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The ACL in the Arthritic Knee: How Often Is It Present and Can Preoperative Tests Predict Its Presence?

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Abstract

Background TKA with retention of the anterior cruciate ligament (ACL) may improve kinematics and function. However, conflicting reports exist concerning the prevalence of intact ACLs at the time of TKA.

Questions/purposes Therefore, we asked: (1) what was the ACL status at TKA; (2) what was the sensitivity and specificity of the Lachman test; (3) did MRI ACL integrity correlate with intraoperative observation; (4) did MRI tibial wear patterns correlate with ACL integrity; and (5) did ACL status depend on age or sex?

Methods We evaluated 200 patients for ACL integrity at the time of TKA. All patients underwent a Lachman test under anesthesia. Intraoperatively, the ACL was characterized as intact, frayed, disrupted, or absent. In 100 patients, MRIs were performed, from which the ACL was graded as intact, indeterminate, or disrupted, and the AP location of tibial wear was categorized.

Results The ACL was intact in 155 patients (78%). The Lachman test alone had poor diagnostic ability. The MRI predicted a tear, but we observed two ACLs with indeterminate status that were disrupted. All knees with anterior wear on the medial tibial condyle had an intact ACL (n = 45), and all knees with posterior wear on the medial tibial condyle had a disrupted ACL (n = 8).

Conclusions Although the Lachman test alone had poor sensitivity, when combined with MRI they together provide a sensitivity of 93.3% and specificity of 99%, which we believe makes these reasonable tests for assessing ACL status in the arthritic knee.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at the Center for Joint Preservation and Reconstruction, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Baltimore, MD, USA, and Methodist Hospital of Sacramento, Sacramento, CA, USA.

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Introduction

Despite high long-term survival of TKA [1, 2], reported patient satisfaction remains low with studies concluding that nearly one-third of patients may not be satisfied with the procedure [8, 16, 32]. Additionally, preoperative expectations of the surgeon and the patient appear to differ [32]. This difference may be the result of the fundamental design of TKA, which originally had goals of relieving pain and restoring mobility to severely debilitated patients. As younger, more active patients demand more from their

prostheses, numerous advances in design have been attempted to increase functionality, including recent designs such as mobile-bearing and high-flexion knees. However, many patients report they feel their function is still limited by their implant [27] and as few as 7% report their knee feels normal after surgery. These low satisfaction rates and function remain problematic and may be a contributing factor for the nearly 46,000 annual reported revision TKAs [6].

Although the exact causes of this dissatisfaction have yet to be elucidated, the current generation of total knee prostheses does not adequately reproduce the complex kinematics of the native knee [3, 8, 9, 13–15, 17, 21, 24, 27–29, 34], which could lead to decreased functionality and consequently dissatisfaction. The anterior cruciate ligament (ACL) is essential in reproducing kinematic features such as femoral rollback [31, 33], screw-home mechanism [19, 22], and a normal gait [2, 10, 25]. It would seem logical, then, that a preserved ACL would improve functionality. Patients who have both a unicompartmental knee arthroplasty with the ACL retained and a contralateral TKA often prefer their unicompartmental implant [23], which might be attributed to the intact ACL. Although some early designs of TKA that retained both cruciate ligaments had excellent survivorship [4, 5, 8, 11, 12, 21], these were largely abandoned as a result of their technical difficulty and sometimes poor function [4, 5, 7, 8]. When the ACL is to be preserved in any type of arthroplasty procedure (whether unicompartmental knee arthroplasty or bicruciate-retaining TKA), one must have the necessary implants and instruments on hand. Therefore, it is important to determine the prevalence of intact ACLs at the time of arthroplasty and whether it is possible to predict its presence preoperatively.

Therefore, we prospectively evaluated 200 patients who underwent TKA and asked the following questions: (1) what was the status of the ACL at the time of arthroplasty; (2) what was the sensitivity and specificity of the Lachman test to predict its presence or absence; (3) did ACL integrity on MRI correlate with intraoperative observation; (4) did the tibial wear pattern seen on MRI correlate with ACL integrity; and (5) did ACL status depend on age or sex at the time of arthroplasty?

Patients and Methods

We prospectively evaluated 200 patients who had a primary diagnosis of osteoarthritis and were undergoing TKA by one of two high-volume joint arthroplasty surgeons (SMH, MAM) from February to August 2011. There were 113 women (56.5%) and 87 men (43.5%), who had a mean age of 66 years (range, 47–91 years), a varus/valgus deformity of 10° of less, and who had preoperative Kellgren-Lawrence changes of Grade 3 or 4. Patients were excluded if they had a history of ACL reconstruction surgery, any history of trauma to the knee requiring operative treatment, a history of osteotomy or other realignment procedure, or any other implanted hardware visible on preoperative radiograph. All patients were evaluated preoperatively and intraoperatively to assess ACL integrity, determine the efficacy of the Lachman test in predicting its integrity, and assessing the ability of MRI to predict ACL integrity and correlate with tibial wear patterns. We obtained appropriate institutional review board approval for this study.

Preoperatively, all patients had a Lachman test performed on physical examination by the senior surgeon (SMH, MAM). The examination was performed after induction of anesthesia and before incision, at which time an anterior force was applied to the posterior aspect of the tibia while the knees was flexed at 20° to 30°. This was graded as 1+ (0–5 mm of displacement), 2+ (5–10 mm of displacement), or 3+ (greater than 10 mm of displacement) [34]. The test was only performed by a single surgeon, so we could not evaluate interobserver variability; however, the test has previously been identified as having high reported interobserver reliability of 0.77 in a prior report [35]. We considered either 2+ or 3+ as indicating ACL instability.

Intraoperatively, all ACLs were visually graded as intact, frayed, disrupted, or absent. Frayed ACLs were distinguished from intact ACLs by any visual appearance of degeneration. ACLs were characterized as disrupted if there was some portion of the ligament present and absent ACLs had no visual sign of the ligament present at the time of arthroplasty.

Of the 200 TKAs, 100 had preoperative MRIs performed. We compared these imaging studies with intraoperative findings and used these to assess the ability of MRI to predict the integrity of the ACL at the time of TKA. All MRIs were taken with 2-mm slices and no gaps with the coronal plane oriented perpendicular to the flexion-extension axis of the knee. Images were assessed for ACL integrity and tibial cartilage wear.

One of us (SMH) graded all of the ACLs on MRI in a blinded manner as intact, indeterminate, or absent when viewed in the oblique viewing plane, which has a high reported interobserver reliability [26, 30]. An intact ACL had normal volume, was observed with a normal course from the femur to tibia, and had consistent low signal intensity over its entire length (Fig. 1A). The ACL was considered indeterminate if the volume and course were normal but there was increased signal intensity on T1-weighted imaging (Fig. 1B). The ACL was considered absent if there was no ACL present on MRI, the ACL was

Fig. 1A–C Sagittal T1-weighted MR images demonstrating the grading system for ACL integrity before TKA. The ACL was graded as intact (**A**) when there was normal ACL volume, the ACL had a normal course from the tibia to femur, and there was consistently low signal intensity through its entire length. The ACL was graded as indeterminate (**B**) if there was normal volume and course but increased signal intensity on T1-weighted imaging. Finally, the ACL was graded as absent (**C**) if the ACL was missing or had both increased signal intensity and decreased volume. Reproduced with permission from Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Inc.

present but had an abnormal course, or if there was decreased volume with increased signal intensity on T1-weighted images (Fig. 1C). When determining sensitivity and specificity of this test to predict the integrity of the ACL, the ACL was considered present if the MRI was graded as either intact or indeterminate. The same observer measured tibial wear on the preoperative MRI, which was correlated with MRI findings by another of the authors (AJJ). This was observed for both the medial and lateral sides of the tibia and was classified as anterior, central, or posterior for each. Wear was classified as anterior when decreased cartilage thickness was observed in the anterior 50% of the tibia (Fig. 2), posterior when decreased cartilage thickness was observed in the posterior 50% of the tibia (Fig. 3), and central when there was no bias to anterior or posterior observed in the areas of decreased cartilage thickness (Fig. 4).

Demographic data including age, sex, and body mass index were collected and compared between the two cohorts to determine if there was any difference between the patients who had an intact ACL and those who did not.

Sensitivity, specificity, positive predictive value, and negative predictive value calculations were performed for each of the tests described. For these calculations, the ACL was considered present if it was graded as intact or frayed intraoperatively and was considered not present if it was graded as disrupted or absent. Additionally, the specificity of parallel screening of ACL integrity by two or more tests was calculated where appropriate. Additionally, a 95% confidence interval was reported for all proportions. Continuous variables (eg, age, body mass index) were compared using a Student's t-test. We collected all data and analyzed them in a database (JMP 8; SAS Institute, Inc, Cary, NC, USA).

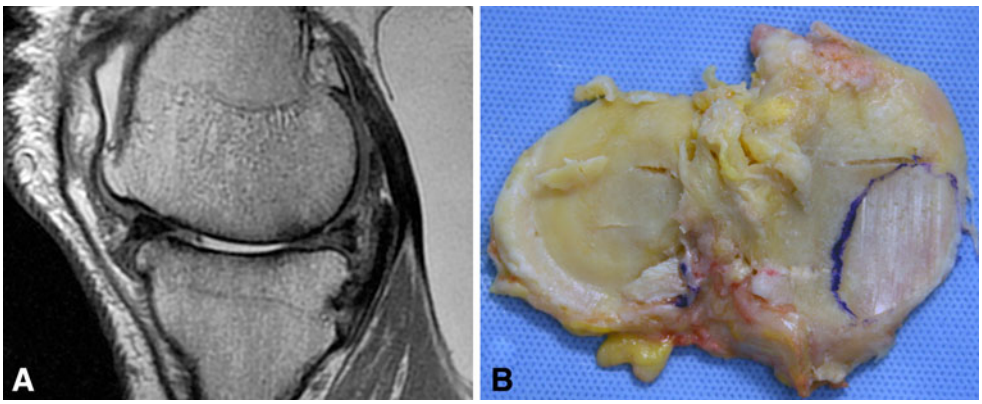

Fig. 2A–B Anterior tibial wear (anterior side of specimen at bottom of photograph) with decreased cartilage thickness in the anterior half of the tibia in both MRI (**A**) and illustrated in intraoperative photographs (**B**). Reproduced with permission from Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Inc.

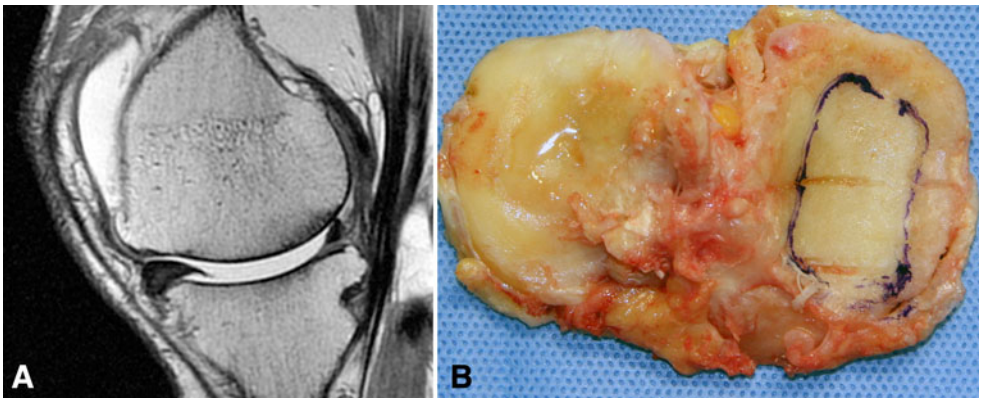

Fig. 3A–B Posterior tibial wear seen with decreased cartilage thickness in the posterior half of the tibia in both MRI (**A**) and illustrated in intraoperative photographs (**B**). Reproduced with permission from Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Inc.

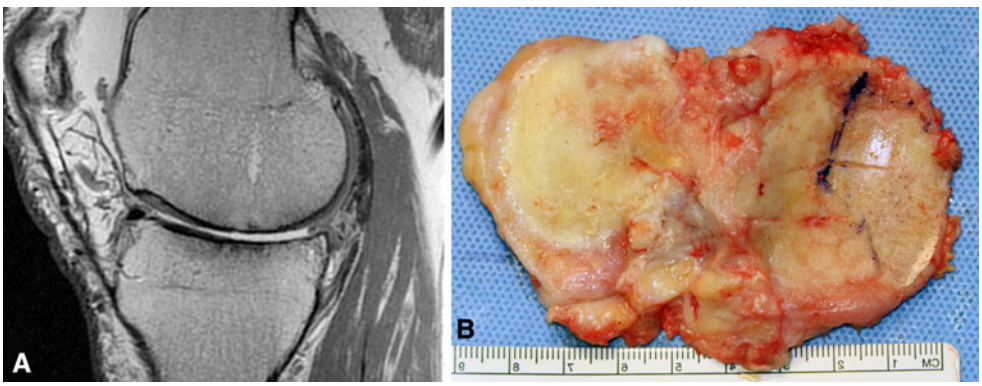

Fig. 4A–B Central tibial wear seen with decreased cartilage thickness with no bias toward anterior or posterior on MRI (**A**) and as illustrated in intraoperative photographs (**B**). Reproduced with permission from Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Inc.

Table 1. Results of intraoperative ACL integrity, Lachman test, and MRI ACL integrity

Results of integrity or Lachman test	Number	Percentage	95% confidence interval
Intraoperative ACL integrity			
Intact	96	48	41–55%
Frayed	59	30	24–36%
Disrupted	18	9	6–14%
Absent			
Lachman test			
Positive	16	8	5–13%
Negative	194	92	87–95%
ACL integrity on MRI			
Intact	69	69	59–77%
Indeterminate	14	14	8–22%
Disrupted	17	17	14–26%
Tibial wear			
Anterior wear (medial condyle)	45	45	36–55%
Posterior wear (medial condyle)	8	8	4–15%

ACL = anterior cruciate ligament.

Results

The ACL was intact in 155 specimens (78%); the remaining ACLs were disrupted or absent (Table 1). In the 100 knees that had MR scans performed, the overall incidence of an intact ACL was 81%.

The sensitivity and specificity of the test were calculated to be 33% and 99%, respectively, with a positive predictive value of 94% and a negative predictive value of 84%. Of the 16 positive Lachman tests, 15 had absent or disrupted ACLs (94%; 95% CI, 70%–100%).

Of the 100 knees that had preoperative MR scans performed, 69 were graded as intact, 14 were graded as indeterminate, and the remaining 17 were graded as disrupted. With indeterminate results considered intact, the sensitivity and specificity were calculated to be 90% and 100%, respectively. The positive predictive value was 100% (for prediction of disrupted or absent ACL), and the negative predictive value was 98% (for prediction of an intact ACL). When combined in parallel with the Lachman test, the sensitivity and specificity of these two combined tests were 93.3% and 99%, respectively.

These same 100 knees had tibial wear measured on sagittal MR images, demonstrating anterior wear on the medial tibial condyle in 45 knees and posterior wear on the medial tibial condyle in eight knees. All 45 patients who had anterior wear had an intact ACL, and all eight patients who had posterior wear had a disrupted or absent ACL.

Table 2. Demographic differences between patients who had an intact ACL and those who did not have an intact ACL

Demographic factor	Intact ACL [mean (range)]	No intact ACL [mean (range)]	p value
Age (years)	59 (31–83)	53 (41–66)	0.04
Body Mass Index (kg/m^2)	34 (19–55)	33 (22–52)	0.001
Preoperative ROM (degrees)	104 (90–20)	101 (85–110)	0.001

ACL = anterior cruciate ligament; ROM = range of motion.

There was no correlation between any other wear patterns and ACL integrity.

The patients who had an intact ACL at the time of surgery were older ($p = 0.04$) than those who did not have an intact ACL (Table 2). The mean body mass index for the ACL-intact and no intact ACL cohorts was 34 kg/m^2 (range, 19–55 kg/m^2) and 33 kg/m^2 (range, 22–52 kg/m^2), respectively (Table 2).

Discussion

Because of patient dissatisfaction, function limitations, and impaired kinematics of the knee after TKA, future implant designs may attempt to retain the ACL in an effort to improve any or all of these metrics. For these prostheses to be effective, however, there should be an intact ACL present at the time of arthroplasty. The current literature has variable reports of the presence of the ACL at the time of surgery [10, 12, 17, 20, 21, 24]. Additionally, because of arthritic degeneration such as joint space narrowing and osteophytic changes at the joint, it may be difficult to assess the ACL preoperatively by physical examination. Consequently, we designed this prospective study to observe and assess the following questions: (1) what was the incidence of an intact ACL at the time of TKA; (2) what was the sensitivity and specificity of the Lachman test; (3) what was the sensitivity and specificity of a preoperative MRI to detect the presence of an intact ACL; and (4) was tibial wear on MRI predictive of ACL integrity?

There were several limitations to this study. First, although we assessed the presence of the ACL, there was no assessment of how functional the ACL was. For example, even if the ACL is present, it may not be biomechanically able to function well after a TKA. Future studies could potentially assess the tensile strength of these intact ACLs to determine if there is a structural difference between intact and frayed-appearing ligaments. A prior study by Hagena et al. concluded that ACLs from osteoarthritic knees have different tensile and viscoelastic properties than healthy adults [18] but did not evaluate the

spectrum of properties within the ACLs from osteoarthritic knees. However, even if the ligament is structurally compromised, there remains potential for the proprioceptive function alone to improve knee kinematics. Another potential future study would be to assess the histologic characteristics of the ACL to determine if there is a correlation between the visual appearance of the ligament and any pathologic degradation of the cellular structure. Additionally, the Lachman test is a subjective test that may have interobserver reliability issues. Similarly, the ability to differentiate between intact and disrupted on an MRI may be subject to a specific observer's experience level. However, we believe that by combining tests, the likelihood of incorrectly identifying the ACL status will be mitigated. As a result of the cost of MRIs, future studies may also be able to correlate specific radiographic changes with ACL integrity; when combined with a physical examination finding such as the Lachman test, this may be sufficient to screen for ACL integrity in specific patient populations. Furthermore, reporting positive and negative predictive values is dependent on the incidence of a condition within a given population. Because one of the purposes of this study was to assess the prevalence of ACL integrity in arthritic knees, and because our prevalence of an intact ACL was consistent with previously reports, we believe that despite a sample size of only 200 knees (which is small in relation to the greater than 500,000 TKAs performed annually), the values calculated here may be consistent with the actual values for positive and negative predictive values for these tests.

Visual assessment in this study was used as the gold standard by which the various tests were assessed for sensitivity and specificity. Prior reports have suggested the ACL is intact in anywhere from 25% to 86% of patients undergoing TKA (Table 3) [10, 12, 17, 21, 24]. The current study is consistent with the previous reports of ACL integrity. Of note, there were two studies that reported an incidence of intact ACLs of less than 50% at the time of arthroplasty. The first is a study by Cloutier et al. [12] of 110 TKAs that were implanted between 1977 and 1980 with only 25% of the ACLs reported intact. The low incidence may be reflective of a different patient population that underwent TKA 30 years ago. The second report, by Jenny and Jenny [21], reports on the results of a bicruciate-retaining prosthesis in which 25% of knees had intact ACLs. The other 75% of the knees that had weakened or absent ACLs had ACL reconstruction performed before arthroplasty. However, they do not report how many of these had a weakened ACL. Therefore, the actual number of intact ACLs at the time of arthroplasty may be much higher than 25%. This emphasizes the necessity of determining the structural integrity of what we observed to be frayed ligaments to better assess their ability to provide structural support for an ACL-retaining prosthesis. Prior work has evaluated the histologic qualities of the ACL in arthritic knees [13]. Cushner et al. [13] reported on a series of 19 ACLs harvested at the time of TKA and graded the amount and quality of degradation observed histologically. They found that nearly half of the ACLs present (47%, nine of 19 ACLs) had some sort of degenerative changes. However, it is unknown how this degeneration affects either the structural or proprioceptive function of the ACL.

Table 3. Reported incidence of intact anterior cruciate ligament at the time of TKA

Authors	Year	Number of knees	Percent intact ACL
Cloutier [10]	1983	110	43
Harman et al. [20]	1998	143	75
Jenny and Jenny [21]	1998	125	25
Cloutier et al. [12]	1999	204	80
Lee et al. [24]	2005	107	71
Dodd et al. [17]	2010	50	86
Current study	2012	200	78

ACL = anterior cruciate ligament.

Two physical examination tests that are commonly used to assess ACL integrity are the Lachman and pivot shift tests. The Lachman test is reportedly not useful for diagnosing ACL deficiency in arthritic knees [17]. In a study by Dodd et al. [17], 50 knees that underwent TKA (seven of which were ACL-deficient) had pivot shift tests performed under anesthesia before surgery. None of the ACL-deficient knees had a positive pivot shift test, which the authors reported was consistent with the degenerative changes found in osteoarthritic knees. Because of this, we did not assess the pivot shift test in our study and instead focused on the Lachman test, which is typically used to test the degree of ACL laxity [34]. We found that this test had some efficacy in diagnosing ACL deficiency. However, the sensitivity was low (33%), which made it unsuitable as a single test sufficient to diagnose ACL deficiency in the arthritic knee. It is notable that 33% of ACL-deficient knees had a positive Lachman, indicating that when the Lachman test is positive, it is a strong indicator for ligament deficiency. However, no conclusions should be made as to the integrity of the ACL if the test is negative.

We found no prior reports that specifically focus on ACL integrity as seen on MRI in the arthritic knee. The sensitivity and specificity found in our study were both high, at 90% and 100%, respectively. The sensitivity was not higher because there was a portion of the imaging studies in which the ACL was not clearly intact or disrupted (Fig. 1B). Of these 14 indeterminate reads, 12 had an intact ACL. However, when used in conjunction with

the Lachman test, the combined sensitivity and specificity of these two was 93.3% and 99%, respectively, indicating that the combination of Lachman and MRI are excellent in predicting the presence or absence of an ACL in the arthritic knee.

Tibial wear predicted ACL integrity in 45% of knees that had MRIs. Harman et al. [20] report on a series of 143 TKAs with similar conclusions. Although tibial cartilage wear did not appear to be useful in the diagnosis of ACL integrity, the findings of our study are consistent with prior reports on the tibial cartilage wear.

We found 78% of osteoarthritic knees that underwent TKA had an intact ACL. The Lachman test alone had poor diagnostic ability. The presence of an ACL on MRI generally predicted an intact ACL at surgery, but 14% of ACLs with an indeterminate status on MRI were in fact disrupted. Although anterior and posterior wear on the medial tibia can help predict the intraoperative integrity of the ACL, it only correlated with a tear in roughly half of the knees. The Lachman test and MRI together provide a sensitivity of 93.3% and specificity of 99%, which indicate useful diagnostic ability when these two tests are combined.

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