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Procedure length is independently associated with overnight hospital stay and 30-day readmission following anterior cruciate ligament reconstruction

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Abstract

Purpose The purpose was to characterize the independent effect of procedure length on the rates of 30-day perioperative complications, hospital readmissions, and overnight hospital stay in patients undergoing arthroscopic anterior cruciate ligament reconstruction (ACLR). We hypothesized that longer procedure length in primary ACLR increases the risk for post-operative complications.

Methods Primary ACLR cases from 2005 to 2015 were identified in the American College of Surgeons National Surgical Quality Improvement Program registry. Patients were categorized into two cohorts based on procedure length, either less than or greater than 90 min. Two equal-sized propensity-matched cohorts were generated to account for differences in baseline and operative characteristics. Thirty-day clinical outcomes were compared using bivariate analyses between propensity-matched groups that controlled for patient-specific factors and concurrent meniscal repair. Multivariate logistic regression models were used to identify independent predictors of hospital readmission and overnight hospital stay.

Results In total, 12,077 ACLR cases were identified. The rate of any 30-day complication was increased in longer procedures relative to shorter procedures (1.6% vs 0.9%, $p = 0.006$), as were the rates of returning to the operating room (0.6% vs 0.3%, $p = 0.03$), hospital readmission (1.0% vs 0.3%, $p = 0.001$), and overnight hospital stay (16.2% vs 6.0%, $p < 0.001$). Obesity was a risk factor for both hospital readmission and overnight hospital stay, while hypertension, diabetes, chronic obstructive pulmonary disease, and a smoking history were associated with increased rates of overnight hospital stay. The most common reasons for hospital readmission were deep vein thrombosis or pulmonary embolism (25.0% of all readmitted patients), surgical site infection (25.0%), and post-operative pain (14.1%).

Conclusions In this propensity-matched analysis adjusting for baseline patient characteristics and operative factors, procedure length of greater than or equal to 90 min in ACLR was independently associated with an increased risk of hospital readmission and overnight hospital stay. As a surrogate measure of surgical complexity, operative time may be a useful perioperative variable for post-operative risk stratification and patient counseling.

Level of evidence III

Keywords Operative duration · Orthopaedic outcomes · ACS-NSQIP · ACL reconstruction · Outcomes · Procedure length · Arthroscopy length

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Introduction

Anterior cruciate ligament reconstruction (ACLR) is one of the most commonly performed orthopaedic procedures [14, 22]. Both short- and long-term clinical outcomes after ACLR have been well characterized [3, 7, 11, 15, 17, 23, 24, 27, 30, 31]. Perioperative complications occur infrequently, with the rate of symptomatic thromboembolic events reported at between 0.53 and 4.0% [11, 15, 30],

septic arthritis between 0.14 and 0.48% [17, 23, 31], urinary tract infection at 0.74% [27], and an inpatient mortality rate under 0.01–0.02% [11, 27]. Risk factors found to be associated with perioperative complications after ACLR include age greater than 20 years and diabetes mellitus, whereas decreased risk has been observed when procedures are performed in hospitals with a high volume of reconstructions [7, 22, 27].

While perioperative complication rates are low with arthroscopic procedures, there are various operative factors which have been associated with an increased incidence of complications. In knee arthroscopy, patient-related risk factors such as corticosteroid injection at the time of arthroscopy have been associated with significantly increased postoperative infection rates [8]. Other known risk factors for infection following knee arthroscopy include: age, obesity, tobacco use, and a number of medical comorbidities [9]. Furthermore, differences in arthroscopic irrigation fluid temperature and osmolarity may also have a variable impact on core body temperature and articular cartilage viability [10, 25, 26]. However, studies assessing the impact of procedure time on short-term clinical outcomes after arthroscopic ACLR are lacking.

The association between operative time and post-operative complications in ACLR is presently unclear. Accordingly, the primary aim of this study was to use a large national registry to assess for independent associations between procedure time in ACLR, and 30-day post-operative complications and readmissions rates. Secondary aims were to identify patient-specific factors associated with hospital readmission and overnight hospital stay and to determine the most common reasons for readmission after ACLR. We hypothesized that longer procedure length in primary ACLR increases the risk for post-operative complications. Procedure length may be a surrogate for surgical complexity, and is also useful as a perioperative variable for risk stratification and patient counseling.

Materials and methods

Following approval of the institutional review board, the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database was accessed. This national registry was established in 2005 and is updated annually, with data available for over 4 million unique surgical encounters as of 2015 [1]. The NSQIP contains patient demographic information, intraoperative variables including operative time, and post-operative complications and readmissions up to 30 days after surgery. Post-operative events for 30 days are reported irrespective of length of hospital stay. Data collection is performed by trained surgical clinical reviewers, and audited by the American College of Surgeons to ensure accuracy and reliability of the data. As a result, there is high interrater reliability, with a disagreement rate of only 1.56% as of 2015 [29]. Perhaps due to this frequent auditing, the NSQIP database is more accurate compared to other large registries, such as insurance administrative claims databases [12, 19].

Baseline patient characteristics and perioperative complications

This study used NSQIP data over a 10-year period, from 2005 to 2015. Patients who underwent ACLR were identified with a primary Current Procedural Terminology (CPT) 29888. Patients with dirty wound classifications, surgical procedures considered emergent, multi-ligament reconstructions, and those with missing baseline patient and operative characteristics were excluded from this study. Baseline patient and operative characteristics that were assessed in this study included: age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) class, operation length, whether or not a patient underwent a concurrent meniscus repair, and medical comorbidities including hypertension, chronic obstructive pulmonary disease (COPD), smoking history, and diabetes mellitus. Concurrent meniscus repair was identified using secondary CPT codes 29882 (medial or lateral repair) and 29883 (medial and lateral repair).

Clinical outcomes assessed in this study included 30-day readmissions, whether or not a patient needed overnight hospital stay, and perioperative complications including surgical site infections, wound dehiscence, urinary tract infection, return to the operating room, deep vein thrombosis or pulmonary embolism (DVT/PE), and respiratory complications. For patients that were readmitted, the reason for readmission was recorded. The NSQIP began collecting readmission information in 2011, and these data were available for 79.1% of patients who underwent arthroscopic ACLR between 2005 and 2015 in this current study. Institutional review board approval for this current study was obtained from the Hospital for Special Surgery (#2017-0463).

Statistical analysis

A propensity score-matched analysis was performed to account for differences in baseline patient and operative characteristics between the two cohorts, patients with an operative time less than 90 min or greater than or equal to 90 min. This methodology has been established in large data set outcomes research in orthopaedic surgery [5, 6, 13]. In the current study, the propensity score is defined as the conditional probability that a patient has an operative time greater than or equal to 90 min, while controlling for patient age, sex, body mass index, medical comorbidities,

ASA class, and concurrent meniscus repair. Two equal-sized, propensity-matched cohorts undergoing arthroscopic ACLR less than and greater than or equal to 90 min were generated using 1:1 matching with tight calipers (0.001) and nearest-neighbor matching [21]. Nearest-neighbor matching selects for patients in both groups with the smallest difference in propensity score. Once these two patients are matched by this method, they are removed from the eligible pool of patients available to be matched. The next two patients in each group with the closest propensity scores are selected for, and this process is continued until no more eligible patients are available. Two operative time cohorts were used in this study to allow for rapid stratification of a patient into the appropriate cohort. Next, clinical outcome variables between both groups, including complications and readmissions, were compared using Pearson's Chi-squared test. A multivariate binary logistic regression with readmission and overnight hospital stay as outcome variables and baseline patient and operative characteristics as covariates was performed to identify preoperative risk factors for these two complications. Statistical significance was defined as a

p value less than 0.05. SPSS version 23 (IBM Corporation, Armonk, NY) was used for all statistical analyses.

Results

Baseline patient and operative characteristics

In total, 12,077 ACLR cases were identified (Table 1). 5584 (46.2%) of these patients had a procedure lasting less than 90 min, and 6493 (53.8%) had a procedure lasting greater than or equal to 90 min. The mean procedure length in the shorter procedure cohort was 67 ($\pm$ standard deviation 15) min, and was 132 ($\pm$ 50) min in the longer procedure cohort. A bivariate comparison of the non-propensity-matched groups found that patients who had a longer procedure were more likely to be younger ($p < 0.001$), male ($p < 0.001$), and have a lower ASA class ($p < 0.001$). After generating propensity-matched cohorts, the differences seen in the unadjusted groups were no longer observed upon bivariate analysis.

Table 1 Baseline patient characteristics of patients undergoing ACL reconstruction

	All patients	Unadjusted cohorts Arthroscopy time (mins) < 90	≥ 90	p value	Propensity-matched cohorts Arthroscopy time (mins) < 90	≥ 90	p value
Number of patients	12,077	5584	6493		4620	4620	
Age				**< 0.001**			n.s.
≤ 30	50.1%	40.8%	58.0%		47.8%	47.9%	
31–40	26.5%	28.7%	24.6%		29.6%	29.5%	
41–50	17.2%	21.8%	13.2%		15.9%	17.0%	
> 50	6.3%	8.7%	4.2%		6.7%	5.6%	
Male %	63.8%	59.0%	68.0%	**< 0.001**	63.0%	62.7%	n.s.
Body mass index (kg/m²)				n.s.			n.s.
< 30 (Non-obese)	72.2%	73.1%	71.4%		74.4%	74.4%	
30–34.9 (Obese I)	17.3%	17.1%	17.6%		16.8%	16.9%	
35.0–39.9 (Obese II)	6.4%	6.1%	6.6%		5.5%	5.4%	
> 40 (Obese III)	4.0%	3.7%	4.3%		3.3%	3.3%	
Comorbidities							
Hypertension	6.5%	7.0%	6.1%	**0.031**	5.6%	5.7%	n.s.
Diabetes mellitus	1.4%	1.8%	1.1%	**0.002**	0.7%	0.8%	n.s.
COPD	0.2%	0.3%	0.2%	n.s.	0.2%	0.2%	n.s.
Smoking history	18.6%	18.0%	19.1%	n.s.	17.4%	17.3%	n.s.
ASA class				**< 0.001**			n.s.
I	54.4%	52.4%	56.0%		55.5%	55.6%	
II	41.6%	43.4%	40.0%		41.4%	41.3%	
III or IV	4.0%	4.1%	4.0%		3.1%	3.1%	
Concurrent meniscus repair	11.2%	9.15%	13.0%	**< 0.001**	9.4%	9.8%	n.s.

Significant p values are defined as < 0.05 and are presented in bold

ASA American Society of Anesthesiologists, *COPD* chronic obstructive pulmonary disease, *n.s.* not significant

Bivariate analysis for perioperative complications

With bivariate analysis of the propensity-matched cohorts, the rate of any complication was found to be significantly increased in ACLR with operative times greater than or equal to 90 min (1.6%), compared to those under 90 min (0.9%, $p = 0.006$) (Table 2). There was also a significantly increased rate of returning to the operating room in the longer procedure length group (0.6%) relative to the shorter procedure length group (0.3%, $p = 0.03$). Furthermore, patients with a longer procedure had a significantly higher rate of 30-day readmission (1.0%, $p = 0.001$) and overnight hospital stay (16.2%, $p < 0.001$) compared to those with a shorter procedure (0.3% and 6.0%, respectively).

Multivariable analysis for risk factors for complications

Operative time greater than or equal to 90 min was an independent predictor of 30-day hospital readmission (OR 2.53, $p = 0.001$), any peri- or post-operative complication (OR 1.61, $p = 0.007$), and overnight hospital stay (OR 2.97, $p < 0.001$) (Table 3). BMI greater than 40 kg/m^2 was also an independent predictor of hospital readmission (OR 5.01, $p < 0.001$) and any peri- or post-operative complication (OR 2.10, $p = 0.025$). Risk factors for overnight hospital stay were male sex (OR 0.86, $p = 0.018$), medical comorbidities such as diabetes mellitus (OR 1.83, $p = 0.004$), COPD (OR 2.56, $p = 0.029$), and a smoking history (OR 1.18, $p = 0.029$), as well as BMI between 30 and 34.9 kg/m^2 (OR 1.25, $p = 0.003$), BMI of 35.0 and 39.9 (OR 14.2, $p = 0.002$), and BMI greater than 40 (OR 1.50, $p = 0.004$).

Table 2 Comparison of adverse outcomes in arthroscopic ACL reconstruction by operation time of propensity-matched cohorts

	Operative time (mins)		p value
	< 90	≥ 90	
	4620	4620	
Any complication	**0.97%**	**1.62%**	**0.006**
Respiratory complications	0.02%	0.02%	n.s.
Deep vein thrombosis/Pulmonary embolism	0.37%	0.54%	n.s.
Return to operating room	**0.30%**	**0.61%**	**0.030**
Urinary tract infection	0.04%	0.11%	n.s.
Wound dehiscence	0.06%	0.06%	n.s.
Surgical site infection	0.26%	0.45%	n.s.
Readmission (30 days)	**0.34%**	**0.95%**	**0.001**
Overnight hospital stay	**6.00%**	**16.2%**	**< 0.001**

Significant p values are defined as < 0.05 and are presented in bold

n.s. not significant

Reasons for hospital readmission

In total, 64 patients (0.7% of all patients in this study) were identified with a 30-day readmission in the unadjusted cohorts. 17 of these (26.6%) had a procedure lasting under 90 min, while 47 (73.4%) had a procedure lasting greater than or equal to 90 min (Table 4). Of all readmitted patients in each group, 11.8% of the patients in the shorter operative time group were readmitted for a deep vein thrombosis or pulmonary embolism, compared to 29.8% in the longer operative time group.

Discussion

The most important finding of the present study was that there are increases in adverse post-operative outcomes as the duration of ACLR increases. Previous studies have incompletely assessed the effect of operative time on clinical outcome and complication risk after ACLR. Using a national, prospectively collected registry, the impact of operative time on 30-day complication and readmission rates was identified. When controlling for baseline patient and operative characterizes using a propensity-adjusted model, we found that there were increased rates of any complication, overnight hospital stay, hospital readmission, and return to the operating room in ACLR requiring greater than or equal to 90 min of operative time, relative to those requiring less than 90 min.

Previous studies assessing procedure time-dependent effects on short-term clinical outcomes in ACLR are lacking. However, procedure length has been associated with poorer outcomes in other arthroscopic procedures. A 2011 study of 418,323 patients undergoing any arthroscopic procedure of the knee found a nearly threefold increase in the odds of symptomatic pulmonary embolisms in procedures lasting greater than 90 min, relative to those lasting under 30 min [16]. Similarly, a study assessing the risk factors for complications in all arthroscopic shoulder procedures identified a nearly twofold increase in any complication when procedures lasted longer than 90 min [28]. However, these studies looked at all knee or shoulder arthroscopic procedures in aggregate, without isolating any particular procedure. Furthermore, they did not control for the number of concurrent arthroscopic procedures performed in each patient in their multivariate analyses. One of the most common reasons for readmission was identified as DVT/PE in the longer operative time cohort relative to the shorter operative time cohort in this current study. Procedure length has also been implicated a negative prognostic factor in longer term and functional outcomes, for instance when assessing rotator cuff repair a longer procedure length was identified as an independent predictor of rotator cuff

Table 3 Multivariate analysis of risk factors for adverse outcomes

	Readmission		Any complication		Overnight hospital stay	
	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Age						
≤ 30	Reference	–	Reference	–	Reference	–
31–40	1.40 (0.79–2.50)	n.s.	0.92 (0.61–1.39)	n.s.	0.98 (0.86–1.13)	n.s.
41–50	1.34 (0.65–2.76)	n.s.	1.22 (0.77–1.92)	n.s.	0.89 (0.74–1.06)	n.s.
> 50	0.68 (0.15–2.99)	n.s.	1.33 (0.68–2.60)	n.s.	0.86 (0.66–1.14)	n.s.
Female gender	0.80 (0.46–1.37)	n.s.	0.94 (0.67–1.33)	n.s.	**0.86 (0.76–0.98)**	**0.018**
Body mass index (kg/m^2)						
< 30 (Non-obese)	Reference	–	Reference	–	Reference	–
30–34.9 (Obese I)	1.20 (0.62–2.35)	n.s.	0.82 (0.51–1.32)	n.s.	**1.25 (1.08–1.45)**	**0.003**
35.0–39.9 (Obese II)	1.11 (0.39–3.22)	n.s.	1.21 (0.65–2.27)	n.s.	**1.42 (1.14–1.77)**	**0.002**
> 40 (Obese III)	**5.01 (2.28–11.0)**	**< 0.001**	**2.10 (1.10–4.01)**	**0.025**	**1.50 (1.14–1.97)**	**0.004**
Comorbidities						
Hypertension	1.68 (0.70–4.07)	n.s.	1.33 (0.72–2.44)	n.s.	1.22 (0.96–1.54)	n.s.
Diabetes mellitus	0.85 (0.11–6.65)	n.s.	0.31 (0.04–2.31)	n.s.	**1.83 (1.22–2.74)**	**0.004**
COPD	–	–	3.94 (0.83–18.7)	n.s.	**2.56 (1.10–5.94)**	**0.029**
Smoking history	1.37 (0.75–2.49)	n.s.	1.24 (0.83–1.86)	n.s.	**1.18 (1.02–1.36)**	**0.029**
ASA class						
I	Reference	–	Reference	–	Reference	–
II	1.03 (0.57–1.85)	n.s.	1.05 (0.72–1.53)	n.s.	0.92 (0.81–1.05)	n.s.
III or IV	0.30 (0.06–1.47)	n.s.	0.96 (0.41–2.25)	n.s.	1.25 (0.93–1.69)	n.s.
Operative time > 90 min	**2.53 (1.44–4.46)**	**0.001**	**1.61 (1.14–2.26)**	**0.007**	**2.97 (2.61–3.38)**	**< 0.001**
Concurrent meniscus repair	1.20 (0.61–2.39)	n.s.	0.73 (0.41–1.30)	n.s.	**0.76 (0.63–0.92)**	n.s.

Significant p values are defined as < 0.05, and are presented in bold

CI confidence interval, *OR* odds ratio, *ASA* American Society of Anesthesiologists, *COPD* chronic obstructive pulmonary disease, *n.s.* not significant

re-tears following arthroscopic rotator cuff repair [20]. Similar studies assessing long-term outcomes, such as the rate of re-tears as a function of procedure length in ACLR have not been described.

In this present study of ACLR, operative time greater than or equal to 90 min was found to be an independent predictor of adverse outcomes, including total 30-day complications, hospital readmission, and overnight hospital stay. The reasons for these associations may not be entirely due to adverse effects of prolonged arthroscopy duration, but is perhaps more likely related to surgical complexity. Our propensity-matching model accounted for concurrent meniscus repair to account for one potential source of increased ACLR procedure complexity. There are, however, additional factors that may prolong the operative time. These can include varying operative techniques, surgeon experience, or the availability of intraoperative support staff who can assist with portions of the procedure such as graft preparation. Therefore, the procedure length may be an overly simplified measure of surgical complexity, but can perhaps act as one helpful tool in post-operative risk stratification. Specifically, patients undergoing ACLR with operative time greater than

or equal to 90 min should be monitored more closely for the incidence of unintended perioperative complications. As a simple surrogate measure of surgical complexity, operative time is a useful perioperative variable for post-operative risk stratification and patient counseling.

In addition to increased procedure duration, BMI greater than 40 kg/m^2 was identified as an independent predictor of hospital readmission, any complication, and overnight hospital stay. Furthermore, in this current study, we identified the most common reason for 30-day hospital readmission after ACLR as DVT/PE in all patients. In procedures lasting greater than or equal to 90 min, the reason for readmission in nearly 30% of these patients was DVT/PE. Increased immobility in longer procedures may increase the risk of subsequent DVT/PE as venous stasis is a risk factor for thromboembolic events. In addition to procedure length, patients with a BMI greater than 40 kg/m^2 had more than five times higher odds of hospital readmission. Obesity has been identified previously as a risk factor for DVT, perhaps due to the pro-thrombotic forces of chronic inflammation and impaired fibrinolysis seen in this patient population [4]. Prophylactic agents such as aspirin or low-molecular-weight heparin are

Table 4 Reasons for Readmission After Arthroscopic ACL

	All patients		Operative time < 90 minutes		Operative time ≥ 90 minutes	
	Number of patients	% of readmitted patients	Number of patients	% of readmitted patients	Number of patients	% of readmitted patients
	Total: 9558		Total: 4622		Total: 4936	
	Readmitted: 64	100%	Readmitted: 17	100%	Readmitted: 47	100.0%
DVT/PE	16	25.0%	2	11.8%	14	29.8%
Surgical site infection	16	25.0%	4	23.5%	12	25.5%
Joint pain	9	14.1%	2	11.8%	7	14.9%
Hematoma	2	3.1%	–	–	2	4.3%
Joint infection	2	3.1%	1	5.9%	1	2.1%
Neurological	2	3.1%	2	11.8%	–	–
Joint effusion	1	1.6%	–	–	1	2.1%
Femoral fracture	1	1.6%	–	–	1	2.1%
Gastrointestinal	1	1.6%	–	–	1	2.1%
Psychiatric	1	1.6%	–	–	1	2.1%
Respiratory	1	1.6%	1	5.9%	–	–
Wound disruption	1	1.6%	–	–	1	2.1%
Unknown reason	11	17.2%	5	29.4%	6	12.8%

Readmission data are only available from 2011 to 2015, which include 79.1% of all patients included in this study

DVT/PE deep vein thrombosis or pulmonary embolism

not routinely used after arthroscopic knee procedures [2, 18], but may be warranted in those with significant risk factors such as increased procedure duration and extreme obesity. Further studies are needed to assess the benefit-to-risk ratio of this approach in these higher risk patients. Whether or not anti-thrombotic agents are utilized, these high-risk patients should be educated on the symptoms of DVT and encouraged to employ non-pharmacological strategies to prevent DVT such as periodic leg elevation, compressive stockings, as well as early ambulation.

This study has several limitations. First, due to limitations in the database, we lack specific clinical variables that are relevant to arthroscopic ACLR. Specifically, information regarding physical examination findings, functional outcomes, graft type, and the rate of graft failure or re-tears was not collected in the NSQIP. In particular, graft selection may have an important impact on procedure length, particularly when comparing allograft with autograft. Furthermore, the NSQIP only contains post-operative outcomes data until 30 days after the index procedure. Therefore, we were unable to identify the time-dependent association impact of procedure length on medium- and long-term clinical outcomes. Finally, the NSQIP only obtains information on surgical procedures at participating institutions, and therefore, the patients included in this study may not be representative of all patients undergoing arthroscopic ACLR. However, as of 2015, there were over 600 separate institutions participating in this registry, ranging from large academic centers to smaller community hospitals [1].

Conclusions

In this propensity-matched analysis adjusting for baseline patient characteristics and operative factors, and procedure length of greater than or equal to 90 min in ACLR was independently associated with an increased risk of hospital readmission and overnight hospital stay. As a surrogate measure of surgical complexity, operative time is a useful perioperative variable for post-operative risk stratification and patient counseling.

Compliance with ethical standards

Conflict of interest Dr. Ranawat reports royalties from Conformis, consulting fees from Stryker, and Arthrex, outside the submitted work. No other authors have financial disclosures.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent This study utilized de-identified publicly available data and therefore formal consent is not required.

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