



## The effect of obesity on complications following isolated posterior cruciate ligament reconstruction



Anna M. Ifarraguerri<sup>a,\*</sup>, Theodore Quan<sup>a</sup>, Sophie L. Bernstein<sup>b</sup>, Alisa Malyavko<sup>a</sup>, Casey Gioia<sup>a</sup>, Alex Gu<sup>a</sup>, Teresa Doerre<sup>a</sup>, Matthew J. Best<sup>c</sup>

<sup>a</sup>Department of Orthopaedic Surgery, George Washington University School of Medicine and Health Sciences, Washington, DC, United States

<sup>b</sup>University of Missouri-Kansas City School of Medicine, Kansas City, MO, United States

<sup>c</sup>Department of Orthopaedic Surgery, Johns Hopkins, Columbia, MD, United States

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### ABSTRACT

**Background:** This study assessed the risk of 30-day complications for obese patients compared to non-obese patients undergoing isolated posterior cruciate ligament (PCL) reconstruction.

**Methods:** From 2006 to 2019, the National Surgical Quality Improvement Program database was queried for patients undergoing isolated PCL reconstruction. Two patient cohorts were defined: patients with obesity (BMI  $\geq 30.0$  kg/m<sup>2</sup>) and patients without obesity (BMI  $< 30$  kg/m<sup>2</sup>). Patients' baseline demographics and medical comorbidities were collected and compared between the cohorts. Postoperative outcomes were assessed using bivariate and multivariate analyses.

**Results:** 414 patients underwent PCL reconstruction. 258 patients (62.3%) were non-obese and 156 patients (37.7%) were obese. Obese patients were more likely to be older, have a higher American Society of Anesthesiologists classification, and have hypertension compared to non-obese patients ( $p < 0.05$  for all). The rates of superficial surgical site infections, wound dehiscence, transfusion necessity, deep vein thrombosis, and re-operation were not significant between obese and non-obese patients. Following adjustment on multivariate analyses, relative to patients without obesity, those with obesity had an increased risk of admission to the hospital overnight (OR 1.66;  $p = 0.048$ ).

**Conclusions:** To our knowledge, this is the first study to evaluate obesity on complications in isolated PCL reconstruction. Our results and the heterogeneity in the literature indicate that obesity significantly impacts the rates of hospital readmission for PCL reconstruction. Therefore, surgeons should carefully weigh the risks and benefits of operating on obese patients and plan accordingly as obese patients may require postoperative hospital admission after PCL reconstruction.

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\* Corresponding author at: Department of Orthopaedic Surgery, George Washington University Hospital, 2300 M St NW, Washington DC, 20037, United States.

E-mail address: amifarra@gwmail.gwu.edu (A.M. Ifarraguerri).

## 1. Introduction

Posterior cruciate ligament (PCL) injuries most commonly occur due to sports or motor vehicle accidents [1]. Some controversy exists regarding the optimal treatment of these injuries, but isolated PCL injuries are often initially treated non-operatively [2], while operative management can be utilized to improve stability and prevent degenerative arthritis [3] in those with persistent functional limitation despite non-operative management.

PCL reconstruction has a relatively high complication rate of up to 20.1% [4], therefore it is imperative to assess preoperative risk factors that may impact the complication rate. Obesity is a known risk factor for post-surgical complications across various orthopedic procedures, including various arthroscopic surgeries [5–12]. As a result of the rising prevalence of obesity in the United States, with the latest estimates at 42% [13], and the fact that patients with a high body mass index (BMI) have an increased need for orthopedic care, it is crucial to evaluate the impact of obesity on postoperative outcomes. In addition, obesity has been associated with a higher cost of care associated with managing comorbidities, increased operative time, and longer hospital stays after surgical procedures [14–16]. Therefore, when selecting patients for surgery, especially procedures with a high complication rate like PCL reconstruction, it is vital to consider the potential increased risk of post-surgical complications in patients with an elevated BMI.

The literature is limited when examining the impact of elevated BMI on postoperative outcomes in patients undergoing PCL reconstruction. In general, PCL injuries usually occur concomitantly with other ligament injuries in the knees. However, to understand the risk factors contributing to the high complication rate associated with PCL reconstruction [4] and adverse surgical outcomes, it is important to assess complication risks for isolated PCL injuries. In addition, most arthroscopic procedures performed on the knee occur in the outpatient setting [17], and the need for whether or not patients require post-operative hospital admission after surgery is critical for surgical planning.

The purpose of this study was to utilize a large database to assess the risk of 30-day complications for obese patients, defined as a BMI  $\geq 30.0$  kg/m<sup>2</sup>, undergoing isolated PCL reconstruction. We hypothesized that obese patients would have an increased risk of postoperative complications compared to non-obese patients who undergo an isolated PCL reconstruction.

## 2. Materials and methods

We performed a retrospective study utilizing the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from the years 2006 to 2019. The NSQIP database is a high-quality, multicenter registry that contains prospectively collected data on surgical patients such as patient demographics, comorbidities, and preoperative variables [18]. It includes patient data from more than 750 hospitals nationwide [19]. It has widely been used to investigate complications following a wide variety of orthopedic procedures [20,21]. The benefit of using this database specifically for this study is that the large sample size allows for the documentation of risk factors and complications for less common procedures such as isolated PCL reconstructions.

### 2.1. Patient selection

Current procedural terminology (CPT) code 29,889 (arthroscopically aided posterior cruciate ligament reconstruction) was used to identify all patients undergoing PCL reconstruction. Patients were excluded from this study if they underwent concomitant procedures. As such, patients with concurrent CPT codes 29,888 (arthroscopically aided anterior cruciate ligament reconstruction), 27,405 (primary, torn ligament and/or capsule, knee; collateral), 27,427 (ligamentous reconstruction (augmentation), knee; extra-articular), 27,428 (ligamentous reconstruction (augmentation), knee; intra-articular (open)), and 27,407 (primary, torn ligament and/or capsule, knee; cruciate) were excluded, which is consistent with prior studies [22]. Therefore, only patients with isolated PCL reconstructions were analyzed in this study. Patients were stratified into two cohorts: patients who were obese (BMI  $\geq 30.0$  kg/m<sup>2</sup>) and patients who were non-obese (BMI  $< 30$  kg/m<sup>2</sup>).

### 2.2. Patient characteristics

From the NSQIP database, variables regarding patient demographics and clinical characteristics included age, gender, race, American Society of Anesthesiologists (ASA) classification, smoking status, and functional status. Patients' medical comorbidities collected included chronic obstructive pulmonary disease (COPD), hypertension, chronic steroid use, bleeding disorder, diabetes mellitus, and dyspnea. The type of anesthesia used during the surgical procedure was also recorded.

### 2.3. Postoperative outcomes

Postoperative complications were assessed up to thirty days following PCL reconstruction. Complications collected from the database included superficial surgical site infections, wound dehiscence, bleeding requiring transfusion, deep vein thrombosis, postoperative hospital admission, and reoperation. Postoperative admission was defined as at least one overnight stay in the hospital immediately after the surgery [22].

## 2.4. Statistical analysis

A power analysis for a power of 0.95 was performed using G\*Power statistical software (Erdfelder, Faul, & Buchner, 1996). The Statistical Package for the Social Sciences (SPSS; Version 26; Armonk, NY) software was used to conduct the various statistical analyses. Bivariate analyses were used to compare patient demographics, clinical characteristics, medical comorbidities, and postoperative outcomes between the two cohorts. Postoperative complication variables with a  $p$ -value  $<0.05$  were chosen for multivariate analyses. Demographic and medical comorbidity variables were included in the multivariate analyses as covariates for  $p$ -values  $<0.20$  [23,24]. Regression analysis was performed to identify the independent risk factors for postoperative outcomes. Statistical significance was set at a  $p$ -value  $<0.05$ .

## 3. Results

A sample size of 74 was calculated for a power of 0.95.

### 3.1. Demographics and comorbidities

In total, 414 patients that underwent isolated PCL reconstruction were included in the analysis after applying the exclusion criteria. 258 patients (62.3%) were non-obese, whereas 156 patients (37.7%) were obese. Compared to non-obese patients, obese patients were more likely to be older (35.9 vs 30.9 years old;  $p < 0.001$ ) and have an ASA classification of III or IV (10.3% vs 1.2%;  $p < 0.001$ ) (Table 1). Also, patients with obesity were more likely to have hypertension (16.7% vs 4.7%;  $p < 0.001$ ) relative to non-obese patients (Table 2). The demographic and medical comorbidities with  $p$ -values  $<0.20$  included as covariates in the multivariate analyses were age, ASA classification, hypertension, COPD, dyspnea, and chronic steroid use.

### 3.2. Complications

Following PCL reconstruction, compared to non-obese patients, those with obesity were more likely to be admitted to the hospital overnight (35.9% vs 25.6%;  $p = 0.026$ ) (Table 3). Rates of superficial surgical site infections, wound dehiscence, transfusion necessity, deep vein thrombosis, and reoperation were not significant between the two cohorts. Following multivariate models' adjustment to control covariates, obese patients had an increased risk of postoperative hospital admission (OR 1.661; 95% CI 1.004–2.749;  $p = 0.048$ ) compared to patients without obesity (Table 4).

**Table 1**  
Demographics and clinical characteristics among patients undergoing PCL reconstruction.

Demographics	Non-Obese	Obese	$p$ -value
Total patients, n	258	156	
Sex, n (%)			0.595 <sup>†</sup>
Female	57 (22.1)	38 (24.4)	
Male	201 (77.9)	118 (75.6)	
Ethnicity, n (%)			0.446 <sup>†</sup>
Caucasian	133 (73.5)	92 (70.8)	
Black or African American	17 (9.4)	14 (10.8)	
Hispanic	17 (9.4)	19 (14.6)	
American Indian or Alaska Native	1 (0.6)	1 (0.8)	
Asian	9 (5.0)	2 (1.5)	
Native Hawaiian or Pacific Islander	4 (2.2)	2 (1.5)	
ASA, n (%)			<b>&lt;0.001<sup>†</sup></b>
I or II	255 (98.8)	140 (89.7)	
III or IV	3 (1.2)	16 (10.3)	
Smoker, n (%)	50 (19.4)	33 (21.2)	0.662 <sup>†</sup>
Dependent Functional Status, n (%)	2 (0.8)	3 (1.9)	0.293 <sup>†</sup>
Mean age, yrs (SD)	30.91 (10.97)	35.88 (12.18)	<b>&lt;0.001<sup>**</sup></b>
Mean BMI (SD)	25.43 (3.09)	35.08 (5.60)	<b>&lt;0.001<sup>**</sup></b>

Bolding equals significance  $p < 0.05$ .

PCL, posterior cruciate ligament; ASA, American Society of Anesthesiologists; SD, standard deviation; BMI, body mass index.

<sup>†</sup> Pearson's chi-squared test.

<sup>\*\*</sup> Analysis of variance.

**Table 2**  
Medical comorbidities and intraoperative variables among patients undergoing PCL reconstruction.

Comorbidities	Non-Obese	Obese	p-value <sup>†</sup>
Total patients, n	258	156	
COPD, n (%)	0 (0.0)	1 (0.6)	0.198
Hypertension, n (%)	12 (4.7)	26 (16.7)	<b>&lt;0.001</b>
Chronic steroid use, n (%)	0 (0.0)	1 (0.6)	0.198
Bleeding disorder, n (%)	1 (0.4)	1 (0.6)	0.719
Diabetes Mellitus, n (%)	4 (1.6)	4 (2.6)	0.468
Dyspnea, n (%)			0.068
No dyspnea	258 (100.0)	154 (98.7)	
Moderate exertion	0 (0.0)	2 (1.3)	
Anesthesia type, n (%)			0.733
General	243 (94.2)	148 (95.5)	
Neuraxial	9 (3.5)	5 (3.2)	
Regional	1 (0.4)	1 (0.6)	
MAC	5 (1.9)	1 (0.6)	

Bolding equals significance  $p < 0.05$ .

PCL, posterior cruciate ligament; COPD, chronic obstructive pulmonary disease; MAC, monitored anesthetic care.

<sup>†</sup> Pearson's chi-squared test.

**Table 3**  
Bivariate Analysis of Postoperative Complications of Patients Following PCL Reconstruction.

Complications	Non-Obese	Obese	p-value <sup>†</sup>
Total patients, n	258	156	
Superficial Surgical Site Infection, n (%)	0 (0.0)	1 (0.6)	0.198
Wound Dehiscence, n (%)	1 (0.4)	0 (0.0)	0.436
Transfusion Requirement, n (%)	1 (0.4)	0 (0.0)	0.436
Deep Vein Thrombosis, n (%)	2 (0.8)	1 (0.6)	0.876
Postoperative Admission, n (%)	66 (25.6)	56 (35.9)	<b>0.026</b>
Reoperation, n (%)	0 (0.0)	1 (0.6)	0.198

Bolding equals significance  $p < 0.05$ .

PCL, posterior cruciate ligament.

<sup>†</sup> Pearson's chi-squared test.

**Table 4**  
Multivariate analysis of postoperative complications of patients following PCL reconstruction.

Obese (versus Non-Obese)	Odds Ratio	95% CI	P-value
Postoperative Admission	1.661	1.004	2.749
			<b>0.048</b>

Bolding equals significance  $p < 0.05$ .

PCL, posterior cruciate ligament; CI, confidence interval.

#### 4. Discussion

Obesity is a known risk factor for post-surgical complications across hip and knee arthroplasty, knee arthroscopy, and fracture treatment [5–10]. Patients who are obese often have a higher cost of care associated with the management of other potential comorbidities, increased operative time, and longer hospital stays [14–16]. PCL reconstruction has a relatively high complication rate of 20.1% [4], but no literature exists on the effects of obesity on postoperative outcomes in patients undergoing PCL reconstructive surgery.

Therefore, our study aimed to address the gaps in the literature by examining the impact of obesity on 30-day complications for isolated PCL reconstruction. We predicted that obese patients would have an increased risk of 30-day complications compared to non-obese patients. Our results do not support our hypothesis, as no significant difference was found among the 30-day complications analyzed between the two cohorts for isolated PCL reconstruction. Compared to non-obese patients, obese patients were more likely to be older, have hypertension, and have a higher ASA score. Following PCL reconstruction, those with obesity were more likely to be admitted to the hospital overnight.

The current arthroscopic literature demonstrates an association of obesity with an increase in postoperative complications [7–12]. A similar study on anterior cruciate ligament reconstruction found that a BMI greater than 40 kg/m<sup>2</sup> is an independent predictor of overnight hospital stay (OR 2.97) and any peri- or postoperative complication (OR 2.10) [12]. However, our study on PCL reconstruction only investigated patients with a BMI over 30 kg/m<sup>2</sup> and the average BMI in the obese group

was 35.08 kg/m<sup>2</sup>. Therefore, the effect of a BMI greater than 40 kg/m<sup>2</sup> on overnight hospital stay and peri-or postoperative complications for PCL reconstruction is unknown.

Other studies have found obese patients to have a significantly longer duration of multi-ligament arthroscopic knee reconstruction compared to those who are not obese (219.8 vs 178.6 minutes) [25]. Furthermore, these studies concluded that increased operative time of various arthroscopic procedures is associated with an increased risk of postoperative hospital admission [12,26,27]. For PCL reconstruction, it has been shown that increased operative duration is associated with an increased risk of hospital stay (OR 5.04) [22]. Therefore, it could be that obese patients experience longer surgical time for PCL reconstruction, thus increasing their risk for postoperative hospital admission compared to non-obese patients.

Our study found that obese patients who undergo PCL reconstruction are more likely to have hypertension and an ASA class of III or IV. A similar study found that obese patients with hypertension exhibit an increased risk of complications with open ankle fracture reduction versus non-obese patients with hypertension (OR, 1.45; 95% CI, 1.04–2.01;  $P = 0.0286$ ) [14]. Additionally, literature on risk factors for knee arthroscopy complications found ASA class III or IV as a risk factor for surgical complications [OR 5.39; CI, 3.11–9.33;  $P < 0.001$ ] [9]. However, our study controlled for hypertension and ASA class on multivariate analysis to solely examine the impact of obesity on complications. Therefore, it is possible that either hypertension or ASA class are also risk factors for PCL complications. Future studies should investigate whether these variables are independent risk factors for complications in PCL reconstruction.

The main strength of our study is that the NSQIP database utilized data from numerous institutions, resulting in a large sample size, which helped strengthen the internal and external study validity. However, there are several inherent limitations to using this database. Our analysis utilized CPT billing codes to determine procedures as well as inclusion and exclusion criteria so the final data could have been affected by human error when billing for the PCL reconstruction included in this study. Additionally, NSQIP does not provide information on the type of graft used for PCL reconstruction, so the exact timing of surgery is unknown.

A second limitation is the inability to evaluate patient-reported outcome measures following the operation, such as additional environmental and social factors that may correspond to a patient's overall well-being and satisfaction. Additionally, some patients may have experienced postoperative surgical complications beyond the 30-day period. Therefore, future studies should include more extended follow-up periods for postoperative outcomes to address this limitation.

There are also limitations associated with evaluating isolated PCL reconstruction. Overall, it is a relatively infrequent procedure that generally has good results. Therefore, the sample size for data analysis needs to be robust to detect differences in complication rates due to the rarity of complications. Studies should continue to examine isolated PCL reconstruction as the sample size should increase over the years.

## 5. Conclusion

To our knowledge, this is the first article to evaluate the impact of obesity on complications in isolated PCL reconstruction. There were no significant 30-day complications between patients with and without obesity. However, our results and the heterogeneity in the literature indicate that obesity has a significant effect on the rates of hospital admission following PCL reconstruction. It merits consideration of refraining from performing isolated PCL injuries on obese patients in stand-alone surgery centers as there is an increased complication of unintended hospitalization. Overall, it is essential for surgeons to carefully weigh the risks and benefits of operating on obese patients and planning surgery settings accordingly, as obese patients may require postoperative hospital admission. This study supports that patients with a BMI > 30 kg/m<sup>2</sup> are at increased risk of requiring postoperative hospital admission after PCL reconstruction.

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Theodore Quan. The first draft of the manuscript was written by Anna Maria Ifarraguerra and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

## 6. Statements and declarations

The authors have no relevant financial or non-financial interests to disclose. The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. Each author certifies that they have no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest with the submitted article.

## 7. Compliance with ethical standards

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was exempt from IRB approval by the George Washington University institutional review board and individual consent from this retrospective analysis was waived.

## Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: 'All authors have completed the ICMJE uniform disclosure form. The authors have no conflicts of interest to declare'.

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