

Concomitant Medial Patellofemoral Ligament Reconstruction and Tibial Tubercle Osteotomy Do Not Increase the Incidence of 30-Day Complications

An Analysis of the NSQIP Database

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Background: Lateral patellar dislocations account for 2% to 3% of total knee injuries, especially in adolescents. Depending on the anatomic abnormality contributing to lateral patellar instability, medial patellofemoral ligament reconstruction (MPFLR) and/or tibial tubercle osteotomy (TTO) may be indicated.

Purpose: To assess the risk of adverse events (AEs) after TTO, MPFLR, and concomitant MPFLR and TTO.

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

Methods: Patients who underwent MPFLR, TTO, and concomitant MPFLR and TTO between 2005 and 2016 were identified through the American College of Surgeons–National Surgical Quality Improvement Program (ACS-NSQIP) database. Medical complications (eg, surgical site infection and deep vein thrombosis), readmission rates, and extended hospital stay within 30 days of the procedure were recorded. Outcomes were compared with bivariate and multivariate Poisson regression.

Results: Out of 882 patients, 617 (70.0%) underwent isolated MPFLR, 170 (19.3%) underwent TTO, and 95 (10.8%) underwent concomitant MPFLR and TTO. The operative time for concomitant MPFLR and TTO was significantly longer (122 ± 45 minutes) compared with isolated MPFLR (97 ± 55 minutes; $P < .001$) and isolated TTO (89 ± 51 minutes; $P < .001$). There were 32 AEs (3.6%), with 10 AEs in the isolated TTO group (5.9%), 18 AEs in the isolated MPFLR group (2.9%), and 4 AEs in the MPFLR + TTO group (4.2%). There was no significant difference in the rate of AEs between the isolated MPFLR and isolated TTO groups ($P = .1$), isolated MPFLR and MPFLR + TTO groups ($P = .5$), and isolated TTO and MPFLR + TTO groups ($P = .8$). Diabetes mellitus was associated with an increased risk of developing an AE (odds ratio, 4.0; $P = .003$), and hypertension resulted in an increased risk of an extended hospital stay (odds ratio, 4.0; $P = .010$).

Conclusion: While concomitant MPFLR and TTO significantly increased operative time, there was no difference in the rate of AEs, extended hospital stay, and readmissions within 30 days after isolated MPFLR, isolated TTO, and concomitant MPFLR and TTO.

Keywords: medial patellofemoral ligament; tibial tubercle osteotomy; patellar instability; patellar dislocation; complications; NSQIP

Lateral patellar dislocations account for 2% to 3% of total knee injuries, especially in adolescents, with the rate of recurrence after an initial dislocation ranging from 13% to 40%.^{3,18} The medial patellofemoral ligament (MPFL) provides nearly 60% of the medial restraining force to the patellofemoral joint and is often implicated in recurrent

lateral dislocations near full extension.^{6,12,15} Disruptions in the bony architecture or mechanical malalignment may also result in patellar maltracking, joint instability, or subsequent dislocations.³⁹ Left untreated, recurrent patellar dislocations can lead to reduced range of motion, quality of life, and activity levels.^{4,5} Operative management is indicated if patients continue to have apprehension after the dislocation event or recurrent dislocations.⁸

Depending on the anatomic abnormality contributing to the symptoms, MPFL reconstruction (MPFLR) and/or tibial

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tubercle osteotomy (TTO) may be indicated. The goal of MPFLR is to restore the restraining force on the patella during early flexion, while TTO addresses osseous abnormalities such as an elevated tibial tubercle–trochlear groove (TT-TG) distance or patella alta.^{9,12} Anatomic characteristics associated with recurrent patellar instability include trochlear dysplasia, patella alta, femoral anteversion, valgus malalignment, and increased TT-TG distance.²⁷ TTO medializes, anteriorizes, and/or distalizes the tibial tubercle to restore the native anatomy and allow for appropriate patellar tracking or engagement. Because of the belief that recurrent patellar instability stems from multifactorial anatomic deformities, TTO and MPFLR may be performed concurrently; however, isolated MPFLR is more commonly performed in the primary setting.²

Despite adequate functional outcomes after MPFLR and TTO,^{5,30} the procedures are associated with an 8.9% and 4.6% incidence of complications, respectively.^{2,27} Differences in the complication rate may be caused by variations in weightbearing status, rehabilitation protocol, or the duration of data collection in previous investigations. Although the incidence of complications after TTO and MPFLR has been previously reported, there is a paucity of evidence supporting whether there is a difference in complication rates in the immediate postoperative period when MPFLR and TTO are performed concomitantly.

The purpose of this investigation was to identify whether there is a higher risk of adverse events (AEs) after TTO or MPFLR in the early postoperative period and whether the rate of AEs increases when MPFLR and TTO are performed concurrently. We hypothesized that there are no inherent differences in the AE rate between TTO and MPFLR; however, the incidence of AEs increases in cases of concurrent TTO and MPFLR.

METHODS

This was a retrospective analysis of prospectively collected data from the American College of Surgeons–National Surgical Quality Improvement Program (ACS-NSQIP). This registry contains demographics, comorbidities, laboratory values, and concomitant procedures with corresponding readmission and complication rates within 30 days of the index procedure. Patients are identified through Current

Procedural Terminology (CPT) and International Classification of Diseases, 9th Revision (ICD-9) and 10th Revision (ICD-10) codes.¹⁷ The ACS-NSQIP database is composed of a network of 687 hospitals. Hospitals included in this database are required to employ clinical reviewers with a background in health care to collect more than 270 variables from surgical procedures. The database implements several quality assurance measures, such as biweekly random internal audits, which have reported less than 1.8% inter-rater disagreement.^{10,42} Because of the anonymity of the database, institutional review board approval was not needed for this investigation.

Patients were included if they were aged ≥ 18 years at the time of surgery and underwent isolated MPFLR (CPT: 27420, 27422, 27427), isolated TTO (CPT: 27418), or concomitant MPFLR and TTO (CPT: 27420, 27422, 27427 + 27418) between the years 2005 and 2016 for the diagnosis of recurrent instability, traumatic dislocations, and patellar instability. The ICD-9 codes for patellar instability that were queried in this investigation included 836.3, 718.36, and 718.86; the ICD-10 codes for patellar instability included M23.51, M23.52, M25.361, M25.362, M22.10, M22.11, M22.12, M22.00, M22.01, M22.02, M22.2X1, M22.2X2, M23.50, S83.004A, S83.005A, and S83.006A. A description of these codes is provided in Appendix Table A1. Patients were excluded if they underwent the aforementioned procedures without the inclusion of a diagnosis of patellar instability at the time of surgery. It was not discernable whether the procedure was primary or secondary for the abnormality. Patient demographics, including age, smoking status, comorbidities, sex, and American Society of Anesthesiologists (ASA) physical status classification score, were collected. An ASA score greater than 3 corresponded to severe systemic disease (new classification of physical status). A history of diabetes was reported as either insulin dependent, oral medication only, or no diabetes.

For each patient, the length of hospital stay, readmission rate, and 30-day complications were collected. Complications included superficial infections, deep wound infections, wound dehiscence, pneumonia, reintubation, progressive renal insufficiency, urinary tract infections, coma, placement on a ventilator, unplanned intubation, stroke/cerebrovascular accident, thromboembolic event (deep vein

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Ethical approval was not sought for the present study.

TABLE 1
Demographic and Comorbidity Characteristics for the Study Groups^a

	TTO (n = 170)	MPFLR (n = 617)	MPFLR+TTO (n = 95)	P Value		
				TTO vs MPFLR	TTO vs MPFLR+TTO	MPFLR vs MPFLR+TTO
Age, y	29 ± 10	31 ± 14	26 ± 8	.123	.064	.001
BMI, kg/m ²	30 ± 7	30 ± 8	29 ± 9	.808	.480	.528
Operative time, min	89 ± 51	97 ± 55	122 ± 45	.069	<.001	<.001
Female sex, %	27	39	33	.004	.397	.257
Dependent functional status, %	0	1	1	.357	.358	>.999
Diabetes mellitus, %	3	4	0	.816	.163	.059
DOE, %	1	3	0	.143	>.999	.148
Hypertension, %	8	11	4	.324	.309	.044
COPD, %	0	1	1	.591	.358	.578
Current smoker, %	21	23	16	.603	.414	.143
Lateral release, n (%)	52 (30.6)	73 (11.8)	11 (11.6)	<.001	<.001	>.999

^aData are reported as mean ± SD unless otherwise specified. Bolded P values indicate a statistically significant difference between groups (P < .05). BMI, body mass index; COPD, chronic obstructive pulmonary disease; DOE, dyspnea on exertion; MPFLR, medial patellofemoral ligament reconstruction; TTO, tibial tubercle osteotomy.

thrombosis or pulmonary embolism), cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, acute renal failure, sepsis, septic shock, return to the operating room, and death. Extended length of stay was defined as days from the procedure to postoperative discharge (≥2 days). This was to exclude patients who were kept on a 23-hour period of observation from being considered a complication. All values collected were from 2005 to 2016, except the readmission rate, which was from 2011 to 2016.

Statistical analysis was performed using RStudio software (version 1.0.143). A post hoc power analysis was performed with regard to AEs after MPFLR and TTO. Outcomes with bivariate variables were compared with bivariate and multivariate Poisson regression. Statistical analysis was performed on the original cohort as well as the matched propensity cohort. Statistical significance was achieved with P < .05.

RESULTS

A total of 882 patients were included in the investigation. With the ICD-9 and ICD-10 diagnosis codes for patellar instability, 617 (70.0%) patients underwent isolated MPFLR, 170 (19.3%) patients underwent TTO, and 95 patients (10.8%) underwent concomitant MPFLR and TTO. There was no statistical difference for most patient demographics between the isolated TTO and isolated MPFLR groups (P > .05) (Table 1); however, there were statistically significantly more female patients in the isolated MPFLR group than the isolated TTO group (P = .004) (Table 1). Patients were significantly older in the isolated MPFLR group than in the MPFLR + TTO group (P = .001), and operative time was significantly longer in the MPFLR + TTO group than in the isolated MPFLR and isolated TTO groups (P < .001 for both). Additionally, there was a statistically significant difference in the incidence of comorbid hypertension in the isolated MPFLR and MPFLR + TTO groups (P = .044). The utilization of isolated MPFLR (R² =

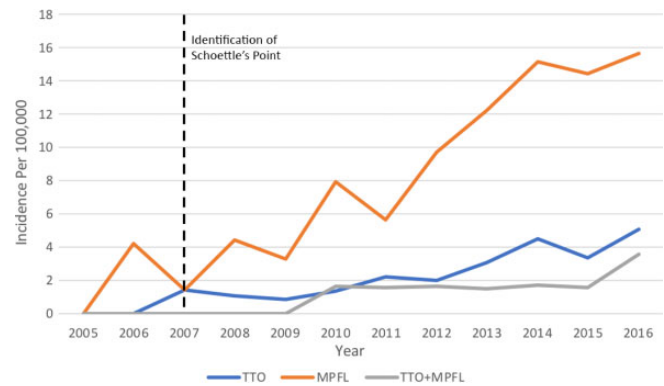


Figure 1. The surgical management of patellar instability significantly increased over the study period. MPFLR, medial patellofemoral ligament reconstruction; TTO, tibial tubercle osteotomy.

0.907, P < .001), isolated TTO (R² = 0.88, P < .001), and concomitant MPFLR and TTO (R² = 0.771, P < .001) increased over the duration of this investigation; however, the incidence of isolated MPFLR was greater at each time point (Figure 1).

There were 32 overall AEs (3.6%) within 30 days of the index procedure recorded in this investigation, with 10 AEs reported in the isolated TTO group (5.9%), 18 AEs in the isolated MPFLR group (2.9%), and 4 AEs in the MPFLR + TTO group (4.2%) (Table 2). There was no significant difference in the rate of developing an AE between the isolated MPFLR and isolated TTO groups (P = .1), isolated MPFLR and MPFLR + TTO groups (P = .5), or isolated TTO and MPFLR + TTO groups (P = .8).

Multivariate analysis of risk factor influences on AEs, extended length of hospital stay, and readmissions demonstrated that comorbid diabetes mellitus increased the risk of AEs (odds ratio, 4.0 [95% CI, 1.6-10.8]; P = .003),

TABLE 2
Adverse Events Overall and for the Study Groups^a

	MPFLR		MPFLR +	Overall
	TTO	MPFLR	TTO	
Any adverse event	10 (5.9)	18 (2.9)	4 (4.2)	32 (3.6)
Wound dehiscence	1 (0.6)	2 (0.3)	0 (0.0)	3 (0.3)
Sepsis	1 (0.6)	1 (0.2)	0 (0.0)	2 (0.2)
Pulmonary embolism	0 (0.0)	2 (0.3)	0 (0.0)	2 (0.2)
Anemia requiring transfusion	0 (0.0)	1 (0.2)	0 (0.0)	1 (0.1)
Deep vein thrombosis	2 (1.2)	2 (0.3)	0 (0.0)	4 (0.5)
Urinary tract infection	1 (0.6)	1 (0.2)	0 (0.0)	2 (0.2)
Surgical site infection	3 (1.8)	8 (1.3)	0 (0.0)	11 (1.3)
Readmission	5 (2.9)	8 (1.3)	4 (4.2)	17 (1.9)

^aData are reported as n (%). MPFLR, medial patellofemoral ligament reconstruction; TTO, tibial tubercle osteotomy.

comorbid hypertension increased the risk of an extended (≥ 2 days) hospital stay (odds ratio, 4.0 [95% CI, 1.4-11.5]; $P = .010$), and no factor was associated with an increased risk of readmissions (Table 3).

DISCUSSION

The most important finding of this investigation was that concomitant TTO and MPFLR significantly increased operative time; however, it did not increase the rate of 30-day complications in comparison to the isolated procedures. There was also a statistically significant increase in the number of patients undergoing operative management for patellar instability over the course of the study period. As evidence supports successful outcomes after patellar stabilization procedures as well as techniques that yield optimal outcomes, the incidence of patellar stabilization procedures becomes more prevalent.^{33,38} Presently, physicians may overutilize isolated MPFLR because of the risks of TTO; however, the results of this investigation suggest that concomitant MPFLR and TTO do not affect the rate of 30-day complications.

The MPFL is not the sole medial stabilizer of the patella, as the medial patellotibial ligament (MPTL) and medial patellomeniscal ligament (MPML) also play significant roles in patellar stabilization.^{22,28} The anatomic position of the MPTL and MPML suggests that these ligaments resist a more superiorly directed force. Because of similar biomechanical profiles of the MPFL and MPTL,²⁰ it may be necessary to repair or reconstruct additional distomedial patellar stabilizers along with the MPFL. However, a patellar dislocation is a multifactorial condition that is dependent on several anatomic variables aside from ligamentous laxity, such as patella alta, lateralization of the tibial tubercle, and trochlear dysplasia.^{13,29,32,37} Skeletal immaturity, a sulcus angle greater than 154° , and an Insall-Salvati ratio greater than 1.3 were identified as independent predictors of redislocations.¹ Therefore, patients with osseous abnormalities may undergo concomitant MPFLR and TTO to assist with patellar alignment and patellar height. Concomitant MPFLR and TTO result in significant clinical improvement as well as a resolution of patellar tilt.²⁴

In this investigation, lateral retinacular release was performed in 30.6% of TTO procedures, 11.8% of MPFLR procedures, and 11.6% of concomitant MPFLR and TTO procedures. While the exact function of the lateral patellar retinaculum remains undefined, it has been described to resist medial patellar translation and medial tilt.^{12,26} However, retinacular release is no longer recommended as an isolated procedure because it can result in patellar subluxation due to a loss of medial stability.^{19,23,31} Patellar instability is multifactorial; thus, the presence of anatomic anomalies must be addressed at the time of surgery to maximize patient outcomes. Because 95% of patients with patellar dislocations have associated patellofemoral chondral defects,²⁵ it is imperative to correct all sources of patellar instability to prevent further damage to the joint, which may result in pain, osteoarthritis, instability, and additional surgery.³⁵ The results of this investigation suggest that there is no increased rate of complications after concomitant MPFLR and TTO; therefore, surgeons should not hesitate to perform concomitant MPFLR and TTO when the osseous anatomy indicates as such.

TABLE 3
Multivariate Analysis for Risk Factor Influence on Adverse Events, Extended Length of Hospital Stay, and Readmissions^a

	Adverse Events		Extended Length of Hospital Stay ^b		Readmissions	
	OR (95% CI)	<i>P</i> Value	OR (95% CI)	<i>P</i> Value	OR (95% CI)	<i>P</i> Value
Age >45 y	1.9 (0.8-4.3)	.267	2.4 (0.9-7.0)	.095	2.4 (0.8-7.1)	.128
Female sex	NS	.698	2.8 (0.8-9.6)	.106	NS	.529
BMI >30 kg/m ²	NS	.717	NS	.415	NS	.993
Diabetes mellitus	4.0 (1.6-10.8)	.003	NS	.182	NS	.227
DOE	NS	.889	NS	.592	NS	.803
Hypertension	NS	.172	4.0 (1.4-11.5)	.010	NS	.932
Current smoker	0.3 (0.1-1.1)	.063	NS	.224	NS	.163

^aBolded values indicate a statistical significance ($P < .05$). BMI, body mass index; DOE, dyspnea on exertion; NS, nonsignificant (variable was dropped from multivariate regression model); OR, odds ratio.

^bLength of stay in hospital over ≥ 2 days.

The incidence of thromboembolic events in this investigation was lower than what has been previously described after isolated TTO or TTO with concurrent MPFLR.⁴⁰ Tanaka et al⁴⁰ confirmed cases of symptomatic deep vein thrombosis with ultrasound, however ACS-NSQIP database that this investigation relied on did not report how deep vein thrombosis was diagnosed. Variations in the threshold of suspicion and diagnostic criteria may have contributed to the discordance in the incidence of deep vein thrombosis. It has previously been shown that the incidence of deep vein thrombosis was nearly 4-fold greater (46.7% vs 15.4%, respectively) in cases with a tourniquet time longer than 60 minutes compared with less than 60 minutes.^{11,40} The mean operative times for isolated MPFLR, isolated TTO, and concomitant MPFLR and TTO were longer than 1 hour; however, there was no difference in the rate of thromboembolic events. Vascular prophylaxis is variably used in sports medicine,^{16,40} and the efficacy of various types of vascular prophylaxis is equivalent.^{7,14,36} In this investigation, we were unable to determine how many patients received chemical prophylaxis, which may have affected the rate of thromboembolic events. Furthermore, infectious complications occurred in 1.3% of cases, which is similar to the incidence of surgical site infections (1.2%) reported by Arshi et al.² Patients undergoing MPFLR or TTO are young and have a low incidence of comorbid conditions; thus, the complication rate after these surgical procedures may be relatively low, despite their degree of invasiveness. As such, clinicians should perform all necessary procedures to correct patellar instability, as additional procedures do not increase the rate of complications.

MPFLR has a higher complication rate in case series and systematic reviews than what was reported in this investigation. The complication rate after MPFLR has been reported as 26.1%; however, the majority of these complications included loss of flexion, recurrent instability, or failure from operative management.³⁴ After TTO, the overall complication rate has been 4.6%; however, this varied depending on the utilized technique.²⁷ Complete removal of the tibial tubercle has resulted in complications in 10.7% of cases, whereas techniques maintaining a distal cortical hinge have resulted in a complication rate of 3.3% to 3.7%.²⁷ The presence of a distal cortical attachment maintains an intact blood supply within the periosteum that may minimize complications in comparison with techniques that sever blood supply to the tibial tubercle.⁴¹ In comparison with MPFLR, the most common complication was the removal of hardware.²⁷ In this investigation, the AE rates after MPFLR and TTO were 2.9% and 5.9%, respectively.

The discordance between reported complication rates lies in the variation of complications captured by this investigation. In the present study, complications were primarily caused by vascular or infectious processes; however, in several case series, the majority of complications occurred because of recurrent instability or iatrogenic causes.^{2,27} In the immediate postoperative period, patients are non-weightbearing or partial weightbearing and are often wearing a brace,²¹ which can protect against complications such as recurrent instability, patellar fractures, or osteotomy nonunion. Postoperative immobility protects patients

against osseous complications; however, it contributes to the development of vascular thrombosis.⁴⁰ Furthermore, previous series had a longer duration of follow-up (>2 years) than this investigation (30 days), which may contribute to the disparity in complication rates.

The results of this investigation may be interpreted with caution, as differing findings may be appreciated with a larger sample size. A post hoc power analysis demonstrated that the sample size was insufficient to discern differences in AE rates between groups. Despite this, the MPFLR + TTO group had marginally fewer AEs than the isolated TTO group, which may simply corroborate the low incidence of AEs in patients undergoing these procedures. However, the ACS-NSQIP database does not collect functional outcomes or long-term complications, such as recurrent instability, patellofemoral osteoarthritis, or stiffness. Thus, the efficacy of each operative intervention is unknown. Furthermore, recurrent instability that may arise in patients after operative management is not captured by the database. Adolescents were not queried in this investigation, which is a patient population in which MPFLR and TTO are most commonly performed.

Another limitation of this study is that the CPT codes for MPFLR may include other soft tissue stabilization procedures, such as medial collateral ligament, MPTL, MPML, or medial quadriceps tendon–femoral ligament reconstruction. These codes can also be used if no formal MPFLR was performed. Additionally, the CPT codes for TTO are not specific toward a specific technique and may be inclusive of several techniques, such as the Elmslie-Trillat procedure, which medializes and/or distalizes the tibial tubercle; Fulkerson osteotomy, which involves anteromedial displacement; and the Maquet procedure, which anteriorly translates the tibial tubercle. Each technique incurs a varying degree of complication rates.²⁷ It was also unknown if isolated TTO cases were performed in primary or revision scenarios. It would be helpful if CPT coding for patellofemoral instability were further developed to reduce the heterogeneity of included procedures for a single code. Certain combinations of CPT codes and ICD-10 diagnosis codes, specifically M23 and M25, with CPT 27427 may not be patellofemoral specific.

Although the ACS-NSQIP database can be queried to 2005, CPT codes for MPFLR and TTO may not have been introduced until after this date. Therefore, cases of MPFLR or TTO and complications may have been unidentified in the early years of this database. However, the contribution of this combination to the overall population is low and does not significantly alter our findings. This database does not record if infectious or thrombosis prophylaxis was given. The database also did not query complications specific toward orthopaedics, such as fractures. There are also variations in techniques, grafts, and rehabilitation protocols that may contribute to heterogeneity in the patient population included in this investigation. Additionally, participation in this database is voluntary on the part of hospitals and outpatient surgery centers, which are where the majority of patellar stabilization cases are performed. Therefore, the included patient population may not be a true representation of the national sample. The ACS-NSQIP database

only tracks patients for the first 30 postoperative days; thus, complications or further interventions to correct recurrent symptoms are unknown. The reliability of the data within this national registry is dependent on those who are entering the data into the database, and errors in data recording may affect the results and conclusions of this investigation. However, the ACS-NSQIP database provides numerous quality improvement efforts to minimize this occurrence.

CONCLUSION

While concomitant MPFLR and TTO significantly increased operative time, there was no difference in the rate of AEs, extended hospital stay, or readmissions within 30 days after isolated MPFLR, isolated TTO, and concomitant MPFLR and TTO. Surgeons should not hesitate to perform concomitant MPFLR and TTO when the osseous anatomy indicates as such.

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APPENDIX

TABLE A1
Queried ICD-9/10 and CPT Codes^a

Code	Description
ICD-9	
718.36	Recurrent dislocation of knee
718.86	Chronic instability of knee
836.3	Closed patellar dislocation
ICD-10	
M22.00	Recurrent dislocation, unspecified knee
M22.01	Recurrent dislocation of right patella
M22.02	Recurrent dislocation of left patella
M22.10	Recurrent subluxation, unspecified knee
M22.11	Recurrent subluxation of right patella
M22.12	Recurrent subluxation of left patella
M22.2X1	Patellofemoral disorders of right knee
M22.2X2	Patellofemoral disorders of left knee
M25.361	Other instability, right knee
M25.362	Other instability, left knee
M23.50	Chronic instability, unspecified knee
M23.51	Chronic instability of right knee
M23.52	Chronic instability of left knee
S83.004A	Unspecified dislocation of right patella
S83.005A	Unspecified dislocation of left patella
S83.006A	Unspecified dislocation, unspecified patella
CPT	
27420	Reconstruction of dislocating patella
27422	Reconstruction of dislocating patella, with extensor realignment and/or muscle advancement or release (MPFLR)
27427	Extra-articular ligament reconstruction

^aCPT, Current Procedural Terminology; ICD-9, International Classification of Diseases, 9th Revision; ICD-10, International Classification of Diseases, 10th Revision; MPFLR, medial patellofemoral ligament reconstruction.