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# ACL Reconstruction in Patients Aged 40 Years and Older

## A Systematic Review and Introduction of a New Methodology Score for ACL Studies

Christopher A. Brown,*† MD, Timothy R. McAdams,‡ MD, Alex H.S. Harris,§ PhD, Nicola Maffulli,‖ MD, PhD, FRCP, FRCS(Orth), and Marc R. Safran,‡ MD
*Investigation performed at Stanford University, Stanford, California*

**Background:** Treatment of the anterior cruciate ligament (ACL)–deficient knee in older patients remains a core debate.

**Purpose:** To perform a systematic review of studies that assessed outcomes in patients aged 40 years and older treated with ACL reconstruction and to provide a new methodological scoring system that is directed at critical assessment of studies evaluating ACL surgical outcomes: the ACL Methodology Score (AMS).

**Study Design:** Systematic review.

**Methods:** A comprehensive literature search was performed from 1995 to 2012 using MEDLINE, EMBASE, and Scopus. Inclusion criteria for studies were primary ACL injury, patient age of 40 years and older, and mean follow-up of at least 21 months after reconstruction. Nineteen studies met the inclusion criteria from the 371 abstracts from MEDLINE and 880 abstracts from Scopus. Clinical outcomes (International Knee Documentation Committee [IKDC], Lysholm, and Tegner activity scores), joint stability measures (Lachman test, pivot-shift test, and instrumented knee arthrometer assessment), graft type, complications, and reported chondral or meniscal injury were evaluated in this review. A new methodology scoring system was developed to be specific at critically analyzing ACL outcome studies and used to examine each study design.

**Results:** Nineteen studies describing 627 patients (632 knees; mean age, 49.0 years; range, 42.6-60.0 years) were included in the review. The mean time to surgery was 32.0 months (range, 2.9-88.0 months), with a mean follow-up of 40.2 months (range, 21.0-114.0 months). The IKDC, Lysholm, and Tegner scores and knee laxity assessment indicated favorable results in the studies that reported these outcomes. Patients did not demonstrate a significant difference between graft types and functional outcome scores or stability assessment. The mean AMS was 43.9 $\pm$ 7.2 (range, 33.5-57.5). The level of evidence rating did not positively correlate with the AMS, which suggests that the new AMS system may be able to detect errors in methodology or reporting that may not be taken into account by the classic level of evidence rating.

**Conclusion:** Patients aged 40 years and older with an ACL injury can have satisfactory outcomes after reconstruction. However, the quality of currently available data is still limited, such that further well-designed studies are needed to determine long-term efficacy and to better inform our patients with regard to expected outcomes.

**Keywords:** anterior cruciate ligament reconstruction; older patients; clinical outcomes; ACL Methodology Score

Anterior cruciate ligament (ACL) reconstruction is one of the most widely performed orthopaedic procedures in the United States, with estimates ranging from 60,000 to 175,000 per year.[37] The success rates for this procedure in younger patients range from 85% to 95%.[3] Historically, older patients with ACL ruptures have been treated nonoperatively and were urged to modify their physical activities. As a worldwide lifestyle change has occurred in people aged 45 to 70 years, the age limitation and management of ACL-deficient knees in these patients have come into question, and indications for surgery and clinical practice are changing.

Nonoperatively treated ACL-deficient knees have shown higher incidences of meniscal tears, rotational instability, articular cartilage degeneration, and posttraumatic

*Address correspondence to Christopher A. Brown, MD, Finger Lakes Bone and Joint Center and Sports Medicine, 875 Pre Emption Road, Geneva, NY 14456 (e-mail: cbrown025@gmail.com).
†Finger Lakes Bone and Joint Center and Sports Medicine, Geneva, New York.
‡Department of Orthopedics, Stanford University, Stanford, California.
§School of Medicine, Stanford University, Stanford, California.
‖Faculty of Medicine, University of Salerno, Italy, and Centre for Sports and Exercise Medicine, Queen Mary University of London, London, United Kingdom.

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arthritis.[18-20,30,40,41,55] For patients who have been willing to accept these potential risks and modify their activity level, satisfactory outcomes of nonoperative treatment have been well documented.[12,14] However, many of these patients wish to remain more active and highly value a stable knee. A decision analysis reported that surgery is an optimum treatment of ACL ruptures in patients aged 40 years and older, with an expected value of 7.99 versus 1.86 for nonoperative treatment.[56] It seems that today "the older patient" tends to be more averse to accepting the risks of nonoperative treatment and the limitations of a modified return to activity; therefore, ACL reconstructions are more frequently being considered in this age group.

Operative treatment is not without risks. Some of these risks include possible infection, deep venous thrombosis, arthrofibrosis, bleeding, graft failure, and associated surgical morbidity. Older patients are more likely to have more comorbidities, and readmission within 90 days after ACL reconstruction is more common.[37] With improved operative techniques and rehabilitation, ACL reconstruction presently produces relatively less surgical morbidity: the earlier concerns of postoperative stiffness and wound complications are thought to be less problematic today.

The uncertainty and controversy associated with the management of ACL deficiency in the older patient are likely associated with the lack of clinical evidence to support decision-making processes in this population of patients. The level of evidence rating, while important, does not take into account all areas of study design. The Coleman Methodology Score (CMS)[15] has been used to assess the quality of reporting and methodology of past reports.[52] However, many clinician-scientists have found current methodology scores insufficient and not specific enough to evaluate outcomes after ACL surgery. As a result, this study included the development and description of a new methodological scoring system that is ACL specific while using the CMS system as a foundation. A systematic review in patients older than 40 years of age undergoing ACL reconstruction was then undertaken, and the new scoring system was then implemented to be more critical of the research published to allow for a more detailed and precise decision-making process. We hypothesized that ACL reconstruction in patients aged 40 years and older who have functional instability would produce favorable outcomes but that the methodological quality of these reports would be average.

## MATERIALS AND METHODS

### Study Design

A systematic Internet search of MEDLINE (PubMed) and Scopus (which includes the content of both MEDLINE and EMBASE) electronic databases was performed for all studies of ACL reconstruction in patients with a minimum age of 40 years that were published between January 1, 1995 and the date of the search on July 28, 2012. The search was limited to 1995 because early studies would be reflective of ACL reconstructive techniques that are outmoded and not reflective of currently performed techniques. As such, limiting the search to studies after 1994 would allow for a systematic review that is more clinically relevant with techniques more similar to what are being performed currently. An experienced medical librarian repeated the search to verify a comprehensive review of the literature. The bibliographies of all included studies were then further searched for any other relevant articles. Search terms included "anterior cruciate ligament," "surgery," "outcome OR follow-up OR retrospective," and "middle-aged OR aged OR aging OR age factors."

Excluded studies included studies not in English, those that included multiligament injuries, nonclinical outcome measures, ex vivo analyses, animal studies, review articles, and studies that mixed patients younger than 40 years of age. Particular attention was placed on identifying studies that described parameters of clinical outcome after ACL reconstruction that had a midterm to long-term outcome.

The systematic search generated 371 abstracts from MEDLINE and 880 abstracts from Scopus. No additional abstracts meeting the inclusion criteria were identified with the previously described search technique. A total of 19 studies[¶] met the inclusion criteria (Table 1). From these 19 studies, data were extracted on study characteristics and design, level of evidence, demographic parameters, time from injury to reconstruction, surgical and rehabilitation protocol, meniscal and cartilage injury at the time of reconstruction, clinical follow-up, and treatment outcomes. Specific focus was placed on extracting data describing the clinical outcome variables after ACL reconstruction and knee function.

### Methodology and Level of Evidence Assessment

Level of evidence was graded based on the classification introduced by Wright et al,[65] while the CMS system[15] was used as a foundation to develop a new scoring system to evaluate the methodological quality of collected data. As the original CMS was developed to evaluate the outcomes after patellar tendon surgery, different variables were considered important in specifically studying ACL reconstruction surgery, including relative frequency of the procedure, and other validated outcome scales and measures. As a result, subscales for the CMS were modified to be more specific in evaluating outcomes and study methodology associated with ACL surgery and defined as the ACL Methodology Score (AMS) (Table 2). This score was developed through an iterative process involving discussion among experienced ACL surgeons (who are members of the ACL Study Group) and an orthopaedic surgery sports medicine fellow.

Each study was scored for each of the 10 criteria to give a total AMS between 0 and 100. A perfect score of 100 represents a flawless study design that largely avoids the influence of chance, different biases, and confounding factors. The factors included in the development of the methodology score help to reduce the influence of being underpowered and a short follow-up. Confounding variables, such as meniscal and chondral injury, surgical

[¶]References 2, 4-6, 8, 9, 16, 24, 29, 31-33, 35, 39, 51, 54, 59, 62, 63.

TABLE 1
Study Characteristics: Age, Sex, Graft Type, Time to Surgery, and Follow-up[a]

| Author | No. of Patients (No. Bilateral ACL) | Age, Mean (Range), y | Patient Sex, M:F, n | Graft | TTS, Mean (Range), mo | Follow-up, Mean (Range), mo |
|---|---|---|---|---|---|---|
| Barber et al[5] | 33 | 44 (40-52) | 19:14 | 12 BPTB autograft, 21 mixed allograft | 50 (1-373) | 21 (12-36) |
| Barber et al[4] | 11 | 46 (40-55) | N/A | BPTB allograft | 8 acute, 3 chronic | 35 (24-58) |
| Khan et al[31] | 21 | 44 (40-56) | 17:4 | HS autograft | 62 (4-360) | 24.5 (12-37) |
| Trojani et al[62] | 18 | 57 (51-66) | 6:12 | HS autograft | 11 (3-72) | 30 (12-59) |
| Marquass et al[39] | 28 | 43.5 (40-61) | 17:11 | HS autograft | 24.5 (0-168) | 30.4 (14-57) |
| Stein et al[59] | 19 | 54 (49-64) | 10:9 | Mixed allograft | N/A | 24 (9-48) |
| Barrett et al[6] | 38 | 47 (40-58) | 20:18 | 38 BPTB allograft | 24.5 (1-319) | 36.4 (24-74) |
| | 25 | 44.5 (40-54) | 15:10 | 25 BPTB autograft | 28 (1-300) | 48.4 (24-99) |
| Blyth et al[8] | 30 (1) | 54.5 (50-66) | 15:15 | 10 BPTB autograft, 21 HS autograft | 88 (2-396) | 46 (24-95) |
| Kuechle et al[35] | 47 | 45 (40.2-60.8) | 29:18 | Mixed allograft | <3 [n = 11], 3-6 [n = 15], >6 [n = 21] | 59.7 (24-110) |
| Brandsson et al[9] | 30 | 43 (40-51) | 21:9 | BPTB autograft | 36 (6-360) | 31 (22-60) |
| Viola and Vianello[63] | 11 | 42.6 (40-47) | 9:2 | BPTB autograft | 12.9 | 29 (12-42) |
| Plancher et al[54] | 72 (3) | 45 (40-60) | 42:30 | BPTB autograft | 48.5 (0.25-299) | 55 (26-117) |
| Heier et al[24] | 45 | 44.6 (40-62) | 17:28 | BPTB autograft | <3 [n = 34], >3 [n = 11] | 37 (24-96) |
| Arbuthnot and Brink[2] | 14 | 60 (55-75) | 7:7 | 9 BPTB autograft, 5 HS autograft | N/A | 114 (2-240) |
| Kinugasa et al[33] | 11 | 58.5 (50-71) | 5:6 | HS autograft | 27.4 (1-158) | 27.4 (1-158) |
| Kim et al[32] | 36 | 48.6 (41-61) | 27:9 | 10 BPTB autograft, 7 HS autograft, 9 QUAD autograft, 10 AT allograft | 8.2 (3-39) | 46.7 (27-74) |
| Dahm et al[16] | 34 (1) | 57 (50-66) | 14:20 | 23 BPTB allograft, 12 BPTB autograft | 24 (1-156) | 72 (25-173) |
| Osti et al[51] | 20 | 56 (50-62) | 12:8 | N/A | 2.87 (2.4-3.33) | 32 (24-49) |
| Javernick et al[29] | 84 | 45 (40-56) | 65:19 | HS autograft | N/A | 43 (12-72) |

[a]ACL, anterior cruciate ligament; AT, Achilles tendon; BPTB, bone–patellar tendon–bone; F, female; HS, hamstring; M, male; N/A, not available; QUAD, quadriceps; TTS, time from injury to surgery.

technique variability, and rehabilitation, are accounted for. Further, credit is given for having independent reviewers/examiners, validated outcome tools, and objective measures. Recruitment methodology and accounting for all patients initially enrolled are also factors that can influence outcomes and thus are accounted for in the AMS. Each paper was deidentified for author and affiliation and coded. Then, 4 reviewers each independently scored the articles, and a mean AMS for each paper was then calculated.

## Outcome Assessment

Credit was given to validated and objective measurement outcome tools. Functional clinical outcome measures included in the reviewed studies were the International Knee Documentation Committee (IKDC) score, Lysholm and Gillquist score, and Tegner activity score. These outcome measures are established as validated assessments of knee function.[10,11,28] According to the IKDC scale, a normally functioning knee is graded as A, a near normally functioning knee is graded as B, a fairly functioning knee is graded as C, and a poorly functioning knee is graded as D.[28] The Lysholm scale ranges from 0 to 100, with 0 representing the worst results and 100 representing optimal results.[38] The Tegner activity scale ranges from 0 to 10, with 0 representing no purposeful activity and 10 representing normal knee activity.[61]

In addition to clinical outcome scores, several parameters were also selected that provide information about knee stability. These included postoperative manual maximum side-to-side differences on arthrometry and clinical Lachman and pivot-shift testing. Stability testing was performed using a KT-1000 arthrometer device (MEDmetric Corp, San Diego, California) or the equivalent, with a manual maximum side-to-side difference of <3 mm representing normal.[17] In the Lachman test, grade 1+ is slightly increased laxity with a good end point, grade 2+ is increased translation with a delayed end point, and grade 3+ is no end point. The pivot-shift test is graded as follows: grade 0, no shift; grade I, sliding; grade II, clunk; and grade III, gross rotary laxity.

## Statistical Analysis

For the subsample of studies that reported each outcome, the mean average, range of averages, and weighted mean of the study sample size were calculated. Almost none of

TABLE 2
ACL Methodology Score System[a]

| Section | Number Factor | Score |
|---|---|---|
| **Part A:** only 1 score to be given for each of the 7 sections (55 points maximum) | | |
| 1. Type of study | Randomized control trial | 15 |
| | Prospective cohort study | 10 |
| | Retrospective cohort or case control | 5 |
| | Case series | 0 |
| 2. Study size[b] | >60 | 10 |
| | 40-59 | 7 |
| | 20-39 | 4 |
| | <20, not stated | 0 |
| 3. Mean follow-up | >24 months | 5 |
| | 12-24 months | 2 |
| | <12 months, not stated, unclear | 0 |
| 4. Number of different surgical procedures included in each | 1 surgical procedure with 1 surgical technique (tunnel position and incision), fixation, graft type, and <10% having partial meniscectomy, repair, or chondroplasty | 10 |
| | 1 surgical technique, fixation, and graft type, but no more than 25% having meniscectomy, chondroplasty, or meniscal repair | 8 |
| | No more than 2 types of surgical techniques or fixations, but 1 graft type with <10% having partial meniscectomy, repair, or chondroplasty | 6 |
| | No more than 2 types of technique or fixation, but 1 graft type but no more than 25% having meniscectomy, chondroplasty, or meniscal repair | 4 |
| | More than 2 different techniques, fixations, or graft types; or >25% of the study population undergoing additional procedure such as meniscectomy, chondroplasty, or meniscal repair; or not stated or unclear | 0 |
| 5. Description of surgical procedure given | Adequate: technique stated with all 5 of the following:<br>a. Tunnel position and type of technique used in drilling (ie, transtibial vs anteromedial portal vs over the top)<br>b. Graft type used and manner of sterilization<br>c. Type of fixation<br>d. Number and Outerbridge grade of cartilage lesion and compartment and how each treated<br>e. Number of meniscal tears, location, and how treated | 5 |
| | Fair (only a, b, and c of above) | 3 |
| | Inadequate, not stated, or unclear | 0 |
| 6. Description of postoperative rehabilitation | Well described with number of compliance reported, description of postoperative time in brace, CPM usage, advancement of range of motion and weightbearing, with description of type of physical therapy used | 5 |
| | Well described with no mention of compliance | 3 |
| | Poorly described | 0 |
| 7. Other injury included | Isolated primary ACL reconstruction in all (excluded revision, bilateral, ipsilateral ligament injuries) | 5 |
| | Primary ACL with MCL | 3 |
| | Unclear or if included revision, concomitant collateral ligament, or PCL | 0 |
| **Part B:** scores may be given for each option (45 points maximum) | | |
| 1. Outcome criteria | A. Outcome measures clearly defined: if >1 graft type used, study must report outcome difference for each graft type (if not, then = 0) | |
| | 1. Clinical stability: | |
| | KT-1000 arthrometer[c] or equivalent | 2 |
| | Clinical Lachman and pivot-shift test | 1 |
| | 2. Functional outcome score: | |
| | IKDC | 2 |
| | Tegner | 1 |
| | Lysholm | 1 |
| | 3. Return to play or sport activity | 2 |
| | 4. Report failures and complications | 2 |
| | 5. Report outcome difference in patients: | |
| | Meniscal tear | 2 |
| | Cartilage injury | 2 |
| | B. Timing of outcome assessment clearly stated at each follow-up both before and at last follow-up outcome measures for each: | |
| | Tegner | 1 |
| | Lysholm | 1 |
| | IKDC | 2 |
| 2. Procedure for assessing outcomes | Patients recruited prospectively (results not taken from surgeons' files) | 7 |
| | Investigator independent of surgeon | 5 |
| | Completion of written assessment by patients with minimal investigator assistance (used a functional outcome score with patient self-reported outcome component) | 2 |
| | Objective stability measure (KT-1000 arthrometer[c] or equivalent) | 2 |
| 3. Description of patient selection process | Recruitment rate reported:<br>a. >80% | 5 |
| | b. <80% | 3 |
| | c. <60% | 0 |
| | Eligible patients not included in the study satisfactorily accounted for or 100% recruitment | 5 |

[a]ACL, anterior cruciate ligament; CPM, continuous passive motion; IKDC, International Knee Documentation Committee; MCL, medial collateral ligament; PCL, posterior cruciate ligament.
[b]Number of ACL reconstructions in patients over 40 years of age per treatment arm.
[c]Side-to-side manual maximum difference.

TABLE 3
Reported Cartilage Findings

| Author | No. of Knees | Cartilage Status[a] |
|---|---|---|
| Barber et al[5] | 33 | 76% with chondral injury |
| Khan et al[31] | 21 | 9 grade II in patellofemoral or medial compartment |
| Trojani et al[62] | 18 | 4 with radiographic arthritis |
| Marquass et al[39] | 28 | 3 grade IV |
| Stein et al[59] | 19 | 8 grade II, 2 grade III |
| Barrett et al[6] | 63 | 31 cartilage defects |
| Blyth et al[8] | 31 | 4 grade IV, 3 grade III, 10 grade II, 8 grade I |
| Brandsson et al[9] | 30 | 11 with cartilage lesions (no grade) |
| Plancher et al[54] | 75 | 2 grade II, 2 grade III, 11 grade IV |
| Heier et al[24] | 45 | 10 cartilage defects in patellofemoral compartment, 10 in medial compartment, 4 in lateral compartment had grade III or IV |
| Arbuthnot and Brink[2] | 14 | 5 grade II cartilage defects, 3 grade IV |
| Kim et al[32] | 36 | 21 grade I, 5 grade III |
| Dahm et al[16] | 35 | 18 grade I, 19 grade II, 8 grade III, 3 grade IV |
| Osti et al[51] | 20 | 3 grade II, 4 grade III, 2 grade IV |
| Javernick et al[29] | 84 | 22 cartilage defects |

[a]Reported Outerbridge grades I to IV for cartilage lesions.

the studies reported standard deviations or standard errors, precluding the prediction of between-study variability by meta-analytic methods. One-way analysis of variance (ANOVA) was used to compare outcomes after specific graft types. Means, ranges, and standard deviations were calculated for individual studies based on the 4 aggregate scores of the independent scorers for the AMS. The reliability of this system was then calculated based on a 4-rater method to provide an associated intraclass correlation coefficient (ICC). The relationship between the AMS and level of evidence rating was tested using the Pearson coefficient of correlation ($r$) in which $P < .05$ was considered significant.

## RESULTS

### Patient and Study Characteristics

A total of 627 patients (632 knees) aged 40 years or older undergoing ACL reconstruction were identified from the 19 studies (Table 1). The mean average postoperative follow-up was 40.2 ± 22.6 months (range, 21.0-114.0 months; weighted mean average, 41.6 months). The mean number of study patients per report was 31.6 (range, 11.0-84.0). In the 18 studies reporting sex, 59% of patients were men. The mean average age at the time of surgery was 49.0 ± 6.1 years (range, 42.6-60.0 years; weighted mean 47.7 years). In the 14 studies[#] reporting the average time to surgery, the mean was 32.0 ± 23.3 months (range, 2.9-88.0 months; weighted mean average, 35.3 months).

There was heterogeneity in the type of graft used for reconstruction. In the 18 studies reporting the type of graft, 71.1% (n = 415) of the knees had an ACL autograft reconstruction. Graft choice included a patellar tendon autograft in 40.92% (n = 239), hamstring tendon autograft in 28.60% (n = 167), patellar tendon allograft in 12.33% (n = 72), Achilles tendon allograft in 1.71% (n = 10), quadriceps tendon autograft in 1.54% (n = 9), and unspecified type of allograft in 14.90% (n = 87). Fourteen studies[**] reported on the number and location of meniscal tears. Of 574 patients, 38.2% (n = 208) had a medial meniscal tear and 21.9% (n = 119) had a lateral meniscal tear at the time of surgery.

The reporting of location and grade of cartilage defects varied markedly in these reports. Cartilage abnormalities were reported in 15 studies.[††] The results on cartilage findings are summarized in Table 3.

### Clinical Outcomes

*IKDC Score.* Ten studies[‡‡] with a total of 348 patients who were available at the time of the latest follow-up included categorized IKDC results. Twenty-nine percent were scored as an A, 54.6% achieved a B, 14.7% were C, and 1.7% were D. An additional 4 studies[16,31,39,51] with a total of 104 patients reported an average IKDC score of 57.5 ± 38.2 (weighted mean, 59.6).

*Lysholm Score.* Eleven studies[§§] with a total of 413 patients who were available at the time of the latest follow-up included preinjury Lysholm scores, with a mean average of 54.8 ± 9.6 (range, 33.0-71.4; weighted mean, 56.7). Eighteen studies[‖‖] with a total of 592 patients who were available at the time of the latest follow-up included postreconstruction Lysholm scores, with a mean average of 91.1 ± 3.8 (range, 79.0-98.0; weighted mean, 91.7).

[#]References 2, 4-6, 8, 9, 24, 29, 31-33, 35, 39, 51, 54, 59, 62, 63.

[**]References 2, 5, 6, 8, 16, 24, 29, 31, 33, 35, 39, 51, 54, 59, 62.

[††]References 2, 5, 6, 8, 9, 16, 24, 29, 31, 32, 39, 51, 54, 59, 62.

[‡‡]References 6, 8, 9, 24, 32, 33, 35, 54, 62, 63.

[§§]References 2, 4-6, 8, 16, 29, 32, 33, 51, 54.

[‖‖]References 2, 4-6, 8, 9, 16, 24, 29, 31-33, 35, 39, 51, 54, 59, 63.

*Tegner Score.* Ten studies[¶¶] with a total of 314 patients who were available at the time of the latest follow-up included preinjury Tegner scores, with a mean average of 3.9 ± 1.4 (range, 1.9-7.0; weighted mean, 4.4). Twelve studies[##] with a total of 357 patients who were available at the time of the latest follow-up included postreconstruction Tegner scores, with a mean average of 4.8 ± 1.0 (range, 3.0-6.6; weighted mean, 4.8).

*Stability Testing.* Thirteen studies[a] with a total of 366 knees reported postoperative arthrometric measurements. Seventy-five percent (n = 275) had a manual maximum side-to-side difference <3 mm, 19% (n = 70) had a side-to-side difference between 3 and 5 mm, and 6% (n = 21) had >5-mm greater laxity of the reconstructed knee compared with the nonoperative control knee. Thirteen studies[b] with a total of 376 patients reported on the manual maximum side-to-side difference in translation, with a mean average of 1.5 ± 0.95 mm (range, –0.2 to 2.7 mm; weighted mean, 1.56 mm) after reconstruction. Fourteen studies[c] with 418 knees reported on postoperative Lachman results, with 75.8% (n = 317) with grade 0, 20.6% (n = 86) with grade 1, and 3.6% (n = 15) with grade 2. Thirteen studies[d] with 403 knees reported on postoperative pivot-shift results, with 78.7% (n = 317) with grade 0, 16.6% (n = 67) with grade I, 4.5% (n = 18) with grade II, and 0.2% (n = 1) with grade III.

### Graft Outcome Comparison

There were similar outcomes between graft types when studies were examined that did not mix graft type and outcomes and compared results.[e] Patients did not demonstrate a significant difference in Lysholm score ($P$ = .28), percentage with IKDC grade A ($P$ = .24), percentage with IKDC grade A or B ($P$ = .95), Tegner score ($P$ = .95), percentage with KT-1000 arthrometer measurement <3 mm ($P$ = .49), percentage with KT-1000 arthrometer measurement <5 mm ($P$ = .88), percentage with Lachman grade 0 ($P$ = .63), percentage with Lachman grade 0 or 1 ($P$ = .25), manual maximum side-to-side difference ($P$ = .55), pivot-shift grade 0 ($P$ = .51), or pivot-shift grade 0 or I ($P$ = .25) after ACL reconstruction when comparing graft type.

### Complications

Seventeen studies[f] (n = 593 patients) documented complications with regard to loss of postoperative motion, symptomatic hardware, bleeding, deep venous thrombosis (DVT), pulmonary embolism (PE), wound healing problems (including superficial infection), and graft failure. Three and one half percent (n = 21) reported loss of postoperative motion, 5.1% (n = 30) reported symptomatic hardware, 0.3% (n = 2) reported DVT, 0.2% (n = 1) reported PE, 0.5% (n = 3) reported wound healing, and 1.9% (n = 11) reported graft failure.

### AMS and Level of Evidence

Of the 19 studies, 2 studies[5,33] were rated as level of evidence II, 6 studies[6,9,33,39,51,63] qualified as level III, and 11 studies[g] were classified as level IV. Table 4 illustrates the mean AMS for each study and corresponding level of evidence rating provided by the 4 independent reviewers. For all articles reviewed in this analysis, the mean AMS was 21.8 ± 5.0 for part A and 22.1 ± 4.2 for part B, with a total score of 43.9 ± 7.2. The ICCs for the average 4 raters for parts A and B and total were 0.57, 0.57, and 0.54, respectively. There was no correlation between the classically defined level of evidence rating and the newly developed AMS ($r$ = −0.25, $P$ = .29) (Figure 1).

## DISCUSSION

Anterior cruciate ligament reconstruction is one of the most widely performed orthopaedic procedures in the United States, but the number of studies reporting on older ACL-injured patients is sparse. Many randomized controlled trials and meta-analyses examine different variables in younger patients with the inclusion of some older patients, but few solely examine the outcome in patients aged 40 years and older with ACL deficiency. In this systematic review, the results of multiple studies were combined to ascertain outcomes in this cohort from the available published literature. In general, a systematic review is dependent on several factors: was the search systematic and reproducible, was the methodological quality of the studies assessed and reported, and was the question focused and clinically relevant? In this review, the literature search was systematic, involving multiple databases, and was validated by being duplicated by an experienced librarian. The search is reproducible by the provided search methodology listed above. The quality was assessed using 2 methods: the new AMS system described in this study as well as the classically utilized level of evidence rating.[65]

It is our hope that this ACL-specific methodological scoring system can be used by readers in their assessment of prior and future ACL reconstruction reports to more rigorously and better quantify the strength of outcome studies in patients who sustain an ACL injury and to provide evidence-based care. As a worldwide lifestyle change has occurred in people aged 45 to 70 years, the age limitation and controversy of conservative versus operative management of ACL-deficient knees in these patients are therefore clinically relevant.

Nonoperative management for older patients with an ACL injury has been advocated in the past with

[¶¶]References 2, 4-6, 8, 16, 29, 31, 33, 63.

[##]References 2, 4-6, 8, 9, 16, 29, 31, 33, 39, 63.

[a]References 2, 4-6, 8, 24, 31, 35, 39, 51, 54, 59, 63.

[b]References 2, 4-6, 8, 9, 24, 31, 33, 35, 39, 54, 59.

[c]References 4-6, 8, 16, 24, 32, 33, 35, 51, 54, 59, 62, 63.

[d]References 4-6, 8, 16, 24, 32, 33, 35, 51, 54, 62, 63.

[e]References 4, 6, 9, 24, 29, 31, 33, 39, 54, 62, 63.

[f]References 2, 5, 6, 8, 9, 16, 24, 29, 31-33, 35, 51, 54, 59, 62, 63.

[g]References 2, 8, 16, 24, 31, 32, 35, 54, 59, 62.

TABLE 4
Modified AMS Result and Corresponding Level of Evidence Rating for Each Study[a]

| Author | AMS Part A, Mean | AMS Part B, Mean | AMS Total, Mean | Level of Evidence |
|---|---|---|---|---|
| Barber et al[5] | 21.25 | 20.25 | 41.50 | II |
| Barber et al[4] | 24.75 | 20.25 | 45.0 | III |
| Khan et al[31] | 18.25 | 18.0 | 36.25 | IV |
| Trojani et al[62] | 19.75 | 18.5 | 38.25 | IV |
| Marquass et al[39] | 24.5 | 18.75 | 43.25 | III |
| Stein et al[59] | 18.25 | 22.5 | 40.75 | IV |
| Barrett et al[6] | 33.50 | 24.0 | 57.50 | III |
| Blyth et al[8] | 23.0 | 27.0 | 50.0 | IV |
| Kuechle et al[35] | 13.50 | 16.25 | 29.75 | IV |
| Brandsson et al[9] | 16.5 | 24.25 | 40.75 | III |
| Viola and Vianello[63] | 25.0 | 15.0 | 40.0 | III |
| Plancher et al[54] | 25.5 | 23.0 | 48.5 | IV |
| Heier et al[24] | 23.5 | 30.75 | 54.25 | IV |
| Arbuthnot and Brink[2] | 13.75 | 19.75 | 33.5 | IV |
| Kinugasa et al[33] | 26.25 | 24.25 | 50.50 | II |
| Kim et al[32] | 23.25 | 25.5 | 48.75 | IV |
| Dahm et al[16] | 15.25 | 24.50 | 39.75 | IV |
| Osti et al[51] | 23.50 | 27.75 | 51.25 | III |
| Javernick et al[29] | 25.25 | 19.0 | 44.25 | IV |

[a]Level of evidence as described by Wright et al.[65] AMS, ACL Methodology Score.

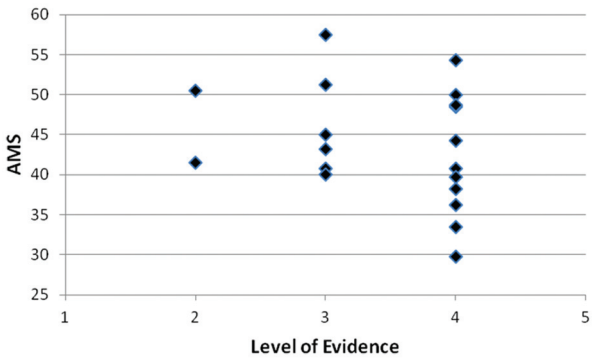


**Figure 1.** Correlation of ACL Methodology Score (AMS) and level of evidence rating.

satisfactory outcomes. Noyes et al[49] in 1983 proposed that one third of ACL-injured patients would resume their previous recreational activity without reconstruction (copers), the second third would manage by adapting their activity level to a satisfactory intensity (adapters), and the last third would require reconstruction secondary to instability episodes (noncopers). With this in mind, patients with nonoperatively treated ACL ruptures have good short-term to midterm outcomes.[47] Moreover, some reports indicate that standard physical therapy augmented with perturbation and proprioception education can potentially allow noncopers to become copers or at least improve outcomes and reduce instability episodes.[7,13,21,23,26] Regardless of mode of treatment, return to sport after an ACL injury may be limited.[48] With improved selection criteria, some authors report a decreased number of noncopers who have continued instability and require surgery, with similar outcomes when compared with those who underwent earlier reconstruction.[22,43,44] Many groups have published algorithms with this in mind with similar results.[25,34,45]

In this systematic review of patients aged 40 years and older who underwent ACL reconstruction, the mean time to surgery of 32 months may indicate that the outcomes of this study would be more applicable to the ACL-deficient patient who was not operated on acutely, potentially a noncoper with continued instability episodes. These patients may be a more difficult group to stabilize and have good outcomes in as they represent a cohort who have proven instability after injury. This current analysis of the outcome in these patients indicates that these patients had favorable outcomes with improvements in both clinical outcome measures and knee stability assessment. In the studies that report IKDC scores, 84% of the patients had normal to near normal knees after ACL reconstruction. The Lysholm score improved from a mean average of 54.8 to 91.1, while the Tegner score improved from 3.9 to 4.8. In the studies that reference arthrometry measurements, 94% of the patients showed less than 5 mm anteroposterior laxity, with a mean manual maximum side-to-side difference of 1.5 mm. Clinical laxity assessment also showed good outcomes, with nearly 86% of patients having grade 1 or less on the Lachman maneuver, while 79% had a negative pivot-shift test finding. Some of the reviewed studies compared outcome measures in these older patients to a younger cohort and indicated that results were comparable.[4,5,9,36,51]

Currently, allograft reconstruction has gained popularity in the older patient with ACL deficiency. During this systematic review, it became apparent that there was great heterogeneity in the type of graft reported. Most of the studies that used allografts did not report on specific donor ages or graft sterilization procedures, which may

affect outcomes. The majority of patients (71%) had an autograft, with bone–patellar tendon–bone (BPTB) being the dominant graft used (40.9%). Despite the potential morbidity associated with this graft in this older patient population, these patients did well with a complication rate comparable with that in younger cohorts. Comparison of studies that did not mix graft type and outcomes showed no significant differences in outcomes.[h] Only 2 studies[6,16] analyzed in this review directly compared outcomes and graft type in this age group and did not find a significant difference between allografts as compared with BPTB autografts. Barrett et al[6] did report that a trade-off may exist between the 2 grafts, with a BPTB allograft allowing for a quicker return to sporting activities, but demonstrated increased laxity despite similar functional outcome scores. While allografts and autografts have good outcomes when used in ACL reconstruction, the maximum strength of an allograft may be less than that of an autograft.[58] Additionally, an allograft takes longer to fully incorporate/reach maturity[57] and displays a slower rate of revascularization.[46] Age of the recipient may also influence graft incorporation. Older patients tend to have less revascularization of their grafts at second-look arthroscopic surgery, and rehabilitation modalities may need to be modified to prevent graft ruptures,[33] although these variables were not specifically evaluated in the studies in this systematic review.

There are some reported reservations by surgeons when considering reconstruction in an older patient with articular cartilage degenerative changes for fear of unfavorable outcomes and patient satisfaction. However, age may not affect outcome as much as the status of the articular cartilage. The degree of reporting the location and grade of the cartilage lesion varied significantly in the papers reviewed for this study. A good portion of patients had some degree of cartilage abnormality for those papers that reported on it (Table 3). Overall, knee function and stability can be achieved in patients above 40 years of age who have evidence of some degree of cartilage wear. Poorer results are, however, correlated with more advanced degenerative changes. Trojani et al[62] reported that reconstruction can restore knee stability with good patient satisfaction but that it does not modify the pain pattern in patients with a prior medial meniscectomy with articular cartilage changes in the medial compartment and preoperative medial joint pain. Kim et al[32] examined older patients who had grade III or IV articular cartilage changes and an intact meniscus at the time of reconstruction and concluded that these patients had improvements in activity-related knee pain and instability but not rest pain. In the present review, of 574 patients who had a meniscal injury, 38.2% (n = 208) had a medial meniscal tear and 21.9% (n = 119) had a lateral meniscal tear at the time of surgery. The reports following ACL reconstruction in these patients also indicate improvements in knee stability and favorable outcomes. Both of these findings are important when selecting and counseling these patients with regard to expected outcomes.

The overall occurrence of complications was only reported in 17 studies,[i] but the complication rate appears to be similar to that reported in younger patients. In this review, 3.5% (n = 21) reported postoperative loss of knee motion, 5.1% (n = 30) reported symptomatic hardware, 0.3% (n = 2) reported DVT, 0.2% (n = 1) reported PE, 0.5% (n = 3) reported wound healing, and 1.9% (n = 11) reported graft failure. In younger patients, the reported range of infection was 0.2% to 0.48%, DVT was 0.12%, and stiffness was 5% to 25%, with graft failure in autografts ranging from 1.9% to 10% and up to 34% for allografts.[1] It is likely that the patients who underwent ACL reconstruction in these comparative studies were healthier counterparts for their respective chronological age. No studies report on body mass index, American Society of Anesthesiologists score, or associated comorbidities in these patients.

In this systematic review of the literature, it became evident that current systems to rate the methodological quality of ACL reconstruction outcomes are lacking. As a result, a new methodology scoring system (AMS) was developed to objectively score ACL studies (Table 2), to both ascertain individual study design strengths and weaknesses and provide a potential system that can be used by readers in their assessment of prior and future ACL reconstruction outcome studies. With the plethora of literature being published, poor methodology has permitted biases with associated confounding variables that can affect the interpretation or significance of the data when not taken into account. Current measures to assess the level of evidence include *The Journal of Bone and Joint Surgery* level of evidence rating[50] as well as the CONSORT[42] and STROBE[64] guidelines. While these are important, they may not specifically explore study methodology, potential bias, and outcome variables that are specific to ACL surgery. A systematic survey of the quality of research reporting in general orthopaedic journals indicates a general lack of statistical rigor when assessing for compliance to CONSORT[42] and STROBE[64] guidelines.[53] The current systematic review found that the level of evidence rating did not have a positive correlation with the AMS. This would suggest that the new AMS detects errors in methodology or reporting that may not be taken into account by the classic level of evidence rating.

The CMS system is an appropriate way to examine study design.[15] Therefore, using it as a foundation and selecting individual parameters that are important to ACL outcomes, the newly developed methodology scoring system described in this article can be used to provide a better appreciation of study methodology directed at this population. The individual parameters selected to be used in this scoring method may be argued as somewhat arbitrary. However, the selected parameters are frequently quoted in the literature in the assessment of outcomes, and a panel of ACL reconstruction experts agreed on the important standards when assessing ACL reconstruction outcomes.

While the methodological score for outcomes after ACL reconstruction in patients aged 40 years and older reviewed in this study tends to be suboptimal, a comparison

[h] References 4, 6, 9, 24, 29, 31, 33, 39, 54, 62, 63.

[i] References 2, 5, 6, 8, 9, 16, 24, 29, 31-33, 35, 51, 54, 59, 62, 63.

was made using the AMS to evaluate some recent randomly selected level I prospective randomized studies on ACL outcomes. As such, the authors scored 2 recently published level I studies[27,60] and found that both of these papers were of much better quality from a methodological standpoint, confirming the responsiveness of the AMS to higher quality research yet not being subject to floor or ceiling effects.

Therefore, at a minimum, this comparison of the AMS is one example of the need for a more standard system in which physicians can better compare results after ACL reconstruction as well as in methodological study design. In the future, as more ACL-specific outcome measures are validated, they may be used in the place of some of the parameters used in this system. For example, it is possible that the IKDC will be replaced with a different lower extremity outcome measure if the evidence both supports its use and reports beginning to use it as an outcome measure. However, the majority of the articles reporting on ACL outcomes in this age group did not implement lower extremity scoring systems other than ones used in this methodological scoring system presented here. Therefore, this scoring system will hopefully help guide readers in the future when methodologically evaluating reports after ACL surgery and highlight the value of having a more ACL-specific set of criteria to better guide patient care.

## CONCLUSION

Anterior cruciate ligament reconstruction in patients aged 40 years and older with functional instability can produce satisfactory results. Meniscal and cartilage defects are commonly found and may affect functional outcomes. This study summarizes what has been published so that physicians may better counsel patients who fall within this age group. Further, a new AMS system is introduced that may be used to analyze the methodology of future ACL reports. The findings of this systematic review indicate that this new system can detect methodological flaws, biases, and confounding variables that may not be considered by the level of evidence rating. Using this methodology scoring system, it is apparent that the quality of currently published studies that report the results of ACL reconstruction in those over the age of 40 years is suboptimal. The methodological quality of the research looking at outcomes in this population is lacking, and more methodologically sound studies will need to be done to better ascertain how well this population does after ACL reconstructive surgery and to better inform our patients with regard to expected outcomes.

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