Functional Outcomes After Isolated and Combined Posterior Cruciate Ligament Reconstruction in a Military Population

LTC Christopher J. Tucker,* MD, Eric J. Cotter,[†] MD, Brian R. Waterman,[‡] MD,
MAJ Kelly G. Kilcoyne,[§] MD, Kenneth L. Cameron,[||] PhD, MPH, ATC,
and Brett D. Owens,[¶#] MD, MC USA
Investigation performed at the William Beaumont Army Medical Center, El Paso, Texas, USA

Background: The rates of return to full activity, persistent disability, complications, and surgical revisions after operative management of posterior cruciate ligament (PCL) tears in a physically active population have not been reported.

Purpose: To evaluate the clinical outcomes of active military patients with symptomatic PCL tears who underwent surgical reconstruction and compare outcomes between isolated PCL and multiligament injuries.

Study Design: Cohort study; Level of evidence, 3.

Methods: Individuals undergoing surgical reconstruction of the PCL (Current Procedural Terminology code 29889) were isolated from the Military Health System Management Analysis and Reporting Tool between fiscal years 2005 and 2010. Demographic variables and rates of postoperative complications, activity limitations, rates of revision surgery, physical disability ratings, and ultimate medical discharge were recorded from the electronic medical record and US Army Physical Disability Agency database.

Results: A total of 182 patients underwent 193 surgeries, including 118 isolated PCL reconstructions and 75 multiligament knee reconstructions, with an average follow-up of 19.5 months. There were 174 primary procedures and 19 revision reconstructions. The mean ± SD patient age was 28.4 ± 7.2 years, with males comprising 96.2% of patients. The overall surgical complication rate was 12.4%, with a significantly higher rate in multiligament knee reconstructions compared with isolated PCL reconstructions (18.7% vs 8.5%; $P = .045$). Overall, 35.1% of patients were discharged from military service due to disability. Rates of discharge were significantly higher in those undergoing surgery at lower volume institutions (those that performed <2 PCL reconstructions per year during the study period) than those at higher volume institutions (41.1% vs 26%; $P = .040$). The overall revision rate was 10.9%, with no significant difference between the isolated PCL and multiligament knee reconstructions. Of the 103 patients with primary isolated PCL reconstructions, 35% underwent medical discharge for persistent knee complaints, and 12.6% required revision PCL reconstruction. The overall failure rate for primary isolated PCL reconstructions, which includes both revision surgery and knee-related medical discharge from military service, was 42.7%.

Conclusion: In a physically active, military population, nearly one-third of patients were unable to return to previous level of military function, and 12.6% required revision at short-term follow-up due to persistent instability. Perioperative complication rates were significantly higher among patients with multiligament knee reconstructions.

Keywords: posterior cruciate ligament; disability; military; knee reconstruction

Posterior cruciate ligament (PCL) injuries occur in up to 44% of acute knee injuries[34]; however, isolated PCL tears are less common, with a reported incidence ranging from 1% to 4%.[23,29] PCL insufficiency has been shown to alter knee kinematics, leading to instability and degenerative chondral changes, especially during functional activities.[9,11,21,36] Authors have described nonoperative management as a viable treatment option for isolated grade 1 or 2 PCL tears or in patients with lower physical demands[3,8,17,24,28,33] and operative management for patients with grade 3 PCL tears or in whom nonoperative management has failed.[3] However, clinical outcomes of operative management remain variable, with many patients continuing to experience knee instability and pain, especially for physically demanding populations such as military personnel.[4,15,16] These injuries are frequently concomitant with multiligament injuries, leading to challenges in isolating clinical outcomes of PCL reconstructions alone. Further, multiligament injuries typically represent high-energy mechanisms leading to more variables that could potentially affect clinical outcome. Despite advances in PCL reconstruction techniques, current operative

approaches have demonstrated inconsistent results in restoring normal knee stability and returning patients to full activity.[13,22,29] Due to the low incidence of PCL injuries and subsequent surgical management, most of the literature regarding operative management of PCL injuries focuses on techniques, with limited data on clinical and functional outcomes. Furthermore, studies that have critically evaluated outcomes mostly consist of smaller patient subsets (ie, <50 patients), with the exception of a recent registry study from the Danish Knee Ligament Reconstruction Registry and a recent study from Denmark.[6,20,25,35] Given the limited number of studies with a large number of cases, it is difficult to evaluate the clinical efficacy of operative management of PCL tears, especially as it relates to highly active patient populations such as military personnel.

Although several case series have been published,[1,10,20] no previous study has rigorously evaluated the rates of return to full activity, persistent disability, complications, and surgical revisions after operative management in a large, physically active population. The purpose of this study was to quantify the rate of surgical failure and postoperative disability after surgical reconstruction of PCL tears as well as to identify demographic and surgical factors associated with poor outcomes in patients who had isolated PCL reconstruction and those who underwent multiligament reconstructions including the PCL. In addition, we sought to compare clinical outcomes between isolated PCL and multiligament reconstructions. We hypothesized that multiligament knee reconstructions and lower facility volume would be associated with worse postoperative outcomes.

METHODS

Military servicemembers and other TRICARE beneficiaries are prospectively entered into the Military Health System (MHS) Management Analysis and Reporting Tool (M2). The M2 database, in conjunction with the MHS database, provides beneficiary data, demographics, selected clinical information, and billing/coding information as it relates to the use of medical and surgical services. This database has more than 9.5 million beneficiaries and has been previously used to define cohorts for clinical research purposes.[38]

All patients who underwent arthroscopic surgical reconstruction of the PCL (Current Procedural Terminology code 29889) between 2005 and 2010 were isolated. After this patient cohort was isolated from the M2 database, a retrospective, independent review of the electronic medical record of clinical encounters and radiology reports from the Armed Forces Health Longitudinal Technology Application (version 3.6.0; 3M Health Information Systems) was performed. Two investigators (C.J.T., B.R.W.) confirmed the clinical diagnosis as well as identified primary and secondary surgical procedures, surgical history, subjective and objective clinical course, medical discharge status, and initiation of a Physical Evaluation Board (PEB) assessment due to persistent ipsilateral knee symptoms.

Operative indications for PCL reconstruction included posterior instability that was refractory to conservative measures with (1) grade 2 or 3 on posterior drawer examination or (2) grade 2 or 3 PCL injury with combined anterior cruciate ligament (ACL), posterolateral corner, and/or posteromedial corner injuries.

Demographic variables including age (collected as a continuous variable at the time of surgery), sex, and military rank were extracted. In addition, surgical variables were recorded, including the treatment facility's surgical volume (defined as low volume if <2 cases per year and high volume if ≥2 cases per year during the study period), revision or primary PCL reconstruction, associated procedures performed, and time to final clinical follow-up. Case volume was defined by 2 cases as we noticed that several centers performed an average of 1 case or fewer per year whereas several other centers performed several cases per year.

We recorded rates of postoperative complications; rates of revision surgery; activity limitations; postoperative physical examination; knee-related disability defined as persistent, rate-limiting knee pain and/or symptomatic instability; and rates of medical discharge. For the purposes of this study, overall surgical failure was the primary outcome of interest and was defined as either the requirement for revision PCL reconstruction surgery or medical discharge due to persistent knee complaints. For

#Address correspondence to Brett D. Owens, MD, MC USA, Brown University Alpert School of Medicine, 1 Kettle Point Avenue, East Providence, RI 02914, USA (email: owensbrett@gmail.com).

*Department of Orthopedic Surgery and Rehabilitation, Fort Belvoir Community Hospital, Fort Belvoir, Virginia, USA.

†Department of Orthopedics and Rehabilitation, University of Wisconsin School of Medicine, Madison, Wisconsin, USA.

‡Department of Orthopaedic Surgery, Wake Forest University School of Medicine, Wake Forest Baptist Health, Winston-Salem, North Carolina, USA.

§Department of Orthopaedic Surgery, William Beaumont Army Medical Center, El Paso, Texas, USA.

‖Department of Orthopaedic Surgery, Keller Army Community Hospital, West Point, New York, USA.

¶Department of Orthopaedic Surgery, Brown University Alpert School of Medicine, Providence, Rhode Island, USA.

complications, loss of range of motion was defined as knee flexion less than 90° or a greater than 5° deficit in terminal extension. For identified military servicemembers who underwent PEB assessment to determine fit-for-duty status, the US Army Physical Disability Agency database was cross-referenced to isolate only those patients who were declared unfit for duty and for whom military discharge was indicated because of significant postoperative knee symptoms. Operational definitions were established for predictors used in the analysis: Patient subjective postoperative instability meant that at the postoperative appointments, the patient noted that the operative knee felt unstable during weightbearing. Postoperative inpatient admission meant that a patient spent at least 1 night in the hospital following surgery. Finally, a positive posterior drawer test was defined on a binary scale of either stable with firm endpoint or positive. The planned analyses included overall complication rates, clinical outcomes including disability rating, medical discharge, and reoperation; subanalysis was performed separating multiligament injuries from isolated PCL reconstructions. Variables including demographics, intraoperative information, and postoperative follow-up subjective patient information as well as examination findings were evaluated for prediction of clinical outcomes.

Statistical Analysis

Standard descriptive statistics including means and standard deviations for continuous variables and counts and frequencies for categorical variables were calculated. Initially, univariate logistic regression analyses were performed to correlate disability with PCL reconstructions as well as variables associated with clinical outcomes. To directly compare for categorical variable comparisons, chi-square tests were performed. The analysis was then repeated on the subset of primary, isolated PCL reconstructions 2 additional times using 2 separate primary outcomes: disability and overall surgical failure rate. Odds ratios (ORs) and 95% confidence intervals were calculated and reported for the variables of interest for all univariate logistic regression analyses. For all analyses, $P < .05$ was deemed significant. All statistical analyses were performed by use of STATA/SE software version 10.1 (StataCorp).

RESULTS

Descriptive Analysis

Of 280 patients identified with PCL reconstruction surgery from the M2 database, a detailed review of electronic medical records led to the exclusion of 87 as duplicate entries or coding errors. Thus, a total of 193 procedures in 182 patients were available for analysis, including 118 isolated PCL reconstructions and 75 multiligament knee reconstructions that included a PCL reconstruction. Of the total procedures, 174 were primary surgeries and

TABLE 1
Demographic and Operative Variables[a]

Total patients	182
Total procedures	193
Isolated PCLR	118 (61.1)
Multiligament reconstruction	75 (38.9)
Primary PCLR	174 (90.2)
Isolated PCLR	103 (59.2)
Multiligament reconstruction	71 (40.8)
Revision PCLR	19 (9.8)
Isolated PCLR	15 (78.9)
Multiligament reconstruction	4 (21.1)
Age, y, mean ± SD	28.4 ± 7.2
Time to final follow-up, mo, mean ± SD	19.5 ± 19.1
Male sex	175 (96.2)
Military rank	
Junior enlisted (E1-E4)	59 (32.4)
Senior enlisted (E5-E9)	84 (46.2)
Commissioned or warrant officers (O1-O6; W1-CW5)	39 (21.4)

[a]Values are expressed as n or n (%) except where otherwise noted. CW, commissioned warrant; E, enlisted; O, officer; PCLR, posterior cruciate ligament reconstruction; W, warrant.

19 were revisions. Complete demographic information can be found in Table 1.

Complications

A total of 24 complications occurred in 23 patients for an overall surgical complication rate of 12.4%. The most frequent complications included symptomatic hardware (n = 11; 5.7%) requiring hardware removal, loss of range of motion (n = 5; 2.6%) requiring either manipulation under anesthesia or arthroscopic lysis of adhesions, infection (n = 4; 2.1%), tibial artery injury (n = 2; 1.0%) requiring surgical repair, (n = 2; 1.0%), and common peroneal nerve injury (n = 2; 1.0%) (Table 2). Multiligament knee reconstructions had a significantly higher rate of total complications than isolated PCL reconstructions (18.7% vs 8.5%; $P = .045$).

Clinical Outcomes

Overall, 61 of 174 patients (35.1%) undergoing primary PCL reconstruction were discharged from military service due to knee-related disability, defined as persistent, rate-limiting knee pain and/or symptomatic instability. Rates of discharge were significantly higher in those undergoing surgery at lower volume institutions than those at higher volume institutions (41.1% vs 26%; $P = .040$).

Of the 193 index procedures analyzed, including both isolated and combined PCL reconstructions, an overall reoperation rate of 30% (n = 58) was noted. The difference in reoperation rates between isolated PCL surgery (n = 31/118; 26.3%) and multiligament surgery (n = 27/75; 36%) did not reach statistical significance ($P = .177$).

TABLE 2
Clinical Outcomes and Complications[a]

Variable	No. (%)
Complications	
Total	24 (12.4)
Symptomatic hardware	11 (5.7)
Loss of range of motion	5 (2.6)
Infection	4 (2.1)
Common peroneal nerve injury	2 (1.0)
Artery injury	2 (1.0)
Deep venous thrombosis	1 (0.5)
Intra-articular loose body	1 (0.5)
Discharged from military	61 (35.1)
Reoperation	
Total	58 (30.0)
Revision PCLR	21 (10.9)
Revision of ligament other than PCL	15 (7.8)
Removal of painful hardware	11 (5.7)
Cartilage procedure	8 (4.1)
MUA or LOA	5 (2.6)
High tibial osteotomy	4 (2.1)
Isolated PCLR, disabled at final follow-up	36 (35)
Isolated PCLR, failed to revision PCLR	13 (12.6)
Overall failure of isolated PCLR	44 (42.7)

[a]A total of 24 patients had complications; several patients had more than 1 complication. LOA, lysis of adhesions; MUA, manipulation under anesthesia; PCL, posterior cruciate ligament; PCLR, PCL reconstruction.

The overall revision PCL reconstruction rate was 10.9%, with no significant difference between isolated PCL (n = 15; 12.7%) and multiligament knee reconstructions (n = 6; 8.0%) ($P = .306$). Of the 103 patients with primary isolated PCL reconstructions, 35% were disabled at final follow-up and 12.6% required revision PCL reconstruction. The overall failure rate for primary isolated PCL reconstructions, which includes revisions or medical discharge from military service, was 42.7% (Table 2).

Risk Factors

Univariate logistic regression analyses on all primary PCL reconstructions including multiligament reconstructions revealed that facility surgical volume as a continuous variable (OR, 0.95; $P = .029$), patient-reported postoperative instability (OR, 3.14; $P = .002$), postoperative inpatient admission (OR, 1.89; $P = .049$), junior enlisted rank (OR, 10.96; $P < .001$), and senior enlisted rank (OR, 6.71; $P = .003$) were significantly associated with disability. The OR of 0.95 means that for every additional case that was performed at a given facility during the study period, there was an associated 5% lower risk of disability for each patient at that facility. These analyses can be found in Table 3.

Given the limited sampling of revision surgeries and the wide variability of the multiligament knee reconstructions, univariate analysis was performed for the subset of isolated, primary PCL reconstructions. Then, 3 separate univariate analyses were conducted on this

TABLE 3
Summary of Univariate Logistic Regression Analysis for Risk Factors Associated With Inferior Clinical Outcomes in All Primary PCLRs Including Multiligament Reconstructions Followed by Only Isolated, Primary PCLR[a]

Variable	Odds Ratio	95% CI	P
Facility surgical volume	0.95	0.91-0.99	**.029**
Patient subjective postoperative instability	3.14	1.55-6.39	**.002**
Postoperative inpatient admission	1.89	1.00-3.55	**.049**
Officer	Ref	Ref	Ref
Junior enlisted rank	10.96	3.03-39.64	**<.001**
Senior enlisted rank	6.71	1.89-23.80	**.003**
Age	0.98	0.94-1.02	.352
Sex	3.36	0.40-28.61	.267
Postoperative VAS pain score	1.79	0.93-3.46	.083
Need for revision PCLR	1.20	0.44-3.28	.719
Positive postoperative posterior drawer	0.91	0.45-1.84	.787

[a]Bolded P values indicate statistical significance ($P < .05$). PCLR, posterior cruciate ligament reconstruction; VAS, visual analog scale.

specific subset, using the primary outcome measures of disability, need for revision surgery, and overall surgical failure. These analyses can be found in Table 4.

DISCUSSION

The results of this study suggest that patients undergoing PCL reconstruction at lower volume military medical institutions are more likely to have inferior clinical outcomes. In addition, although the revision rate for isolated, primary PCL reconstruction was only 12.6%, the overall failure rate due to persistent pain and/or instability was significantly higher at 42.7%. In those patients who underwent isolated, primary PCL reconstruction, patient-reported postoperative instability (OR, 6.96), visual analog scale pain score ≥3 out of 10 (OR, 2.62), repeat surgery (OR, 2.65), and junior enlisted rank (OR, 3.21) were associated with overall surgical failure. Collectively, these demographic and operative factors were associated with inferior clinical outcomes in the current study, and these factors can be addressed during counseling of patients who may be candidates for PCL reconstruction.

To date, the vast majority of studies regarding PCL reconstruction are relatively small (<50 patients), retrospective investigations focusing on specific reconstruction techniques as opposed to variables associated with superior or inferior clinical outcomes.[14] The present study contributes an analysis of one of the largest known single cohorts of patients to date,[20] with full clinical disability outcomes data analysis on 193 procedures in 182 patients, of which there were 103 primary isolated PCL reconstructions. This sample size, along with the available disability data, allows for a unique analysis of certain risk factors for failure, complications, and

TABLE 4
Summary of Univariate Logistic Regression Analysis
for Risk Factors Associated With Inferior Clinical
Outcomes in Only Isolated, Primary PCLR[a]

Variable	Odds Ratio	95% CI	*P*
Isolated, primary PCLR risk factors for revision			
Age	0.99	0.91-1.08	.167
Sex	NA		
Facility surgical volume	1.05	0.97-1.13	.243
Patient subjective postoperative instability	17.33	3.54-84.82	**<.001**
Same-day surgery	1.03	0.31-3.40	.962
Postoperative VAS pain score $\geq$3	2.42	0.69-8.48	.083
Revision of other ligament(s)	26.7	2.53-281.57	**.006**
Complication	3.09	0.53-17.89	.208
Positive postoperative posterior drawer	2.63	0.448-1.838	.787
Isolated, primary PCLR risk factors for overall surgical failure			
Age	0.98	0.92-1.03	.374
Sex	3.26	0.35-30.22	.298
Facility surgical volume	0.97	0.92-1.03	.343
Patient subjective postoperative instability	6.96	2.65-18.29	**<.001**
Same-day surgery	1.17	0.53-2.62	.694
Postoperative VAS pain score $\geq$3	2.62	1.13-6.02	**.023**
Repeat surgery	2.65	1.06-6.61	**.037**
Positive postoperative posterior drawer	1.16	0.49-2.75	.738
Junior enlisted rank	3.21	1.01-10.26	**.049**
Senior enlisted rank	2.40	0.81-7.13	.116

[a]Bolded *P* values indicate statistical significance (*P* < .05). NA, not applicable; PCLR, posterior cruciate ligament reconstruction; VAS, visual analog scale.

surgical outcomes not otherwise seen in smaller sample sizes. Our study demonstrated the importance of surgical volume on clinical outcomes in what is an infrequently performed procedure. Specifically, for each additional PCL case a center performs, patients are 5% less likely to be discharged from military service, to be on disability, or to meet criteria for surgical failure. This point has been reported previously within orthopaedics, as investigators noted improved outcomes and fewer adverse events when procedures were performed by high-volume surgeons and in high-volume medical centers.[18,32] Scott et al[32] also noted the economic benefits of having procedures, including ACL reconstruction, performed at high-volume centers as compared with medium- or low-volume centers due to lower readmission, prolonged readmission, and subsequent surgery rates. The present study identified high rates of disability in isolated and multiligament reconstructions that led to inpatient admission. This is likely due to many of these patients undergoing multiligament reconstructions, which are longer, more complex cases than isolated PCL reconstructions. Providers may keep these patients overnight in the hospital for pain control and postanesthesia monitoring.

As reported in this study, the surgical complication rate was significantly higher in multiligament reconstructions, so inpatient admission is likely a surrogate marker of more complex cases with more complications, given that these findings were not present when isolated PCL reconstructions were analyzed alone.

The present study found that lower enlisted rank (junior) had significantly greater odds of surgical failure compared with higher enlisted rank, including officers. This finding of worse outcomes in more junior-ranked military servicemembers has been reported previously in several military studies.[2,5,39] Others have noted a decreased incidence of orthopaedic injuries in military officers compared with junior enlisted ranked personnel.[12] These data support the findings of the current study and are not surprising. More junior military personnel are more frequently involved in higher activity level military exercises and combat compared with officers.

Recently, the Danish Knee Ligament Reconstruction Registry reported clinical outcomes of 237 isolated PCL reconstructions and 344 multiligament reconstructions with combined PCL reconstruction at 1-year follow-up.[20] The authors were able to obtain patient-reported outcome measures, specifically, the Knee injury and Osteoarthritis Outcome Score (KOOS) and Tegner functional score, to better quantify the patients' subjective experience of their outcome. The authors reported an improvement in the KOOS from preoperative to 1-year follow-up for both isolated PCL reconstructions and multiligament reconstructions but were careful to note that the degree of improvement was not commensurate with that seen with ACL reconstruction. By comparison, the authors reported a significantly lower reoperation rate for both isolated PCL reconstructions (3%) and multiligament PCL reconstructions (3.4%) than the current study (isolated PCL reconstruction, 26.3%; multiligament, 36%).[20] One potential reason for this disparity in reoperation rates is that the current study population is an extremely active patient demographic with routine mandated physical fitness requirements that likely subject PCL grafts to high tensile loads and shear stress. However, rates of clinical failure, defined as a KOOS less than 40 at final follow-up, were far more commensurate with the current study. Under this framework, the Danish study documented that up to 35% of isolated PCL reconstructions and 45% of multiligament reconstructions were classified as subjective failures, indicating a high rate of residual surgical site morbidity.[20] Although we did not have KOOS and Tegner outcomes in the current study, our overall failure rate was comparable with the subjective failure rate reported by the Danish investigators. What is clear from the results of the study by Lind et al[20] and the present study is that further investigation is necessary in this challenging patient population to identify patient- and surgery-specific variables, specifically patient age, the presence of concomitant meniscal and/or cartilage lesions, double-bundle versus single-bundle technique, choice of graft, and preoperative Tegner scores, all of which may be integral in achieving a successful outcome with diligent assessment of patient-reported outcome measures at longer term follow-up.

The complications seen in PCL reconstructions are not unlike those seen in ACL reconstructions. Different graft techniques, graft types, approaches, and fixation strategies have been proposed for both PCL and ACL reconstructions.[6] What remains of paramount importance in minimizing complications in both is tunnel placement. Poorly placed tunnels that do not re-create the native anatomic features predispose patients to instability and inferior outcomes. Using a biomechanical model, Okoroafor et al[26] demonstrated how nonanatomic tibial tunnel placement led to greater posterior tibial translation. This has been described in the ACL literature as a common cause of failure as well.[7] With a transtibial approach in PCL reconstruction, the graft may undergo abrasion and attenuation due to the "killer turn," potentially resulting in graft failure over cyclic loading.[19] Other complications including septic arthritis and venous thromboembolic events are rare but serious complications of both PCL and ACL reconstruction surgery. The rates of septic arthritis ($\sim$0.5%) are low in both PCL and ACL reconstruction.[30,31,37] Blood vessel injury is a complication that is more commonly seen in PCL reconstruction than in ACL reconstruction due to the anatomic nature of the ligaments. Although injury to the popliteal vessels is rare, it must be discussed with patients preoperatively.[27] The complication rate of PCL reconstructions demonstrated in the present study is higher than that of ACL reconstructions reported in prior studies, with multiligament reconstructions having the highest complication rates of all. These data should be discussed with patients at preoperative appointments to set appropriate expectations.

Limitations

The strengths of this study include its large sample size; high-demand, physically active cohort; closed patient population; and required periodic health assessments. However, this study had several limitations and entailed some factors that could not be controlled. The surgical technique including type of graft and specific approach (all-inside vs inlay, single-bundle vs double-bundle) was inconsistently reported in the medical charts and thus could not be assessed. This study used a large, closed health care network that included patients from multiple centers and from multiple surgeons with different levels of experience; therefore, it is likely that surgical technique including graft type varied as well as rehabilitation protocols. This study had a relatively short mean follow-up of 19.5 ± 19.1 months and included a wide follow-up range (1.2-85.3 months), which is in large part due to the significant number of patients who met a failure endpoint, specifically medical discharge from the military shortly after their procedure. Preoperative and postoperative radiographic and magnetic resonance imaging data were inconsistently recorded in the charts and could not be analyzed as part of this study. The time from injury to surgery was inconsistently recorded and could not be analyzed as a variable correlated with clinical outcomes, nor could we analyze what role this may have had in development of chondral changes. Likewise, the process of medical discharge from the military is a protracted process,

making it challenging to follow the initiation date, decision date, and final separation date. Patient discharge from the military is not a standardized process; therefore, according to subjective and objective data, patients could be discharged from the military by the treating center prior to a 9-month recovery period. The present study evaluated only those patients treated operatively, so we cannot comment on PCL injuries successfully managed nonoperatively or on patients who received medical discharge prior to PCL reconstruction. Multivariate regression analysis was not performed due to insignificant findings on univariate analysis for many demographic predictors including age and sex, which would not have been carried forward in a multivariate model. Further, a limited number of variables were available in sufficient numbers to accommodate multivariate models. Validated patient-reported outcome measures were inconsistently obtained at the various clinical sites and thus were not available for analysis. As a result, these data may represent a more conservative estimate of surgical failure after PCL reconstruction and may fail to account for those patients experiencing significant impact on quality of life and functionality who have not yet received medical discharge or undergone revision PCL reconstruction. Conversely, some servicemembers may have persistent knee instability, but their operational specialty or other motivating factors preclude their pursuit of medical discharge or clinical evaluation for revision surgery. Of note, some patients may have required treatment at the Veterans Administration health system after they left active duty, which would not be captured in this study. Finally, we cannot exclude those servicemembers with secondary gain motivations who may pursue medical discharge under the pretense of persistent knee instability or other functional complaints. As the military moves toward a more robust and integrated multicenter orthopaedic registry, we will be better able to control for and provide more details regarding patient- and surgery-specific variables not available in this study.

CONCLUSION

PCL deficiency is a significant contributor to disability in the active military population. Overall, a relatively high rate of disability occurs following PCL reconstruction surgery, both in isolated, primary PCL reconstructions and in all-comers (including multiligament reconstructions and revision surgery). Complication rates are significantly higher in multiligament reconstructions involving the PCL compared with isolated PCL reconstructions. Patient-reported postoperative subjective knee instability was the only variable associated with all 3 outcome measures of disability, revision surgery, and overall surgical failure after primary isolated PCL reconstruction.

REFERENCES

1. Ahmad S, Mahidon R, Shukur MH, Hamdan A, Kasmin M. Reconstruction for chronic grade-II posterior cruciate ligament deficiency

in Malaysian military personnel. *J Orthop Surg (Hong Kong)*. 2014; 22(3):325-328.

2. Balazs GC, Brelin AM, Donohue MA, et al. Incidence rate and results of the surgical treatment of pectoralis major tendon ruptures in active-duty military personnel. *Am J Sports Med*. 2016;44(7):1837-1843.

3. Bedi A, Musahl V, Cowan JB. Management of posterior cruciate ligament injuries: an evidence-based review. *J Am Acad Orthop Surg*. 2016;24(5):277-289.

4. Boynton MD, Tietjens BR. Long-term followup of the untreated isolated posterior cruciate ligament-deficient knee. *Am J Sports Med*. 1996;24(3):306-310.

5. Brelin AM, Donohue MA, Balazs GC, LeClere LE, Rue JH, Dickens JF. Incidence and risk factors for reoperation following meniscal repair in a military population. *J Surg Orthop Adv*. 2018;27(1):47-51.

6. Chahla J, Moatshe G, Cinque ME, et al. Single-bundle and double-bundle posterior cruciate ligament reconstructions: a systematic review and meta-analysis of 441 patients at a minimum 2 years' follow-up. *Arthroscopy*. 2017;33(11):2066-2080.

7. Di Benedetto P, Di Benedetto E, Fiocchi A, Beltrame A, Causero A. Causes of failure of anterior cruciate ligament reconstruction and revision surgical strategies. *Knee Surg Relat Res*. 2016;28(4):319-324.

8. Fowler PJ, Messieh SS. Isolated posterior cruciate ligament injuries in athletes. *Am J Sports Med*. 1987;15(6):553-557.

9. Gill TJ, DeFrate LE, Wang C, et al. The effect of posterior cruciate ligament reconstruction on patellofemoral contact pressures in the knee joint under simulated muscle loads. *Am J Sports Med*. 2004; 32(1):109-115.

10. Glenesk K, Fogarty BT, Westrick RB. Isolated posterior cruciate ligament injury. *J Orthop Sports Phys Ther*. 2013;43(10):759.

11. Goyal K, Tashman S, Wang JH, Li K, Zhang X, Harner C. In vivo analysis of the isolated posterior cruciate ligament-deficient knee during functional activities. *Am J Sports Med*. 2012;40(4):777-785.

12. Gun B, Dean R, Go B, Richardson C, Waterman BR. Non-modifiable risk factors associated with sternoclavicular joint dislocations in the U.S. military. *Mil Med*. 2018;183(5-6):e188-e193.

13. Gwinner C, Weiler A, Roider M, Schaefer FM, Jung TM. Tibial slope strongly influences knee stability after posterior cruciate ligament reconstruction: a prospective 5- to 15-year follow-up. *Am J Sports Med*. 2017;45(2):355-361.

14. Hammoud S, Reinhardt KR, Marx RG. Outcomes of posterior cruciate ligament treatment: a review of the evidence. *Sports Med Arthrosc Rev*. 2010;18(4):280-291.

15. Hermans S, Corten K, Bellemans J. Long-term results of isolated anterolateral bundle reconstructions of the posterior cruciate ligament: a 6- to 12-year follow-up study. *Am J Sports Med*. 2009; 37(8):1499-1507.

16. Jackson WF, van der Tempel WM, Salmon LJ, Williams HA, Pinczewski LA. Endoscopically-assisted single-bundle posterior cruciate ligament reconstruction: results at minimum ten-year follow-up. *J Bone Joint Surg Br*. 2008;90(10):1328-1333.

17. Jacobi M, Reischl N, Wahl P, Gautier E, Jakob RP. Acute isolated injury of the posterior cruciate ligament treated by a dynamic anterior drawer brace: a preliminary report. *J Bone Joint Surg Br*. 2010;92(10): 1381-1384.

18. Jain NB, Pietrobon R, Guller U, Ahluwalia AS, Higgins LD. Influence of provider volume on length of stay, operating room time, and discharge status for rotator cuff repair. *J Shoulder Elbow Surg*. 2005; 14(4):407-413.

19. LaPrade CM, Civitarese DM, Rasmussen MT, LaPrade RF. Emerging updates on the posterior cruciate ligament: a review of the current literature. *Am J Sports Med*. 2015;43(12):3077-3092.

20. Lind M, Nielsen TG, Behrndtz K. Both isolated and multi-ligament posterior cruciate ligament reconstruction results in improved subjective outcome: results from the Danish Knee Ligament Reconstruction Registry. *Knee Sports Surg Traumatol Arthrosc*. 2018;26(4): 1190-1196.

21. Logan M, Williams A, Lavelle J, Gedroyc W, Freeman M. The effect of posterior cruciate ligament deficiency on knee kinematics. *Am J Sports Med*. 2004;32(8):1915-1922.

22. MacGillivray JD, Stein BE, Park M, Allen AA, Wickiewicz TL, Warren RF. Comparison of tibial inlay versus transtibial techniques for isolated posterior cruciate ligament reconstruction: minimum 2-year follow-up. *Arthroscopy*. 2006;22(3):320-328.

23. Margheritini F, Rihn J, Musahl V, Mariani PP, Harner C. Posterior cruciate ligament injuries in the athlete: an anatomical, biomechanical and clinical review. *Sports Med*. 2002;32(6):393-408.

24. Matava MJ, Ellis E, Gruber B. Surgical treatment of posterior cruciate ligament tears: an evolving technique. *J Am Acad Orthop Surg*. 2009; 17(7):435-446.

25. Mygind-Klavsen B, Nielsen TG, Lind MC. Outcomes after posterior cruciate ligament (PCL) reconstruction in patients with isolated and combined PCL tears. *Orthop J Sports Med*. 2017;5(4): 2325967117700077.

26. Okoroafor UC, Saint-Preux F, Gill SW, Bledsoe G, Kaar SG. Nonanatomic tibial tunnel placement for single-bundle posterior cruciate ligament reconstruction leads to greater posterior tibial translation in a biomechanical model. *Arthroscopy*. 2016;32(7):1354-1358.

27. Osti M, Hierzer D, Seibert FJ, Benedetto KP. The arthroscopic all-inside tibial-inlay reconstruction of the posterior cruciate ligament: medium-term functional results and complication rate. *J Knee Surg*. 2017;30(3):238-243.

28. Parolie JM, Bergfeld JA. Long-term results of nonoperative treatment of isolated posterior cruciate ligament injuries in the athlete. *Am J Sports Med*. 1986;14(1):35-38.

29. Petrigliano FA, McAllister DR. Isolated posterior cruciate ligament injuries of the knee. *Sports Med Arthrosc Rev*. 2006;14(4):206-212.

30. Schuster P, Gesslein M, Mayer P, Schlumberger M, Mayr R, Richter J. Septic arthritis after arthroscopic posterior cruciate ligament and multi-ligament reconstructions is rare and can be successfully treated with arthroscopic irrigation and debridement: analysis of 866 reconstructions. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(10): 3029-3038.

31. Schuster P, Schulz M, Immendoerfer M, Mayer P, Schlumberger M, Richter J. Septic arthritis after arthroscopic anterior cruciate ligament reconstruction: evaluation of an arthroscopic graft-retaining treatment protocol. *Am J Sports Med*. 2015;43(12):3005-3012.

32. Scott DJ, Sherman S, Dhawan A, Cole BJ, Bach BR Jr, Mather RC III. Quantifying the economic impact of provider volume through adverse events: the case of sports medicine. *Orthop J Sports Med*. 2015;3(3): 2325967115574476.

33. Shelbourne KD, Clark M, Gray T. Minimum 10-year follow-up of patients after an acute, isolated posterior cruciate ligament injury treated nonoperatively. *Am J Sports Med*. 2013;41(7):1526-1533.

34. Shelbourne KD, Davis TJ, Patel DV. The natural history of acute, isolated, nonoperatively treated posterior cruciate ligament injuries: a prospective study. *Am J Sports Med*. 1999;27(3):276-283.

35. Spiridonov SI, Slinkard NJ, LaPrade RF. Isolated and combined grade-III posterior cruciate ligament tears treated with double-bundle reconstruction with use of endoscopically placed femoral tunnels and grafts: operative technique and clinical outcomes. *J Bone Joint Surg Am*. 2011;93(19):1773-1780.

36. Van de Velde SK, Bingham JT, Gill TJ, Li G. Analysis of tibiofemoral cartilage deformation in the posterior cruciate ligament-deficient knee. *J Bone Joint Surg Am*. 2009;91(1):167-175.

37. Waterman BR, Arroyo W, Cotter EJ, Zacchilli MA, Garcia EJ, Owens BD. Septic arthritis after anterior cruciate ligament reconstruction: clinical and functional outcomes based on graft retention or removal. *Orthop J Sports Med*. 2018;6(3):2325967118758626.

38. Waterman BR, Burns TC, McCriskin B, Kilcoyne K, Cameron KL, Owens BD. Outcomes after Bankart repair in a military population: predictors for surgical revision and long-term disability. *Arthroscopy*. 2014;30(2):172-177.

39. Zarkadis NJ, Belmont PJ Jr, Zachilli MA, et al. Autologous chondrocyte implantation and tibial tubercle osteotomy for patellofemoral chondral defects: improved pain relief and occupational outcomes among US Army servicemembers. *Am J Sports Med*. 2018;46(13): 3198-3208.