High Tibial Osteotomy Survivorship

A Population-Based Study

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Background: High tibial osteotomy (HTO) was developed to treat early medial compartment osteoarthritis in varus knees.

Purpose: To evaluate the midterm and long-term outcomes of HTO in a large population-based cohort of patients.

Study Design: Case-control study; Level of evidence, 3.

Methods: Data from the California Office of Statewide Health Planning and Development were used to identify patients undergoing HTO from 2000 to 2014. Patients with infectious arthritis, rheumatological disease, congenital deformities, malignancy, concurrent arthroplasty, or skeletal trauma were excluded. Demographic information was assessed for every patient. Failure was defined as conversion to total or unicompartmental knee arthroplasty. Differences between patients requiring arthroplasty and those who did not were identified using univariate analysis. Multivariate analysis was performed, and Kaplan-Meier survivorship estimates for 5- and 10-year survival were computed.

Results: A total of 1576 procedures were identified between 2000 and 2014; of these, 358 procedures were converted to arthroplasty within 10 years. Patients who went on to arthroplasty after HTO were older (48.23 ± 6.76 vs 42.66 ± 9.80 years, respectively; $P < .001$), had a higher incidence of hypertension (25.42% vs 17.82%, respectively; $P = .001$), and had a higher likelihood of having ≥1 comorbidity (38.0% vs 31.4%, respectively; $P = .044$). Patients were 8% more likely to require arthroplasty for each additional year in age (relative risk [RR], 1.08). Female patients were also at an increased risk of conversion to arthroplasty compared with male patients (RR, 1.38). Survivorship at 5 and 10 years was 80% and 56%, respectively, and the median time to failure was 5.1 years.

Conclusion: HTO may provide long-term survival in select patients. Careful consideration should be given to patient age, sex, and osteoarthritis of the knee when selecting patients for this procedure.

Keywords: knee; osteotomy; varus; malalignment

High tibial osteotomy (HTO) was developed as a joint-preserving surgical procedure to treat young patients with isolated medial or lateral compartment arthritis of the knee and corresponding varus or valgus malalignment of the lower extremity.[9] The procedure is carried out in patients with good or minimally reduced knee range of motion in whom nonoperative measures have failed to improve disabling knee pain. When joint-preserving measures fail, total or unicompartmental knee arthroplasty (TKA or UKA, respectively) has grown in popularity as a treatment option for severe knee osteoarthritis (OA). Consequently, knee arthroplasty may serve a complementary role to HTO in treating patients with advanced disease. However, there may still be significant overlap in the patient population meeting indications for either HTO or knee arthroplasty, particularly for unicompartmental disease or in knees with less severe OA.

The increased utilization of UKA and TKA has resulted in a decline in the frequency of tibial osteotomy.[1,5,6,17,24] For younger patients, however, the risk of prosthesis loosening and polyethylene wear after knee arthroplasty must be considered because these implants may be subjected to greater mechanical stress over a longer period of time compared with those in elderly patients.[11] Recent literature[12] also suggests that HTO may be more cost-effective than knee arthroplasty in patients aged 50 to 60 years.

Although some studies[1,5,13,19] report greater than 90% survivorship at 10 years from surgery, risk factors such

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as increasing age and severity of OA have repeatedly been shown to reduce survivorship after HTO. More research is needed to better establish guidelines for appropriate patient selection for HTO. The purpose of this study was to evaluate the midterm and long-term outcomes of HTO in a large population-based cohort of patients.

METHODS

Data from the California Office of Statewide Health Planning and Development (OSHPD), a mandatory statewide discharge database, were utilized for this study. This database contains data from all public and private inpatient hospitals, ambulatory surgery centers, and emergency departments in the state of California. It includes demographic data for each patient, such as age, sex, race, total hospital charges, and up to 25 medical diagnoses with each admission. Diagnosis and procedure codes are listed as International Classification of Diseases, Ninth Revision (ICD-9) and Current Procedural Terminology (CPT) billing codes. Patients are tagged with a unique record linkage number that remains consistent throughout all admissions within the state of California.

HTO procedures were identified by flagging any admission containing ICD-9 procedure code 77.27 and CPT codes 27705, 27709, and 27457. Patients with lower extremity trauma, infectious arthritis, rheumatological disease, congenital deformities, malignancy, or concurrent arthroplasty were excluded. A full list of inclusion and exclusion codes is provided in Appendix Table A1. While laterality cannot be determined directly from the database, concurrent diagnosis and procedure codes were reviewed for all patients with 2 qualifying osteotomy procedures to determine whether the second HTO was a revision or contralateral procedure. This methodology is similar to what has been conducted in other database studies of this type.[4,23]

Failure was defined as conversion to TKA or UKA, and the cohort was stratified based on whether each patient went on to fail. For the purposes of this study, conversion to TKA or UKA was combined into a single outcome as "conversion to arthroplasty." Age, sex, race, diagnosis group (OA, acquired genu varum, other acquired deformity, derangement of internal knee structures, osteochondral defects, traumatic arthritis, and other arthropathy), concurrent procedures (arthroscopic surgery, osteochondral graft, synovectomy, and meniscectomy), and comorbidities (asthma, chronic kidney disease, congestive heart failure, depression, diabetes mellitus, hypertension, obesity, and peripheral vascular disease) were assessed for each admission. The grade of OA in each knee was not available through the OSHPD. Obesity was based on an ICD-9 diagnosis code (Appendix Table A1) and was calculated based on body mass index, which was also not directly available in this database. Subsequent readmissions to an inpatient hospital, ambulatory surgery center, or emergency department in California after the index procedure were identified and sequenced using the record linkage number and discharge or service dates.

Total reoperation rates were identified and summarized. Statistically significant differences between patients who required arthroplasty and those who did not were identified using the Student *t* test and chi-square test. Multinomial logistic regression was constructed using variables with $P < .2$ in the univariate analysis. To check for confounding, variables were individually dropped from the model, and the new model was then compared with the original model. Any variable that was found to cause more than a 15% change in another variable was considered a confounder and removed from the final model. A Hosmer-Lemeshow goodness-of-fit test was used to evaluate model fit, which assesses whether the observed event rates match expected event rates in subgroups of the model population.[3] Kaplan-Meier survivorship curves were constructed to estimate 5- and 10-year survival. If a patient underwent multiple revisions, only the time to initial arthroplasty was included in the analysis. Statistical significance was set at $P < .05$. All statistical analyses were performed using Stata/MP 13.1 software (StataCorp).

RESULTS

Patient Characteristics

After exclusions, 1576 procedures were identified between the years 2000 and 2014 (Table 1). Within the identified cohort, 44 patients underwent bilateral procedures. A total of 358 procedures (23%) were converted to arthroplasty within the time period investigated (2000-2014). On univariate analysis, patients who went on to arthroplasty after HTO tended to be older at the time of osteotomy (48.23 ± 6.76 vs 42.66 ± 9.80 years, respectively; $P < .001$), with a higher incidence of hypertension (25.42% vs 17.82%, respectively; $P = .001$) and a higher likelihood of having ≥1 comorbidity (38.0% vs 31.4%, respectively; $P = .044$) compared with those who did not. Those patients who converted to arthroplasty were also more likely to have a diagnosis of OA (81.6% vs 58.3%, respectively; $P < .001$) and genu varum (20.7% vs 14.0%, respectively; $P = .002$) at the time of their osteotomy procedure. Yet, patients undergoing arthroplasty were less likely to have a diagnosis of any other acquired deformity (13.7% vs 20.8%, respectively; $P = .003$) or other

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Ethical approval was not sought for the present study.

TABLE 1
Patient Demographic Information[a]

	Total Cohort (N = 1576)	Arthroplasty (n = 358)	No Arthroplasty (n = 1218)	*P* Value
Age, mean ± SD, y	43.93 ± 9.49	48.23 ± 6.76	42.66 ± 9.80	**<.001**
Sex				.067
Male	1092 (69.29)	234 (65.36)	858 (70.44)	
Female	484 (30.71)	124 (34.64)	360 (29.56)	
Race				**<.001**
White	972 (61.68)	228 (63.69)	744 (61.08)	
Black	92 (5.84)	16 (4.47)	76 (6.24)	
Hispanic	248 (15.74)	40 (11.17)	208 (17.08)	
Asian	48 (3.05)	7 (1.96)	41 (3.37)	
Other	41 (2.60)	4 (1.12)	37 (3.04)	
Missing	175 (11.10)	63 (17.60)	112 (9.20)	
Primary health insurance				**<.001**
Medicare	44 (2.79)	15 (4.19)	29 (2.38)	
Medi-Cal	50 (3.17)	9 (2.51)	41 (3.37)	
Private	973 (61.74)	247 (68.99)	726 (59.61)	
Workers' compensation	318 (20.18)	78 (21.79)	240 (19.70)	
Self-pay	10 (0.63)	2 (0.56)	8 (0.66)	
Other payer	44 (2.79)	3 (0.84)	41 (3.37)	
Missing	137 (8.69)	4 (1.12)	133 (10.92)	
Comorbidities				
Obesity	191 (12.12)	44 (12.29)	147 (12.07)	.910
Hypertension	308 (19.54)	91 (25.42)	217 (17.82)	**.001**
Diabetes mellitus	80 (5.08)	19 (5.31)	61 (5.01)	.821
Depression	67 (4.25)	15 (4.19)	52 (4.27)	.948
Asthma	94 (5.96)	29 (8.10)	65 (5.34)	.052
Chronic kidney disease	3 (0.19)	0 (0.00)	3 (0.25)	>.999
Congestive heart failure	2 (0.13)	1 (0.28)	1 (0.08)	.403
Peripheral vascular disease	2 (0.13)	1 (0.28)	1 (0.08)	.403
No. of comorbidities				**.044**
None	1058 (67.13)	222 (62.01)	836 (68.64)	
1	336 (21.32)	89 (24.86)	247 (20.28)	
2	142 (9.01)	34 (9.50)	108 (8.87)	
3	33 (2.09)	9 (2.51)	24 (1.97)	
4	7 (0.44)	4 (1.12)	3 (0.25)	
Diagnosis category				
Osteoarthritis	1002 (63.58)	292 (81.56)	710 (58.29)	**<.001**
Other acquired deformity	302 (19.16)	49 (13.69)	253 (20.77)	**.003**
Derangement of internal structures	465 (29.51)	96 (26.82)	369 (30.30)	.204
Osteochondral defect	324 (20.56)	68 (18.99)	256 (21.02)	.405
Traumatic arthropathy	37 (2.35)	8 (2.23)	29 (2.38)	.872
Other arthropathy	187 (11.87)	27 (7.54)	160 (13.14)	**.004**
Concurrent procedure				
Arthroscopic surgery	400 (25.38)	76 (21.23)	324 (26.60)	**.040**
Osteochondral graft	15 (0.95)	3 (0.84)	12 (0.99)	>.999
Synovectomy	84 (5.33)	11 (3.07)	73 (5.99)	**.031**
Meniscectomy	354 (22.46)	76 (21.23)	278 (22.82)	.525
Chondroplasty or microfracture	78 (4.95)	7 (1.96)	71 (5.83)	**.003**

[a]Data are reported as n (%) unless otherwise indicated. Bolded *P* values indicate statistically significant difference between the arthroplasty and no arthroplasty groups ($P < .05$).

arthropathy (7.5% vs 13.1%, respectively; $P = .004$). Other patient characteristics can be found in detail in Table 1.

Risk Factors

After controlling for potential confounders identified on univariate analysis, patients were 8% more likely to require arthroplasty for each additional year in age (relative risk [RR], 1.08 [95% CI, 1.06-1.10]). Female patients were also at an increased risk of conversion to arthroplasty compared with male patients (RR, 1.38 [95% CI, 1.06-1.79]). In contrast, those who underwent simultaneous arthroscopic surgery (RR, 0.74 [95% CI, 0.55-1.00]) or synovectomy (RR, 0.50 [95% CI, 0.25-0.96]) were at a decreased risk of conversion to arthroplasty. The Hosmer-Lemeshow goodness-of-fit test indicated a good model fit ($P > .05$). Risk factor analysis is presented in detail in Table 2.

TABLE 2
Adjusted Risk Factors for Conversion to Arthroplasty After High Tibial Osteotomy[a]

	Relative Risk (95% CI)	*P* Value
Age	1.08 (1.06-1.10)	**<.001**
Female sex (reference: male)	1.38 (1.06-1.79)	**.017**
Osteoarthritis	2.40 (1.78-3.25)	**<.001**
No. of comorbidities	1.00 (0.86-1.17)	.986
Arthroscopic surgery	0.74 (0.55-1.00)	**.048**
Synovectomy	0.50 (0.25-0.96)	**.038**

[a]Bolded *P* values indicate statistical significance ($P < .05$).

Survivorship

The mean follow-up during the study period was 4.5 years (range, 0-15 years). Overall survivorship at 5 and 10 years was 80% and 56%, respectively, and the median time to failure was 5.1 years (range, 0.15-14.5 years) (Figure 1).

In patients with OA (n = 1002), survivorship at 5 and 10 years was 78% and 52%, respectively, and the median time to failure was 5.5 years (range, 0.27-14.5 years) (Figure 2). In patients without OA (n = 574), survivorship at 5 and 10 years was 85% and 67%, respectively, and the median time to failure was 4.9 years (range, 0.16-13.6 years) (Figure 2). The rate of conversion to total hip arthroplasty in patients without OA was 12%.

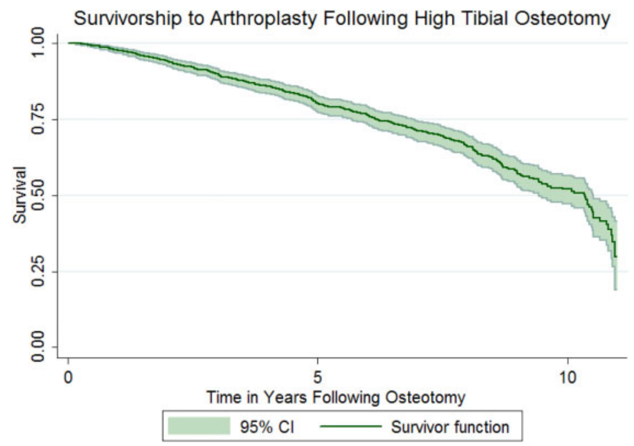

Figure 1. Kaplan-Meier survival estimate for survivorship to knee arthroplasty after high tibial osteotomy.

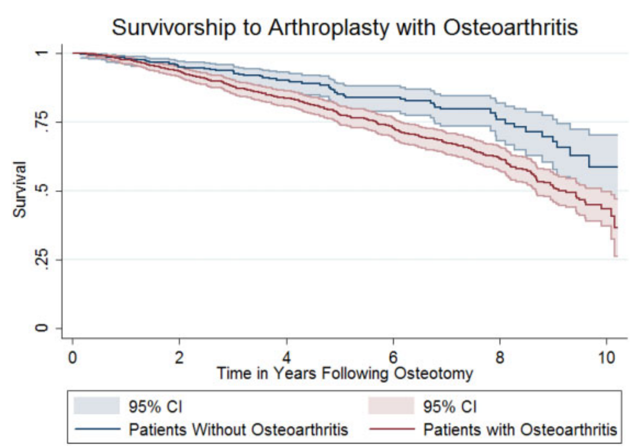

Figure 2. Kaplan-Meier survival estimate for survivorship to knee arthroplasty after high tibial osteotomy for patients with and without osteoarthritis.

DISCUSSION

HTO in a large database cohort of patients revealed overall survival rates similar to those of prior studies.[13,16,22] Although a diagnosis of OA was the strongest risk factor for conversion to arthroplasty, increasing age and female sex were also found to be risk factors on multivariate analysis. Concomitant procedures such as synovectomy and arthroscopic surgery were associated with lower rates of conversion to arthroplasty, whereas patient factors such as number of comorbidities and race did not affect outcomes.

The 5-year survival rate of 80% and 10-year survival rate of 56% are within the range of published survival rates, although on the lower end. In our study, patients who converted to hip arthroplasty were significantly older than those who did not undergo arthroplasty. However, further analysis to control for potential confounding variables showed that patients were 8% more likely to require arthroplasty for each additional year in age. The discrepancy in the survival rates with previous studies may be because the mean follow-up time was just 4.5 years, with only about half our patient cohort having 5- to 10-year follow-up. Studies with at least 10-year follow-up report 5-year survival rates from 73% to 99% and 10-year survival rates from 51% to 98%, with the average time to revision between 6 and 13 years. The differences in the current data may in part be caused by the age of the cohort and the prevalence of OA, which prior studies have found to be risk factors for failure.[5,6,8,15,16,22] In the subgroup of patients without OA, the median age was 41 years (range, 18-60 years), and the 5- and 10-year survival rates were 85% and 67%, respectively. Additionally, 12% of patients in this group were converted to arthroplasty, which is in agreement with results published by Flecher et al[5] and Koshino et al.[13]

Several prior studies have demonstrated that increasing severity of OA leads to shorter survival times after HTO. A study by van Raaij et al[22] found 10-year survival rates of 90% in patients with Ahlback grade ≤1 compared with 62% in patients with grade ≥2. Flecher et al[5] found that patients with Ahlback grade 1 or 2 OA had significantly lower failure rates with a hazard ratio of 0.29. In contrast, DeMeo et al[2] performed HTO in 20 patients with Outerbridge grade 4 OA and found a 25% rate of conversion to arthroplasty at an average of 6.6 years. The current data were obtained from a large database with defined variables, and it was therefore impossible to grade the severity of OA for patients. However, it is reasonable to assume that patients without a diagnosis of OA had at most Ahlback grade 1 OA (ie, joint space narrowing without obliteration of the joint), making it an appropriate surrogate. Of note, the high prevalence of concomitant OA accompanying genu varum in the general population makes it difficult to determine the differential effects of genu varum versus OA in our sample of patients.

Increasing patient age has also been correlated with higher failure rates after HTO in multiple studies.[5-8,16] Flecher et al[5] reported that the failure rate was 2.1 times higher in patients older than 50 years compared with those younger than 30 years. Gstöttner et al[6] found a 5% increase in the rate of conversion to TKA with every 1-year increase in the patient's age. Hui et al[8] compared patients younger and older than 50 years and found a hazard ratio of 3.7 in patients older than 50 years. On multivariate analysis, age was a significant predictor of patients undergoing arthroplasty, with an 8% increased risk with every 1-year increase in age. Although it is unclear what age cutoff should be used, a large increase in failure rates tends to occur in the 50- to 60-year-old age group. For patients in older age groups who may be candidates for HTO, other risk factors should also be considered when deciding to operate. Notably, the effect of age on revision compared with that of a preoperative diagnosis of OA is relatively small, and thus, physiological age and disease severity may be better indicators of revision likelihood rather than absolute biological age.

Female sex was found to be associated with a 38% increase in the likelihood of conversion to arthroplasty. In the study by van Raaij et al,[22] 100 patients were evaluated after closing wedge HTO with an average follow-up of 12 years and survival rates were found to be 59% for female patients and 85% for male patients. Niinimäki et al[16] reported on 3195 HTO procedures using a national registry and found poorer survivorship in female patients, with a hazard ratio of 1.26. Although several studies have reported worse survivorship in female patients compared with male patients after HTO, it is unclear why. Sprenger and Doerzbacher[21] suggested that the degree of valgus correction may play a role, but further studies are needed to elucidate this finding.

HTO performed simultaneously with cartilage repair or meniscal procedures has shown promising results. Schuster et al[20] analyzed 85 patients (91 knees) who underwent HTO with medial femoral condyle debridement. A subset of patients also underwent microfracture as well as partial medial meniscectomy. The authors found a 95% survival rate at 5-year follow-up, with 3 patients converting to UKA and 1 patient converting to TKA. Although all of the patients had Kellgren-Lawrence grade 3 or 4 OA, the average age was 50 years, and this younger age may have contributed to the relatively high survival rate. Pascale et al[18] performed a prospective randomized trial comparing HTO alone (20 patients) with HTO with microfracture (20 patients). At 5-year follow-up, no significant difference was found between the study groups, and only 2 patients (5%) converted to TKA. Kahlenberg et al[10] in 2017 published a systematic review of 4 studies (839 knees) that evaluated the use of cartilage repair in conjunction with HTO. The most common cartilage technique used was microfracture (22%), and the overall rate of conversion to arthroplasty was 6.8% at a mean of 4.9 to 13 years. Patients who had concurrent osteochondral grafts did not have higher rates of conversion to arthroplasty. Patients who underwent concomitant arthroscopic surgery (25%) or meniscectomy (22%) did not have significantly higher rates of conversion to arthroplasty, further supporting prior literature. A 2018 systematic review and meta-analysis confirmed the major benefit of HTO itself and the negligible benefit of concomitant procedures during HTO on clinical or radiological outcomes.[14] However, these concurrent procedures do not appear to be detrimental, and in the case of cartilage repair/restoration procedures, there may be some utility, as they lead to improved arthroscopic, histological, and magnetic resonance imaging findings.

This study is limited by factors inherent in database research, including the potential for sampling bias, the lack of radiographic and clinical data, and errors in data entry and coding. In particular, the OSHPD database does not report functional outcomes of surgery, surgical techniques, patient-reported outcomes, previous surgery at outside institutions or before the study time point, or radiographic analysis of deformity severity or correction. Therefore, it was not possible to determine the severity of OA in our patient population, which has been shown in multiple studies to be a significant predictor of outcomes after HTO. Additionally, there was no opportunity to comment on preoperative and postoperative coronal alignment, another important factor in HTO survival, or to report on patient outcomes or indications for conversion to arthroplasty. Finally, it was not possible to quantify clinical failures that forgo further surgical intervention, and thus, the true failure incidence is likely underreported in the present study.

The greatest strength of this study is the large number of patients who underwent HTO with midterm to long-term follow-up from a data source that captures all patients, procedures, and admissions within the state of California. The all-inclusive nature of this database limits sampling bias inherent in other databases. The current study also presents clinically meaningful data with regard to the primary endpoint of conversion to arthroplasty. These findings may provide data for further cost analysis studies, as they report on a population of 38 million people. These data may also be used to guide clinical decision making as well as to counsel patients on the risk factors of conversion to arthroplasty after HTO.

CONCLUSION

HTO may provide long-term survival in select patients. Careful consideration should be given to patient age, sex, and OA of the knee when selecting patients for this procedure.

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APPENDIX

TABLE A1
Inclusion and Exclusion Codes[a]

	Code
Inclusion procedures	
CPT	
Osteotomy, tibia	27705
	27709
	27457
ICD-9	
Wedge osteotomy, tibia	77.27
Inclusion diagnoses	
ICD-9	
Osteoarthritis	715.00-715.98
Genu varum	736.42
Other acquired deformity	736.41
	736.5-736.9
	738.8-738.9
Derangement of internal structures	717.0-717.9
Osteochondral defect	717.7
	718.05-718.09
	733.92
Traumatic arthritis	716.10-716.19
Other arthritis	716.50-716.99
	718.80-718.99
	719.80-719.99
Exclusion procedures: prior or index admission	
CPT	
Hip arthroplasty	27125-27138
Knee arthroplasty	27440-27488
Ankle arthroplasty	27702-27003
	27870-27871
ICD-9	
Hip arthroplasty	00.70-00.77
	81.51-81.53
Knee arthroplasty	00.80-00.84
	81.54-81.55
Ankle arthroplasty	81.56
Open reduction of fracture, with internal fixation	79.35
Ankle fusion	81.11
Exclusion diagnoses: prior or index admission	
ICD-9	
Poliomyelitis	138
Neoplasm	170.6-170.9
	171.3-171.9
	173.7
	195.5-195.8
	196.5-196.9
	198.5
	203.00-203.82
	213.7
	238.0
Rickets	268.0-268.1

(continued)

TABLE A1 (continued)

	Code
Mucopolysaccharidosis	277.5
Developmental delay	315.8-315.9
	783.40
Intellectual disability	318.0-318.2
	319
Hereditary spastic paraplegia	334.1
Cerebral palsy	343.0-343.9
Paraplegia and quadriplegia	344.01
	344.1
Infective arthritis	711.00-711.99
Pressure ulcer	707.0-707.09
Rheumatological disease	710.0-710.2
	714.0-714.9
	720.0
Dislocation	718.20-718.76
Soft tissue infection	682.6
	728.0
	728.86
Osteomyelitis	730.00-730.99
Osteitis deformans	731.0-731.1
Osteochondropathy	732.1-732.9
Pathological fracture	733.10-733.19
Bone cyst	733.20-733.29
Aseptic necrosis	733.42
Malunion of fracture	733.81
Nonunion of fracture	733.82
Spina bifida	741.00-741.93
Congenital deformity	754.30-754.44
	755.30-755.69
Other congenital anomalies	756.4-756.9
Lower extremity trauma	808.0-808.9
	820.00-821.39
	823.00-823.92
	827.0-828.1
	835.00-835.13
	836.0-836.69
	905.4-905.4
Complication of orthopaedic device	996.4-996.49
	996.66-996.67
	996.77-996.78
Joint replacement status and care	V43.64-V43.65
	V54.81-V54.82
Arthrodesis status	V45.5
Care for internal fixation device	V54.01-V54.09
Outcome procedure	
CPT	
Knee arthroplasty	27440-27447
	27486-27487
ICD-9	
Knee arthroplasty	00.80-0082
	81.54-81.55

[a]CPT, Current Procedural Terminology; ICD-9, International Classification of Diseases, Ninth Revision.