced OA excluded	7
Radwan, 2014[10]	Prospective cohort study (II)	>40 (OA) (23) >40 (non-OA) (19)	Autograft: SGT (100) Autograft: SGT (100)	42 mo (14) 41 mo (15)	NR NR	NR NR	NR/4 (17.4) NR/2 (10.5)	Associated ligamentous injury requiring reconstruction excluded	11
Baker, 2014[29]	Retrospective case series (IV)	≥60 (13)	Autograft: BPTB (30.8), HT (46.2) Allograft: TT or Achilles tendon (23.1)	**115.7 mo (53-193)**	8 (61.5)	3 (23.1)	1 (7.7)/NR		9
Wolfson, 2014[9]	Retrospective case series (IV)	>50 (32)	Allograft: TAT (50), PT (25), TPT (3.1), Achilles tendon (3.1) Autograft: BPTB (12.5), HT (6.3)	**5.0 y (2.2-9.0)**	NR	NR	NR		7
Conteduca, 2013[18]	Retrospective cohort study (III)	>40 (36)	Autograft: STG (100)	3.5 y (NR)	NR	NR	NR/11 (30.6)		8
Gee, 2013[22]	Retrospective cohort study (III)	≥40 (46)	Allograft: BPTB (93.5), Achilles tendon (2.2), TAT (2.2) Autograft: BPTB (2.2)	5.4 y (NR)	22 (47.8)	22 (47.8)	NR	Concomitant ligament surgery for combined injuries excluded	10
Ventura, 2012[50]	Retrospective case series (IV)	≥50 (50)	Autograft: HT (100)	**4.4 y (2-7)**	6 (12.0)	3 (6.0)	1 (2.0)/NR	Multiligament injuries excluded	8

(continued)

Table 1. Continued

First Author, Year	Study Design (Level of Evidence)	Age Group, yr (n)	Graft (%)	Follow-up	Medial Meniscus Lesion, n (%)	Lateral Meniscus Lesion, n (%)	Bicompartmental/ Unspecified Meniscus Lesion, n (%)	Comments	MINORS
Kinugasa, 2011[30]	Prospective cohort study (II)	≥50 (11)	Autogenous: ST (100)	**15.5 mo (12-20)**	7 (63.6)	2 (18.2)	NR		7
Osti, 2011[23]	Retrospective cohort study (III)	≥50 (20)	NR	*32 mo (24-49)*	8 (40)	3 (15)	NR	Multiligament injuries excluded	12

NOTE. Reported as mean (SD), **mean (range)**, *median (range)*.
BPTB, bone-patellar tendon-bone; HT, hamstring tendon; LCL, lateral collateral ligament; MCL, medial collateral ligament; MINORS, Methodological Index for Nonrandomized Studies; NR, not reported; OA, osteoarthritis; PCL, posterior cruciate ligament; PT, patellar tendon; ST, semitendinosus tendon; STG, semitendinosus and gracilis tendon; TAT, tibialis anterior tendon; TPT, tibialis posterior tendon; TT, tibialis tendon.
*Did not explicitly report if grafts were allograft or autograft.

narrowed inclusion of studies to those reporting on failures and/or other postoperative complications, identified 21 publications for review. These 21 studies subsequently underwent data extraction and were scored for methodological quality, as outlined in Table 1.

All included studies were published in the English language between 2011 and 2021 and contained data pertaining to failure and/or other complications in ACL rupture patients ≥40 years of age who underwent primary ACLR.

Demographics

The 21 included studies comprised 1,302 independent ACLRs in patients over 40 years old. The median follow-up time was 42 months (range, 14.3-115.7 months). Data regarding use of allograft versus autograft for the primary reconstruction was reported in 19 studies (90.5%); 97 patients received an allograft (11.0%). Demographic data and associated meniscus pathology are shown in Table 1.

Study Outcomes

Study outcomes pertaining to failures, graft ruptures, and revision surgeries are displayed in Table 2. The criteria for ACLR failure were explicitly defined in 4 of the included studies (19.0%).[9,10,17,18] Failure definitions varied, ranging from (1) revision ACLR,[9,17] (2) graft rupture,[9,10] (3) clinical examination of increased knee laxity,[9,18] and (4) postoperative arthrofibrosis requiring an additional surgery.[17] An additional 5 studies (23.8%) reported failure rates but provided no information regarding specific failure criteria.[19-23] The median failure rate was 5.0% (range, 0%-12.1%) among these 9 studies.

Graft rupture rates were reported in 13 studies (61.9%), with a median rate of 2.7% (range, 0%-9.1%).[9,10,17,20,22-30] Of note, Kinugasa et al.[30] performed second-look arthroscopies in ACLR patients ≥50 years at a mean follow-up of 15.5 months and found superficial tears present in 4 patients (36.4%) (who were not included as graft ruptures) and substantial tears in 1 patient (9.1%) (who was included as a graft rupture). While the study failed to explicitly comment on failure rates, clinical examination showed none to have a positive Lachman test or grossly positive pivot-shift test. Also of note, Toanen et al.[20] used a reference value of a >9-mm side-to-side difference to define complete graft ruptures. While they explicitly reported zero cases of graft ruptures at 41 months post-ACLR, 1 patient (8.3%) was found to have a side-to-side difference of 10.5 mm, which for the purposes of this review we have considered a graft rupture.

Revision ACLR rates were reported in 15 studies (71.4%). The median rate of revision ACLR was 0% (range, 0%-7.7%), and 8 of these studies had

Table 2. Failures, Graft Ruptures, and Revision Surgeries

First Author	Failure Definition	Failure, n (%)	Graft Rupture, n (%)	Revision ACLR, n (%)	Non-ACLR Revision Surgery, n (%)
Weng[24]	NR	NR	0 (0.0)	0 (0.0)	1 (1.5) (debridement for superficial infection)
Ovigue[19]	NR	NR (8)	NR	0 (0.0)	5 (6.7) (1 cyclops syndrome, 4 secondary partial meniscectomy)
Dejour[25]	NR	NR	2 (0.9)	2 (0.9)	19 (8.3) (1 hematoma, 6 pain, 9 stiffness, 3 unstable meniscal lesion)
Fayard[26]	NR	NR	6 (1.5)	6 (1.5)	51 (12.8) (10 hematoma, 1 sepsis, 11 recurrence of meniscal lesion, 16 stiffness, 13 pain)
Iorio[31]	NR	NR	NR	0 (0.0)	0 (0.0)
Tay[27]	NR	NR	0 (0.0)	0 (0.0)	0 (0.0)
Nishio[47]	NR	NR	NR	NR	NR
Cinque[17]	Any subsequent ligament surgery for graft failure or arthrofibrosis, defined as any reconstruction that required an additional lysis of adhesions	4 (12.1)	0 (0.0)	0 (0.0)	4 (12.1) (4 arthrofibrosis)
Wierer[48]	NR	NR	NR	NR	NR
Toanen[20]	NR	0 (0.0)	1 (8.3)*	0 (0.0)	NR
Bali[21]	NR	0 (0.0)	NR	0 (0.0)	NR
Figueroa[28]	NR	NR	2 (4.0)	2 (4.0)	1 (2.0) (arthroscopic debridement for infection)
El-Sallakh[49]	NR	NR	NR	NR	NR
Radwan[10]	Graft rupture	OA: 1 (2.4) Non-OA: 1 (2.4)	OA: 1 (2.4) Non-OA: 1 (2.4)	OA: 0 (0.0) Non-OA: 0 (0.0)	OA: 3 (7.1) (3 arthroscopic arthrolysis) Non-OA: 1 (2.4) (arthroscopic lateral partial meniscectomy)
Baker[29]	NR	NR	1 (7.7)	1 (7.7)	1 (7.7) (superficial wound infection requiring irrigation and debridement)
Wolfson[9]	ACL revision surgery or abnormal laxity evidenced by a 2+ Lachman, 1+ pivot shift, or greater than 5 mm side-to-side difference in the operative knee	2 (6.3)	1 (3.1)*	1 (3.1)†	11 (34.4) (3 arthroscopic lysis of adhesions, 3 arthroscopic partial medial meniscectomy, 2 removal of painful tibial hardware, 3 unspecified)
Conteduca[18]	Jerk test of 2++ or 3+++ or/and a KT-1000 side-to-side difference of >5 mm at maximum manual exertion	4 (11.1)	NR	NR	NR

(continued)

Table 2. Continued

First Author	Failure Definition	Failure, n (%)	Graft Rupture, n (%)	Revision ACLR, n (%)	Non-ACLR Revision Surgery, n (%)
Gee[22]	NR	1 (2.2)	1 (2.2)	1 (2.2)	3 (6.5) (1 arthroscopic removal of loose bodies, 1 arthroscopic lysis of adhesion, 1 arthroscopic debridement for infection)
Ventura[50]	NR	NR	NR	NR	NR
Kinugasa[30]	NR	NR	1 (9.1)*	NR	NR
Osti[23]	NR	1 (5.0)	1 (5.0)	1 (5.0)	NR

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; NR, not reported; OA, osteoarthritis.
*Presence of graft rupture was inferred, as explained in the main body of the review.
†This patient also received a concomitant partial lateral meniscectomy with removal of osteochondral loose body.

individual rates of 0%.[10,17,19-21,24,27,31] The median rate of non-ACLR revision surgery was 7.2% (range, 0%-34.4%), with reoperations occurring secondary to arthrofibrosis/stiffness or meniscal lesions being among the most common (Table 2).

A wide range of additional complications was reported in the included studies, which are presented in Table 3, with commonly reported complications including pain (range, 0%-14.0%), stiffness (range, 0%-12.7%), hematoma (range, 2.5%-8.8%), neurovascular (range, 0%-41.7%), and undefined (range, 0%-13.8%).

Discussion

In this study, we identified substantial variability in the reporting of failure and complications following ACLR in patients ≥40 years old. Reported ACLR failure rates ranged from 0% to 12.1%, with variable definitions including graft rupture, objective knee laxity, need for revision ACLR, or arthrolysis for arthrofibrosis. Revision ACLR rates ranged from 0% to 7.7%, and most studies evaluating this outcome reported rates of 0%. Non-ACLR revision surgery was a relatively common complication and was most often secondary to

Table 3. Postoperative Complications

Complication	Number of Studies Addressing Complication	Range of Complication Occurrence, %
Graft rupture*	13	0.0-9.1
Revision ACLR	15	0.0-7.7
Non-ACLR revision†	12	0.0-34.4
Major complications (undefined)‡	5	0.0
Complications (undefined)	8	0.0-13.8
Deep venous thrombosis, thromboembolic disease, or cardiopulmonary complication	8	0.0
Neurovascular complication (i.e., saphenous/peroneal nerve injury, unspecified neurovascular injury, etc.)	4	0.0-41.7
Hematoma	3	2.5-8.8
Superficial infection	4	2.4-7.7
Deep infection/sepsis	2	0.0-0.3
Infection (undefined)	7	0.0-2.2
Arthrofibrosis/knee stiffness/contracture	10	0.0-12.7
Pain (i.e., generalized, donor site, painful tibial hardware, patellar syndrome, RSD)	4	0.0-14.0
Intraoperative complications (i.e., iatrogenic cartilage injury, serious malpositioning of tunnels, graft fixation failure)	1	0.0
Fracture	1	0.0

ACLR, anterior cruciate ligament reconstruction; RSD, reflex sympathetic dystrophy.
*If a patient received ACLR revision surgery, we have assumed graft rupture necessarily occurred, even if not explicitly specified in the study.
†Specific non-ACLR revision procedures performed are included in Table 2.
‡If a study reported undefined complications, we made no further assumptions regarding those complications. If a study reported "no complications including x, y, z," we have included n = 0 for that study in "complications (undefined)" as well as n = 0 in the categories for "x," "y," "z.".

arthrofibrosis/stiffness or related to meniscal lesions/meniscectomy. Eight studies (38.1%) reported on undefined complications, which highlights the importance of explicit reporting of complications in future research studies so that both clinicians and patients can fully appreciate the specific nature of potential postoperative events following ACLR in older populations.

Various definitions of ACLR failure are used in the literature.[32] As a result, there is wide variability in the reported incidence of failure that is contingent upon the applied criteria. For example, Crawford et al.[33] previously performed a systematic review on studies reporting ACLR failure rates with 10 years of minimum follow-up. They found the ACL graft rupture rate among patients of all ages to be 6.2%. However, when including patients who experienced a "clinical failure" (overall IKDC score C or D, >2+ pivot shift, >5 mm KT arthrometer testing), the cumulative failure rate increased to 11.9%. Large database studies have previously reported failure rates for patients ≥40 years to range from 1.9% to 2.6%, but these studies exclusively defined failures as revision ACLR, which is likely a consequence of the inherent limitations of such databases.[8,34] Consequently, these studies may underestimate the failure rate, as they do not account for clinical failures defined by objective knee laxity or arthrofibrosis.[33] Our review underlines the importance of providing explicit definitions for failure by demonstrating a 0% median revision ACLR rate but an 8.7% median failure rate among studies that defined a specific criterion for failure, which included clinical failures (i.e., objective knee laxity). Such comprehensive reporting of failures following ACLR can increase transparency and may improve the discourse surrounding shared decision-making with patients.

Although the etiology of ACLR failure may be the consequence of improper surgical technique, patient characteristics and biology may largely influence the likelihood and mode of failure. In a previous analysis of 2,488 primary ACLRs (mean age, 27 ± 11 years) from the Multicenter Orthopaedic Outcomes Network, the incidence of ipsilateral ACL graft rupture was 4.4%,[35] which is within range of our reported values (median, 2.7%; range, 0%-9.1%). This prior study found a stepwise decrease in graft rupture associated with increasing age and decreasing activity level, which suggests a protective effect of lower activity demands and lifestyle modifications in older patients.[35] A 5.2 times greater risk of graft rupture with allograft compared to autograft was also observed in this study. In our current review, while substantially fewer patients (11.0%) received an allograft, we were unable to comment on the specific rupture rates according to graft type, as these data were not available in each included study.

Rates of arthrofibrosis/knee stiffness ranged from 0.0% to 12.7%, which is lower than the reported range of 7% to 26% in previous studies on patients of a younger average age.[36] Nonetheless, this finding is in concordance with the results of a recent insurance claims database study from Salesky et al.,[8] in which the rate of postoperative stiffness was significantly lower among patients ≥50 years (odds ratio, 0.79; $P < 0.001$). Prior risk factor analysis studies have identified female sex, preoperative stiffness, healing bone contusions, early surgery following injury, concomitant intra-articular procedures, and adolescent age as being associated with postoperative knee range of motion deficits.[36-38] In the total knee arthroplasty literature, younger age is a well-defined independent risk factor for postoperative stiffness, which is a consequence of an exuberant biologic response (i.e., fibroblast proliferation and tissue metaplasia).[39,40] We believe this corollary may offer an explanation as to the relatively low post-ACLR stiffness rates shown in our study and those previously published.

Regarding potentially serious postoperative complications, no patients in this review experienced a deep vein thrombosis (DVT) or pulmonary embolism (PE), and only 1 patient developed a deep infection requiring subsequent revision surgery.[26] However, only 8 (38.1%) and 2 (9.5%) of the included studies explicitly reported on these 2 classes of complications, respectively. A large database study from Cvetanovich et al.[41] previously reported symptomatic DVT requiring treatment within 30 days of ACLR to be the most common short-term complication, occurring at an overall rate of 0.55% in patients ranging from <20 years to >50 years. The study found that age was not an independent risk factor for minor or major complications following ACLR. Conversely, a more recent database study by Salesky et al.[8] reported that patients over 50 years were 1.27 times and 1.83 times more likely to experience DVT and PE compared to younger patients, respectively (DVT: 1.4% vs 1.1%, $P = .008$; PE: 0.4% vs 0.2%, $P < .001$). Schmitz et al. similarly found patients ≥40 years to have 2.3 times greater odds of developing DVT or PE and recommended considering the routine use of postoperative thromboprophylaxis in this older patient population.[42] Despite this, the American College of Chest Physicians and the American Academy of Orthopaedic Surgeons do not recommend routine thromboprophylaxis after ACLR unless patients have a known history of DVT.[43] Finally, prior research assessing deep infection rates found the incidence range among patients of all ages following ACLR to be 0.28% to 1.8%.[44,45] Patients <40 years old have also been identified as having a slightly higher risk of infection of any type.[8,46]

Limitations

There were several limitations to our current study. First, as we did not exclude studies based on low MINORS scores, we were limited by level of evidence of

the included studies, most of which were retrospective in nature. Second, it was often unclear whether the omission of reporting a particular complication suggested that patients in the study did not experience the complication, or there was merely a lack of assessing for the complication. Lastly, we do not report on subjective failures of ACLR, as our focus was on the definitions of objective failures.

Conclusions

Anterior cruciate ligament reconstruction in patients over 40 years shows low failure rates.

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Disclosures

The authors report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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Appendix

SEARCH STRATEGY

Ovid MEDLINE(R)

1. exp *anterior cruciate ligament/su
2. exp *anterior cruciate ligament reconstruction
3. exp * anterior cruciate ligament injuries/rh,su,th
4. "anterior cruciate ligament" .tw.
5. 1 or 2 or 3 or 4
6. exp young adult
7. exp child
8. 6 or 7
9. 5 not 8
10. exp lupus erythematosus, systemic or lupus.mp.
11. 9 not 10
12. Limit 11 to humans
13. 12 and "case reports".sa_pubt
14. 12 not 13
15. exp osteoarthritis
16. 14 not 15
17. exp middle aged
18. exp age factors
19. (forty or 40 or aging or older or "advanced age" or middle age*").tw
20. 17 or 18 or 19
21. 16 and 20
22. exp treatment outcome
23. lysholm knee score
24. exp joint instability
25. exp follow-up studies
26. exp range of motion, articular
27. exp treatment failure
28. exp patient outcome assessment
29. exp recovery of function
30. exp patient reported outcome measures
31. prgnosis.mp or exp prognosis
32. lever sign.mp
33. assess*.tw
34. 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33
35. 21 and 34

Embase

1. 'anterior cruciate ligament'/exp/mj OR 'anterior cruciate ligament reconstruction'/exp/mj OR 'anterior cruciate ligament injury'/exp/mj
2. 'anterior cruciate ligament':ti,ab,kw
3. #1 OR #2
4. 'non-surgical':ti,ab,kw OR nonsurgical:ti,ab,kw OR 'non operative':ti,ab,kw OR nonoperative:ti,ab,kw OR 'conservative treatment'/exp OR 'physiotherapy'/exp OR 'exercise'/exp
5. #3 AND #4
6. surgery:Ink OR rehabilitation:lnk OR therapy:Ink OR 'disease management':Ink
7. #3 AND #6
8. #5 OR #7
9. 'treatment outcome'/exp OR 'outcome assessment'/exp OR 'musculoskeletal disease assessment'/exp OR 'joint instability'/exp OR 'range of motion'/exp OR 'follow up':ti,ab,kw OR 'prognosis'/exp OR assess*:ti,ab,kw
10. #8 AND #9
11. #10 NOT lupus:ti,ab,kw OR "lupus erythematosus'/exp OR antibod*:ti,ab,kw
12. 'middle aged'/exp OR 'aged'/exp OR forty:ti,ab,kw OR aging:ti,ab,kw OR "advanced age':ti,ab,kw OR older:ti,ab,kw
13. #11 and #12

Web of Science

1. "anterior cruciate ligament or acl
2. reconstruct* or sugery or operat* or nonsurgery or nonoperative or "non surgery" or "non operative"
3. #1 AND #2
4. adult or "middle age*" or forty or 40 or aging or older or "advanced age"
5. #3 AND #4
6. child* or adolescent* or "young adult"
7. #5 NOT #6
8. prognosis or assess* outcome* or laxity or score or instability or "treatment failure"
9. #7 AND #8
10. lupus or antibod*
11. #8 NOT #9
12. "case study" or "case report"
13. #10 NOT #11"

SportDiscus

1. DE anterior cruciate ligament OR DE anterior cruciate ligament injuries OR DE anterior cruciate ligament surgery OR DE anterior cruciate ligament transplantation
2. DE physical training and conditioning OR DE compound exercises OR DE continuous training (exercise) or DE alternative medicine
3. KW nonoperative or "non operative" or nonsurgical or "non surgical" or surgery or reconstruct* or exercise or conservative
4. S2 OR S3
5. S1 and S4
6. KW prognos* or outcome* or assess* or laxity or instability or "treatment failure" or "range of motion"
7. S5 AND S6

CINAHL

1. MM anterior cruciate ligament or KW "anterior cruciate ligament" or MM anterior cruciate ligament injuries or anterior cruciate ligament reconstruction
2. KW surgery or operation or surgical procedure or surgical treatment or nonoperative or non operative or nonsurgery or non surgery or conservative treatment or conservative management
3. MH adult or aged or middle age
4. S1 AND S2 AND S3
5. S4 NOT young adult or child or adolescent or children or teenager
6. forty or 40 or aging or older or advanced age
7. AND S6
8. S7 NOT case report of case study

Ovid MEDLINE and Epub Ahead of Print, In-Process, In-Data-Review, & Other Non-Indexed Citations, Daily and Versions

1. (acl or "anterior cruciate ligament").mp.
   (reconstruct* or surgery or operat* or nonsurgery or nonoperative or "non surgery" or "non operative").mp. supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
2. 1 and 2
   (adult or "middle age*" or forty or "40" or aging or older or "advanced age").mp
3. 3 and 4
   (child* or adolescent* or "young adult").mp.

   5 not 6
   (prognosis or assess* or outcome* or laxity or score or instability or "treatment failure").mp.

   7 and 8
4. (lupus or antibod*).mp. [
5. 9 not 10
   ("case study" or "case report").mp.

   11 not 12

Cochrane Databases

1. (acl or "anterior cruciate ligament").mp. [mp=ti, ot, ab, tx, kw, ct]

PubMed

((((((((((age factors[MeSH Terms]) OR (adult[MeSH Terms])) OR (middle aged[MeSH Terms])) OR (aging [Title/Abstract])) OR (older[Title/Abstract])) OR ("advanced age"[Title/Abstract])) OR (forty[Title/Abstract])) OR (40[Title/Abstract])) AND (((((((anterior cruciate ligament[MeSH Terms]) OR (anterior cruciate ligament reconstruction[MeSH Terms]))) OR (acl [Title/Abstract])) OR (anterior cruciate ligament[Title/Abstract])) AND ((((surgery[MeSH Subheading]) OR (therapy[MeSH Subheading])) OR (nonoperative [Title/Abstract])) OR (nonsurgical[Title/Abstract]))) AND ((((((((((treatment outcome[MeSH Terms]) OR (lysholm knee score[MeSH Terms])) OR (joint instability[MeSH Terms])) OR (follow up studies[MeSH Terms])) OR (range of motion, articular[MeSH Terms])) OR (treatment failure[MeSH Terms])) OR (patient outcome assessment[MeSH Terms])) OR (recovery of function[MeSH Terms])) OR (patient reported outcome measures[MeSH Terms])) OR (laxity[Title/Abstract]))))) NOT (lupus or antibod*)) NOT (((case reports[MeSH Terms])) OR ("case report"[Title/Abstract] OR "case series"[Title/Abstract]))