**Original Article**

# Increasing Patient Age, Ambulatory Surgery Center Setting, and Surgeon Experience Are Associated With Shorter Operative Duration for Anterior Cruciate Ligament Reconstruction

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**Purpose:** To identify variables associated with operative duration and intraoperative or perioperative complications after primary anterior cruciate ligament reconstruction (ACLR). **Methods:** Surgeons who performed a minimum of 20 arthroscopic cases per month were recruited for participation through the Arthroscopy Association of North America from 2011 through 2013. All participants agreed to voluntarily submit data for 6 months of consecutive knee and shoulder arthroscopy cases. Only subjects coded for ACLR were analyzed, whereas revision cases were excluded. ACLRs were subdivided into isolated ACLR, ACLR with minor concomitant procedures, and ACLR with major concomitant procedures. Patient, surgeon, and surgical variables were analyzed for their effect on operative duration and complications. **Results:** One hundred thirty-five orthopaedic surgeons participated, providing 1,180 primary ACLRs (399 isolated ACLRs, 441 ACLRs plus minor procedures, and 340 ACLRs plus major procedures). Most surgeons were in private practice (72.8%). Most patients were male patients (58.8%), and the mean body mass index (BMI) was 26.2 ± 5.1. The overall mean operative duration was 95.9 ± 42.0 minutes (isolated ACLRs, 88.4 ± 36.8 minutes; ACLRs plus minor concomitant procedures, 90.1 ± 37.6 minutes; and ACLRs plus major concomitant procedures, 118.5 ± 112.4 minutes; $P < .001$). Patient age was inversely correlated with operative duration ($\rho = -0.221$, $P < .001$). Surgical procedures performed in an ambulatory surgery center had a shorter mean operative duration (91.5 ± 40.4 minutes) compared with those performed in a hospital setting (105.0 ± 43.8 minutes, $P < .001$). There were 22 intraoperative and 47 early postoperative complications, with the most common being deep vein thrombosis (n = 15). Surgical volume (knee arthroscopy cases per month) correlated inversely with operative time

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($\rho = -0.200$, $P = .001$) and complication rate ($\rho = -0.112$, $P < .001$). Patient BMI was associated with increased odds of early postoperative complications on multivariate analysis (odds ratio, 1.060; $P = .044$; 95% confidence interval, 1.002-1.121). **Conclusions:** Increasing patient age, private practice, ambulatory surgery center setting, and surgeon experience are associated with a shorter operative duration for ACLR. Although an increasing number of arthroscopic knee procedures performed by surgeons correlated with fewer complications, only increasing patient BMI significantly predicted odds of complications. **Level of Evidence:** Level IV, prognostic case series.

Anterior cruciate ligament reconstruction (ACLR) is one of the most commonly performed orthopaedic procedures, with over 130,000 procedures reported annually in the United States.[1-3] Advances in health care policy and reimbursement for care have continued to emphasize the quality, safety, and efficacy of treatments, with a more recent push to maximize value through models such as reference-based benefit designs.[4] This, in part, entails optimizing operating room times to provide high-quality surgical care efficiently, given that operating room time constitutes a significant portion of hospital bills.[3,5,6] A recent study using the State Ambulatory Surgery and Services Database found that time spent in the operating room increased the cost of ACLR by $108 per minute.[6] Increased operative duration has been associated with adverse events after orthopaedic surgery, including infection and unplanned hospital admission.[7-13] One avenue for decreasing operative duration while maintaining a high standard of care has been the transition of outpatient procedures to specialty ambulatory surgery centers (ASCs). Most arthroscopic surgical procedures are now performed in ASCs, often specifically designed to facilitate efficient surgical care, minimize costs, and mitigate the risk of perioperative complications.[14,15] It has previously been reported that several variables are associated with decreased operative time and increased efficiency and safety, including working with the same operating room team,[16,17] involvement in a fellowship training program,[18] and use of an ASC.[14]

Few studies have evaluated patient, surgeon, and surgical setting variables associated with operative duration and acute complications in patients undergoing arthroscopically assisted ACLR. In a study using the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database, Cooper et al.[3] found that obesity was associated with longer operative times and increased 30-day readmission rates in patients undergoing ACLR. Furthermore, they reported that male sex, black race, and younger age were associated with increased operative duration. More recently, a study using the NSQIP database that included 14,159 isolated ACLRs found that the patient variables of male sex, age of 18 to 30 years, and nondiabetic status were correlated with longer operative durations. The authors also noted that 15-minute increases in operative duration were associated with higher risks of deep vein thrombosis, sepsis, surgical-site infection, readmission, and extended length of stay.[19] Owing to the nature of the database, variables including practice setting, surgeon volume, and surgeon training background could not be analyzed.

The purpose of our investigation was to identify variables associated with operative duration and intraoperative or perioperative complications after primary ACLR. Our hypothesis was that surgeon-related variables of higher knee arthroscopy case volume, access to an ASC, and additional sports medicine or arthroscopy subspecialty training would be associated with a decreased mean operative duration and a decreased acute complication rate for ACLR.

## Methods

This study received institutional review board exemption status. Board-certified orthopaedic surgeons who performed a minimum of 20 arthroscopic cases (knee and/or shoulder) per month were recruited via email for participation in the database through the Arthroscopy Association of North America (AANA) societal membership registry, as well as at AANA meetings. It was not a requirement to be an AANA member to contribute cases. Data were prospectively collected from 2011 through 2013 and were surgeon reported. All participants agreed to voluntarily submit 6 months of consecutive knee and shoulder arthroscopy cases, as well as short-term follow-up regarding those cases at 2, 4, and 6 weeks postoperatively. All deidentified data were entered electronically through an online portal. Surgeon demographic characteristics collected included number of knee and/or shoulder arthroscopy cases per month, number of years in practice, practice setting (academic, private, or military practice), and sports medicine or arthroscopy fellowship training status. Patient demographic data collected included age, sex, body mass index (BMI), tobacco use, diagnosis of diabetes mellitus, and previous surgery on the operative extremity. Treatment variables collected included anesthesia type, tourniquet use, tourniquet time, tourniquet pressure, operative duration (from surgical incision to complete skin closure), intraoperative complications, concomitant procedures, postoperative weight-bearing status, and surgical setting (ASC vs hospital). Graft choice was not reliably reported in the database and therefore was not analyzed. Only subjects who underwent arthroscopically assisted ACLR (Current Procedural Terminology code 29888) were analyzed. Revision ACLR cases were excluded.

For analyses, primary ACLRs were categorized into isolated ACLR, ACLR plus minor concomitant procedures, and ACLR plus major concomitant procedures. A minor concomitant procedure was defined as an additional procedure alongside ACLR that did not alter a patient's weight-bearing status or rehabilitation. Minor concomitant procedures were defined as follows: lateral release or retinacular lengthening, partial meniscectomy, synovectomy, chondroplasty, and loose body removal. Procedures requiring additional instrumentation or tissue repair were defined as major concomitant procedures. A full list of concomitant procedures is presented in Table 1.

### Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics Software (version 26; IBM, Armonk, NY). Spearman rank-order correlation was used to measure strength and direction of correlation of operative duration, a continuous variable, with various ordinal and nominal variables. Analysis of variance was used to compare mean operative duration between 3 or more continuous variables with post hoc analysis using the Fisher least significant difference test when appropriate. The $\chi^2$ test of homogeneity was used to compare complication rates between isolated ACLRs, ACLRs plus minor concomitant procedures, and ACLRs plus major concomitant procedures. The Fisher exact test was used to determine whether there were associations between dichotomous variables. Multivariate regression was used to identify variables independently predictive of longer operative duration and increased odds of complications. The level of statistical significance was set at $P < .05$.

## Results

In total, 135 orthopaedic surgeons participated in this investigation and contributed data for 11,180 cases, including 1,305 ACLRs. Of these ACLRs, 1,180 were primary ACLRs, with 399 isolated ACLRs, 441 ACLRs plus minor concomitant procedures, and 340 ACLRs plus major concomitant procedures. Most patients were male patients (58.8%), and the mean BMI of the patients in the cohort was 26.2 ± 5.1. Complete patient demographic characteristics can be found in Table 1. Most cases (70.6%) were performed in an ASC. Complete surgeon demographic characteristics and operative setting information can be found in Table 2.

### Patient and Intraoperative Parameters

The overall mean operative duration was 95.9 ± 42.0 minutes (isolated ACLRs, 88.4 ± 36.8 minutes; ACLRs plus minor concomitant procedures, 90.1 ± 37.6 minutes; and ACLRs plus major concomitant procedures, 118.5 ± 112.4 minutes; $P < .001$). Patient age was negatively correlated with operative duration ($\rho = -0.221$, $P < .001$). Female sex ($\rho = -0.009$, $P = .779$), smoking status ($\rho = 0.025$, $P = .432$), and diabetes mellitus status ($\rho = -0.0049$, $P = .127$) did not correlate significantly with operative duration. Increasing BMI also did not have a significant correlation with operative duration ($\rho = 0.008$, $P = .757$). The mean tourniquet time for all procedures was 70.6 ± 29.2 minutes, with a mean pressure setting of 283.8 ± 34.90 mm Hg. Tourniquet pressure was inversely correlated with operative time, but the correlation did not reach the level of significance ($\rho = -0.072$, $P = .057$). Surgery in a hospital setting (105.0 ± 43.8 minutes) as opposed to an ASC setting (91.5 ± 40.4 minutes; $\rho = 0.077$, $P < .001$) and the presence of intraoperative complications (Spearman $\rho = 0.077$, $P = .016$) were significantly correlated with a longer operative duration.

### Surgeon Parameters

Private-practice surgeons showed a significantly shorter mean operative duration (88.3 ± 38.7 minutes) than military surgeons (121.7 ± 28.7 minutes, $P = .001$) and academic surgeons (124.5 ± 45.6 minutes, $P < .001$). Sports medicine or arthroscopy fellowship-trained surgeons showed a shorter mean operative duration (94.7 ± 43.0 minutes) than orthopaedic surgeons without sports medicine or arthroscopy fellowship training (101.0 ± 37.2 minutes), but this did not reach the level of significance ($P = .532$). The number of knee arthroscopy cases per month was inversely correlated ($\rho = -0.200$, $P < .001$) with operative duration. Specifically, surgeons who performed more than 20 knee arthroscopy cases per month had shorter operative durations than those who performed 20 knee arthroscopy cases per month or fewer ($\rho = -0.117$, $P = .001$). The number of years in practice was also inversely correlated with operative duration ($\rho = -0.267$, $P < .001$). A complete breakdown of variables correlated with operative duration can be found in Table 3. On multivariate linear regression analysis, only younger patient age, fewer years in practice of the surgeon, and presence of concomitant procedures were significantly associated with increased operative duration (Table 4). ASC setting showed a correlation with operative time, but this did not reach the level of significance on multivariate analysis.

### Intraoperative and Postoperative Complications

There were 22 reported intraoperative complications (1.9%), consisting of instrument breakage (n = 8), implant breakage (n = 6), implant pullout (n = 6), suture breakage (n = 1), and meniscal cinch suture failure (n = 1). Factors correlated with intraoperative complications are presented in Table 5.

Forty-seven postoperative complications were reported in 42 patients (4.0%). Deep vein thrombosis was the most commonly reported complication (n = 15), followed by persistent sensory deficit (n = 7), infection (7), arthrofibrosis or stiffness (n = 6), bleeding (n = 6), skin or wound healing issues (4), atelectasis (1), and pulmonary embolism (n = 1). There were no deaths. The early postoperative complication rate was 5.0% in the cohort undergoing isolated ACLR versus 3.2% in the group undergoing ACLR plus minor concomitant procedures and 2.4% in the group undergoing ACLR plus major concomitant procedures. These differences were not significant ($P = .130$). On multivariate analysis, the only factor significantly predictive of increased odds of postoperative complications was increasing patient BMI (odds ratio, 1.060; $P = .044$; 95% confidence interval, 1.002-1.121) (Table 6).

**Table 1.** Patient Demographic Characteristics and Treatment Data

| Variable | Data |
|---|---|
| Total patients | 1,180 |
| Sex, n (%) | |
| Male | 694 (58.8) |
| Female | 486 (41.2) |
| Median patient age bracket (range), yr | 26-30 (10-70) |
| Body mass index, mean ± SD | 26.2 ± 5.1 |
| Diabetic status, n (%) | 11 (0.1) |
| Active tobacco smoker, n (%) | 85 (7.2) |
| Previous surgery on operative extremity, n (%) | 79 (6.7) |
| Anesthesia, n (%) | |
| General | 1,152 (98.2) |
| Local | 31 (2.6) |
| Spinal | 23 (1.9) |
| Combined | 28 (2.3) |
| Pre-emptive peripheral nerve block | 807 (68.7) |
| Not reported | 5 (0.4) |
| Isolated ACLR, n (%) | 399 (33.8) |
| ACLR plus minor concomitant procedure,* n (%) | 441 (37.4) |
| Lateral release | 4 |
| Loose body removal | 11 |
| Synovectomy | 24 |
| Chondroplasty | 90 |
| Meniscectomy | 389 |
| ACLR plus major concomitant procedure,* n (%) | 340 (28.8) |
| Tibial plateau fixation | 1 |
| Osteochondral autograft | 1 |
| Osteochondral allograft | 3 |
| Autologous chondrocyte implantation | 2 |
| Microfracture | 3 |
| Osteochondritis dissecans drilling or fixation | 2 |
| Meniscal repair | 290 |
| Meniscal transplant | 1 |
| Posterior cruciate ligament reconstruction | 10 |
| Collateral ligament repair or reconstruction | 17 |
| Early postoperative weight-bearing instructions, n (%) | |
| Immediate weight bearing as tolerated | 536 (45.4) |
| Limited weight bearing | 472 (40.0) |
| Non−weight bearing | 143 (12.1) |
| Not reported | 29 (2.4) |

ACLR, anterior cruciate ligament reconstruction; SD, standard deviation.

*These data are not mutually exclusive, that is, some patients may have undergone more than one of the concomitant procedures in this category.

## Discussion

The main findings of this study show that increasing patient age, surgery performed in an ASC, surgeons in a private-practice setting, and surgeon experience (years in practice and arthroscopic volume) are associated with a shorter operative duration of primary ACLR. Although an increasing number of arthroscopic knee procedures performed by surgeons correlated with fewer complications, only increasing patient BMI significantly predicted odds of complications. Furthermore, performing major concomitant procedures at the time of primary ACLR did not lead to higher intraoperative or early postoperative complications compared with isolated primary ACLR or ACLR performed with minor concomitant procedures.

The effects of surgeon experience and practice setting on operative duration and complication risk when performing ACLR have not previously been investigated on a large scale. The results of a recent study by Cooper et al.[3] using the NSQIP database evaluating 9,000 patients who underwent isolated ACLR—primary or revision—showed an overall mean operative time of 100.7 minutes. Older age was predictive of decreasing operative time, with the operative duration being 32.75 minutes shorter in patients older than 65 years compared with patients younger than 25 years. This finding is corroborated by our study, which showed an inverse correlation between patient age and operative duration ($\rho = -0.221$, $P < .001$). One potential explanation for these differences that was not able to be analyzed in either data set was trends in graft selection patterns based on age. These results are likely due to the higher incidence of allograft use in older populations.[20] Cooper et al. also noted obesity to be predictive of an increase in operative duration. Our study did not find increasing BMI to be associated with operative duration; however, it was predictive of increased odds of early postoperative complications.

Other authors have used the NSQIP database to evaluate patient-specific variables associated with operative duration for isolated ACLR. Agarwalla et al.[19] conducted a recent NSQIP study including 14,159 isolated ACLR patients and found several patient-specific variables to be associated with longer operative duration. Specifically, patient age between 18 and 30 years, nondiabetic status, and male sex were all associated with longer operative durations. Unfortunately, owing to the nature of the NSQIP database, surgeon-specific variables could not be analyzed as part of their study and primary versus revision ACLR could not be discerned. The age-related findings of the study by Agarwalla et al. are consistent

**Table 2.** Surgeon Demographic Characteristics and Operative Setting Information

| Variable | Data |
|---|---|
| Total No. of surgeons | 135 |
| Median age bracket of surgeons (range), yr | 51-55 (30-75) |
| Median years-in-practice bracket (range) | 11-15 (0 to ≥40) |
| Median bracket of No. of knee arthroscopy cases/month (range) | 16-20 (5 to ≥50) |
| Practice setting of cases, n (%) | |
| Private | 841 (72.8) |
| Academic | 300 (25.9) |
| Military | 15 (1.3) |
| Fellowship training in sports medicine or arthroscopy, n (%) | 1,032 of 1,156 (89.3) |
| Location of surgery, n (%) | |
| Ambulatory surgery center | 832 (70.6) |
| Hospital | 346 (29.4) |

**Table 3.** Variables Correlated With Operative Duration

| Variable | Spearman ρ | *P* Value |
|---|---|---|
| Patient age | −0.221 | <.001* |
| Female sex | −0.009 | .779 |
| Body mass index | 0.008 | .801 |
| Active tobacco smoker | 0.025 | .432 |
| Diabetic status | −0.049 | .127 |
| Previous surgery on operative extremity | 0.020 | .543 |
| Tourniquet pressure | −0.072 | .057 |
| No. of knee arthroscopy cases performed by surgeon per month | −0.200 | <.001* |
| Surgeon performing >20 knee arthroscopy cases per month | −0.117 | .001* |
| Surgeon years in practice | −0.267 | <.001* |
| Hospital setting (vs ASC) | 0.377 | <.001* |
| Intraoperative complication | 0.077 | .016* |

ASC, ambulatory surgery center.
*Statistically significant ($P < .05$).

with those of our study. Sex and diabetic status were not found to be significantly associated with operative duration in this study.

Our study also identified several significant findings related to surgeon experience and practice setting. Surgeon years in practice and increased volume of arthroscopic knee surgical procedures performed monthly were found to be correlated with a shorter operative duration. In a recent retrospective study comparing high-volume and low-volume surgeons performing primary ACLR, Harato et al.[21] reported a mean 42.9-minute difference in case duration, with lower-volume surgeons taking longer to perform ACLR. "High-volume" surgeons were defined as those who performed greater than 50 procedures per year and greater than 300 total career anterior cruciate ligament surgical procedures, whereas surgeons in the "low-volume" group were defined as those who performed fewer than 10 procedures per year and fewer than 30 total career anterior cruciate ligament surgical procedures. The authors noted that graft harvest, in particular, required more time for procedures performed by lower-volume surgeons. Significant differences in case durations were identified by practice setting; specifically, surgeons in private practice had a nearly 30-minute shorter operative duration on average than surgeons practicing in an academic or military setting. The difference in operative times may be attributable to the presence of learners of various levels and, importantly, was not found to be associated with higher rates of intraoperative or early postoperative complications, similar to findings of prior orthopaedic studies.[22-26]

The operative setting, hospital based compared with ASC based, was also correlated with significant differences in operative duration. Surgical procedures performed in ASCs were, on average, 14 minutes faster than those performed in the hospital setting (91.5 ± 40.4 minutes vs 105.0 ± 43.8 minutes, $P < .001$). Most surgical procedures in this study were performed in an ASC (70.6%), which reflects trends seen nationally over the past 20 years.[15] In addition to a shorter operative duration, Kadhim et al.[14] reported greater operating room work efficiency in ASCs compared with the inpatient hospital setting for a single surgeon performing primary ACLR. Along with quicker operative times, the move toward performing arthroscopic procedures in ASCs is likely related to cost incentives and improved patient experience. This alignment of the goals of the entire operative team, in addition to a higher potential for operative team consistency in an ASC setting, may be what is driving the increased efficiency noted in ASC settings. Unsurprisingly, a study in 2015 reported that the median price for knee arthroscopy was $5,668 in hospital-based outpatient settings compared with $3,083 in ASCs.[4] Given this information, many health systems are moving to ASC models for same-day surgery in an effort to contain costs.

Operative duration was not associated with intraoperative or early postoperative complications in our study. The overall rates of intraoperative complications (1.9%) and early postoperative complications (4.0%) were relatively low. When we considered the complication rates of isolated ACLR (5.0%), ACLR plus minor concomitant procedures (3.2%), and ACLR plus major concomitant procedures (2.4%), the differences were not significant ($P = .130$) between any of the groups. We note that the rate was unexpectedly higher in the isolated ACLR group. This finding may be a result of

**Table 4.** Multivariate Linear Regression for Duration of Surgery of Overall ACLR Cohort

| Variable | Coefficient | P Value | 95% CI |
|---|---|---|---|
| Age | −4.050 | <.001* | −6.240 to −1.860 |
| Male sex | −2.947 | .588 | −13.620 to 7.726 |
| Hospital vs ASC | 6.864 | .181 | −3.190 to 16.917 |
| Fellowship | −4.801 | .197 | −12.095 to 2.493 |
| Surgeon years in practice | −6.906 | <.001* | −10.160 to −3.652 |
| Concomitant procedures (isolated ACLR vs ACLR with minor concomitant procedures vs ACLR with major concomitant procedures) | 10.033 | .022* | 1.474 to 18.592 |

ACLR, anterior cruciate ligament reconstruction; ASC, ambulatory surgery center; CI, confidence interval.
*Statistically significant ($P < .05$).

chance alone. The only surgeon-specific variable associated with a lower intraoperative complication rate was performing greater than 20 knee arthroscopy cases per month, suggesting the importance of surgical volume and technique. On multivariate regression analysis, age, sex, and surgeon arthroscopy volume were not found to have greater odds of complications; however, increasing patient BMI did lead to a significantly higher odds of complications (odds ratio, 1.060; $P = .044$).

### Limitations

Several limitations of this study must be acknowledged. There was no reporting of operative technique available in the database, which may influence operative duration and complication rate. Furthermore, the type of graft was not consistently recorded, and therefore, these data could not be analyzed. This variable may have had an effect on operative duration given the added time necessary to harvest autograft tissue as compared with allograft. All data were self-reported by the surgeons, including complication data, which may lead to reporting bias and inadequate capture of more complicated practice setups, such as hybrid private practice—academic medicine positions. It was not possible to know if a trainee was present for a surgical case or to what degree the trainee was involved in the case using this database. Patient-reported outcomes, imaging data, and clinical follow-up beyond 6 weeks were not recorded as part of this database; we acknowledge that this is a limitation of our study. It is not known how operative duration affected patient-reported outcomes and return to sport, which are major components in assessing surgical quality for ACLR.

**Table 5.** Variables Correlated With Intraoperative Complications

| Variable | Spearman ρ | P Value |
|---|---|---|
| Patient age | −0.036 | .237 |
| Female sex | 0.019 | .506 |
| Body mass index | −0.013 | .658 |
| Active tobacco smoker | −0.026 | .364 |
| Diabetic status | 0.038 | .192 |
| Previous surgery on operative extremity | 0.059 | .042 |
| Surgeon performing >20 knee arthroscopy cases per month | −0.112 | <.001* |
| Surgeon years in practice | −0.034 | .279 |
| Ambulatory surgery center setting | 0.030 | .310 |
| Fellowship training | −0.009 | .748 |
| Practice type (private vs academic or military) | −0.042 | .156 |

*Statistically significant ($P < .05$).

**Table 6.** Multivariate Logistic Regression for Complications in Overall ACLR Cohort

| Variable | Odds Ratio | P Value | 95% CI |
|---|---|---|---|
| Age | 1.060 | .426 | 0.919-1.222 |
| Female sex | 1.709 | .135 | 0.846-3.452 |
| BMI | 1.060 | .044* | 1.002-1.121 |
| No. of knee arthroscopy cases performed by surgeon per month | 0.872 | .183 | 0.712-1.067 |

ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; CI, confidence interval.
*Statistically significant ($P < .05$).

## Conclusions

Increasing patient age, private practice, ASC setting, and surgeon experience are associated with a shorter operative duration for ACLR. Although an increasing number of arthroscopic knee procedures performed by surgeons correlated with fewer complications, only increasing patient BMI significantly predicted odds of complications.

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