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Comparative Analysis of Unicompartmental Total Knee Arthroplasty and High Tibial Osteotomy: Time to Total Knee Arthroplasty and Other Outcome Measures

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ABSTRACT

Background: There is no consensus on whether unicompartmental arthroplasty (UKA) or high tibial osteotomy (HTO) is superior for unicompartmental arthritis. While there are studies comparing revision and complication rates, none matched a large number of patients undergoing HTO and UKA in the United States and compared these outcomes. We investigated TKA conversion rate and the complications following HTO or UKA.

Methods: This retrospective study queried the PearlDiver database of all patients undergoing UKA and HTO using CPT codes between January 2011 and January 2020. We compared propensity-matched populations based on age, gender, Charlson comorbidity index, and Elixhauser comorbidity index to compare odds of complications, TKA conversion, and drug use between UKA and HTO groups. Two-independent sample t-test for unequal variances and test of significance were performed.

Results: We found 32,583 UKA patients and 816 HTO patients. Each matched group had 535 patients. One-year complication showed higher risk of pneumonia, hematoma, infection, and mechanical complications among HTO patients. UKA patients used narcotics on average of 10.3 days compared to 9.1 days among HTO patients ($P < .01$). UKA conversion rates were 4.1%, 5.4%, 7.7%, and 9.2% at 1-, 2-, 5-, and 10-year intervals, respectively. HTO conversion rates were less than 2% at 1- and 2-year intervals, 3.4% at 5-year, and 4.5% at 10-year intervals. This difference was statistically significant at 5- and 10-year intervals ($P < .01$).

Conclusions: Using large matched cohorts, HTO may be converted to TKA later than UKA in short- to mid-term follow-up, and HTO patients used opioids for shorter duration.

Introduction

The prevalence of knee osteoarthritis (OA) continues to rise globally with the increasingly aging population. The treatment options for knee OA are relatively well-defined with clinical data-based evidence [1]. The majority of the patients with knee OA have disease involvement in all the knee compartments. Some patients may have more advanced knee OA predominantly in 1 compartment, in particular in the medial compartment [2]. In some selected patients with end-stage unicompartmental arthritis, 2 surgical treatments (1) unicompartmental knee arthroplasty (UKA) and (2) high tibial osteotomy (HTO) can be effective [3,4].

HTO was introduced and popularized in the 1960s prior to the development of the prosthetic knee arthroplasty [5,6]. UKA was introduced into the clinical application approximately a decade and a half later [7]. Historically, HTO is considered in patients who are younger and more active. On the other hand, UKA is considered in patients who are older and have lower activity demands [8–10]. Controversies remain regarding the best and the most appropriate patient selection criteria for both of these procedures [11–13]. Moreover, the clinical outcomes were unpredictable with both, when compared to the outcomes of total knee arthroplasty (TKA) [14–16]. Thus, as the TKA design, instrumentation, and surgical techniques continued to improve over the past 4 decades, both of these operations were performed with lower frequency [17]. However, more recently, especially with the introduction of robotic-assisted surgery, UKA has become increasingly popular once again [18–20]. As a result, the

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number of UKAs has been rising consistently worldwide in recent decades [21–23].

Part of the reasons for historically poorer outcomes with both HTO and with UKA could be that the surgeons selected some of the patients inappropriately with the goal of delaying the need for TKA. The most common failure etiology for both HTO and UKA is the progression of disease in the other compartments, for which the treatment for those patients is conversion to TKA. Other failures included mechanical loosening of the UKA and progression of the deformity after HTO [24–27].

The purpose of this study is to investigate (1) the rate of conversion to TKA following HTO or UKA and (2) the complications following each procedure.

Material and methods

Data source and study population

This retrospective study queried the PearlDiver Patient Records Database (www.pearldiverinc.com, Colorado Springs, CO, USA) for all the patients who underwent UKA and HTO using the current Procedural Terminology (CPT) codes between January 2011 and January 2020. The PearlDiver database contains the hospital and the physician billing records along with the prescription medication records for 91 million distinct patients from all U.S. states and territories. These patients were covered by a diverse group of payers including commercial insurance, Medicare, Medicaid, and self-pay. The database meets the criteria for patient information protection and is compliant with the Health Insurance Portability and Affordability Act. Thus, this study did not require the review by our institutional review board.

Patients who underwent UKA (group 1) were identified using the CPT code 27,446. Those patients who underwent HTO (group 2) were identified using the CPT code 27,457. Patient's comorbidities including diabetes, obesity, and tobacco use disorder were identified using the International Classification of Diseases-10 codes.

Patient data extracted from the database included the following: age, gender, the Charlson comorbidity index (CCI), the Elixhauser comorbidity index (ECI), and the length of stay. The CCI and the ECI are both reliable predictors of the long-term prognosis and the survival used to estimate the risk of death from comorbid disease conditions. It has been reported that the ECI is more appropriate for predicting death after in-patient orthopaedic surgeries. Both of these indices have also been validated to have predictive value in perioperative complications following orthopaedic surgery procedures.

Failure assessment

We selected to extract the data of complications at the 30-day, the 90-day, and the 1-year postoperative follow-up intervals using International Classification of Diseases-10 codes. The complications studied included the following: myocardial infarction, acute kidney injury, deep venous thrombosis, pneumonia, pulmonary embolism, blood transfusion, surgical site infection, wound complication, hematoma, mechanical complications, and wound dehiscence. The odds of complications for each group were assessed and compared, along with the 95% confidence intervals and *P*-value for each of the complications. In addition, we extracted data of conversion to TKAs at the 1-year, the 2-year, and the 5-year interval following the index HTO or UKA.

Cost analysis

The database provides data on the total costs for patient care and on the total costs of the medications. We chose to extract the total costs and the medical costs for the first 30 days following the index operation for both the groups.

Statistical methods

Statistical analysis was performed using the Bellwether-PearlDiver application, which generated propensity-matched populations from both group 1 and group 2 based on age, gender, CCI, and ECI.

Patient characteristics were described using the mean (standard deviation) for continuous variables and the frequency (proportion) for the categorical variables where appropriate. Two-independent sample t-test was used for the unequal variances (continuous variables) and the test of significance was used to identify any differences between the 2 groups. Statistical analyses were performed using the MedCalc's Odds Ratio Calculator and the MedCalc's Comparison of Means Calculator. The statistical significance was defined as $P < .05$.

Results

Over the study period, 32,583 patients underwent UKA (53.7% female) and 816 patients underwent HTO (41.4% female). After matching, there were 535 patients in each group, consisting of 214 women (40%) and 321 men (60%) in each group. PearlDiver does not give exact ages but rather age ranges, which can be seen in Table 1. There were 295 patients between 40 and 55 years of age (55.1%). Of these patients, 71 patients had diabetes (13.3%) and 95 patients were documented to have obesity (body mass index >30) (17.8%) with equal distribution/frequency amongst both men and women. Three hundred fifty-five patients had a CCI of zero (62.6%), 120 patients had a CCI of 1 (22.4%), 55 patients had a CCI of 2 or 3 (10.3%), and 5 patients had CCI above 3 (0.93%). There were 33 smokers in each group.

Complications

The database does not report complications if the occurrence is below 11 patients. We did not find any difference between the groups with regard to the complications at the 30-day and at the 90-day postsurgery intervals. When analyzing the 1-year complications, our data demonstrated higher pneumonia (11 patients, 2.06%), hematoma (11 patients, 2.06%), surgical site infection (12 patients, 2.24%), and mechanical complications (24 patients, 4.49%) in the HTO patients. Corresponding numbers were zero or less than 11 in the UKA group and hence were unable to be compared.

Table 1
Demographic data for matched cohorts.

n	535
Sex	321 men (60%)
Age	
25-29	11
30-34	28
35-39	74
40-44	108
45-49	97
50-54	90
55-59	45
60-64	33
65-69	19
70-74	14
Diabetes	71 (13.3%)
BMI > 30	95 (17.8%)

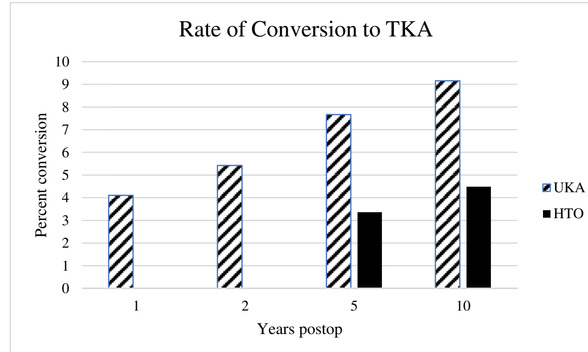
Narcotic use

The 60-day narcotic use was reported in 380 UKA patients (71.0%) and 385 HTO patients (72.0%). The Mean Morphine milliequivalent group was 1821.28 (standard deviation = 4731.31) for the UKA and 2022.24 (standard deviation = 2925.78) for the HTO group. The difference in the narcotics use between the 2 groups was not statistically significant (P = .48). There was a marginal difference between the 2 groups with regard to the length of narcotics use (10.33 days for the UKA and 9.10 days for the HTO) (P < .01).

Conversion to total knee replacement

We calculated the rate of conversion to TKA in both the unmatched and in the matched data due to the low number of HTO available for analysis. For the unmatched cohorts, conversion to TKA after 1 year was noted in 792 (2.4%) patients in the UKA group. The 1-year conversion to TKA data was unavailable from the HTO group for comparison (less than 11, <1.3%). Similarly, the rate of conversion to TKA after the 2-year interval was noted in 1166 (3.6%) patients in the UKA group. Similarly, the 2-year conversion to TKA data was unavailable from the HTO group for comparison (less than 11, <1.3%). The 5-year conversion to TKA was noted in 1718 (5.27%) patients in the UKA group and in 22 (2.69%) patients in the HTO group. This difference was statistically significant with a P value <.01. The odds of conversion to a TKA in the UKA group at 5 years was double the conversion rate for the HTO group (odds ratio [OR] = 2.01, 95% confidence interval [CI] = 1.31 to 3.07). The 10-year conversion to TKA was noted in 2010 (6.17%) patients in the UKA group and in 32 (3.92%) patients in the HTO group. This difference was statistically significant with a P value <.01. The odds of conversion to a TKA in the UKA group at 10 years was nearly double the conversion rate for the HTO group (OR = 1.61, 95% CI = 1.31 to 3.07).

For the matched cohorts, conversion to TKA at the 1-year interval was noted in 22 (4.11%) patients in the UKA group. The 1-year exact number of conversions to TKA was unavailable for the HTO group for comparison (less than 11, <2%). Similarly, conversion to TKA at the 2-year interval was noted in 29 (5.42%) patients in the UKA group. Again, the 2-year exact number was unavailable from the HTO group for comparison (less than 11, <2%). Conversion to TKA at the 5-year interval was noted in 41 (7.67%) patients in the UKA group. Conversion to TKA at the 5-year interval was noted in 18 (3.36%) patients in the HTO group. This difference was statistically significant with a P value <.01. The odds of conversion to a TKA in the UKA group at the 5-year interval was more than double the conversion rate for the HTO groups (OR = 2.38, 95% CI = 1.31 to 3.07). Conversion to TKA at the 10-year interval was noted in 49 (9.16%) patients in the UKA group. The conversion to TKA at the 10-year interval was noted in 24 (4.49%) patients in the HTO group. This difference was statistically significant with a P value <.01. These results can be seen in Figure 1. The odds of conversion to a TKA in the UKA group at the 10-year interval was more than double the conversion rate for the HTO groups (OR = 2.14, 95% CI = 1.31 to 3.07).



Note: not enough data for HTO at one- and two-year intervals

Figure 1. Rates of conversion to TKA in matched cohorts of UKA vs HTO at designated time intervals. Note: not enough data for HTO at 1- and 2-year intervals.

Discussion

This database study assessed the conversion rates to TKA following UKA or HTO, as well as the complication rates and the narcotic use between the 2 groups. The principal finding in this study was the differences in the rates of conversion to TKA following UKA and HTO. Realizing the limitations of a large commercial database, these short- to mid-term results and conversion rates may show that UKAs were converted to TKAs sooner and at higher rates at the 1-, the 2-, 5-, and 10-year intervals compared to conversion TKA from the HTO group. There were no differences in 30- and 90-day postoperative complications. However, patients with HTO exhibited more complications at 1 year, including mechanical problems, pneumonia, and surgical site infections. There was no statistically significant difference in the narcotic use, however patients with UKA required narcotics for a longer period of time (10.33 days for the UKA and 9.10 days for the HTO; P < .01).

There is no clear consensus in the literature between the outcomes of UKA and HTO, with respect to complications and conversion to TKA. Some studies report better longevity in UKA. A recent meta-analysis was conducted by Cao et al using studies that directly compared UKA and HTO [4]. They found that the conversion rate of UKA was less than that of HTO. However, limitations of this study included (1) nearly half of the included studies were >10 years older than the time interval of our study and (2) the heterogeneity of their data inclusion and analysis including differences in the study designs, the matching criteria, the sample size, the operative techniques, and the measurement instruments use for the outcomes [4]. Jin et al [28] reported the 10-year data comparing UKAs to opening-wedge HTOs. They demonstrated that there was no statistical difference in the survival rates at 10 years. Song et al [29] reported that the HTO had better survival for the first 12 years after the surgery. There was then a sharp decline. In contrast, the UKA had a better survival rate at 15 and at 20 years. Morris et al [30] performed a study utilizing the PearlDiver database to analyze the outcome differences between UKA and TKA. They showed that the 5-year survivorship for UKA was between 91% and 93%. Their finding was similar to our analysis of the UKA 5-year survivability of 94.7%.

The complication rates in the 30- and 90-day postsurgery time interval were not reportable in either group as there were less than 11 complications in each group. However, at the 1-year postsurgery interval, the HTO patients were found to have higher rates of pneumonia, surgical site infection, hematoma, and mechanical problems compared with the UKA patients. This is consistent with previous literature showing either higher complication rates in the HTO patients [10,31] or low to similar complication rates for each of the groups. Two midterm follow-up studies comparing the complications between the UKA and the HTO patients demonstrated no significant differences in the complications or in the complication rates between the 2 groups [32,33]. Jin et al [28] reported no significant differences in the complications between the 2 groups at the 10-year follow-up interval. In contrast, Cao et al [4] reported higher complications in the HTO patients in 5 of the included studies for their meta-analysis.

To our knowledge, this is the first study comparing the opioid use in patients undergoing UKA vs HTO. Our results showed that the patients undergoing HTO used narcotics for a statistically significant shorter time period (10.33 days for the UKA, and 9.10 days for the HTO; $P < .01$).

There are several limitations to this study. First, this is a database study and the inherent limitations of these types of studies rely on accurate coding and documentation. Thus, the study could be limited by incomplete data collection and the lack of detailed clinical information. Administratively coded data has been validated to correlate well with the clinical record [34]. Second, CPT codes were used to identify patients for the study and there is no specific CPT code to indicate whether the patients underwent opening- or closing-wedge HTO. Therefore, we were unable to confirm the pre-operative indication or diagnosis for patients who underwent HTO. The available evidence however shows no difference in the outcomes between the 2 different surgical techniques for the HTO [35–37].

In the present study, the 2 patient groups were matched for age, sex, nonelective admission status, obesity, and other patient factors. Third, there are potential confounding factors that may not have been accounted for including the preoperative diagnosis and the CCI. Fourth, the analysis of the postoperative complication is limited to the in-hospital stay since the NIS data do not include any data beyond the patient's inpatient stay. Fifth, it was not possible to distinguish whether a patient underwent a TKA on the ipsilateral knee with prior HTO or UKA vs in the contralateral knee. This lack of specificity could have overestimated the conversion to TKA. Finally, the PearlDiver platform uses its own proprietary software and matching algorithm, which only allows 1:1 matching and is standardized for all PearlDiver-based research studies. We acknowledge that using the Pearldiver database for our study limits our ability to vary the matching protocol.

Conclusions

Recognizing the limitations of a large administrative database study, the data from the present study demonstrated that UKAs may be converted to TKAs at an earlier postsurgery time interval than in the HTO patient group. Additionally, the patients undergoing HTO may have used opioids for a shorter duration after surgery but had higher complication rates. This information can be utilized when counseling the patients with regard to what treatment option is the best for the patients with unicompartmental arthritis.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101107.

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Appendix

Appendix 1 ICD and CPT Codes Used.

Unicompartmental Knee Arthroplasty	High Tibial Osteotomy	Total Knee Arthroplasty	Comorbidity Codes	Medical Complication Codes	Surgical Complication Code
27,446	27,457	P-8154	Diabetes without complications	Acute kidney injury	Dehiscence
		P-0SRC069	E199	D-5845	D-99830, D-99831, D-99832, D-99833, D-T8130XA, DT8130XD, D-T8130XS, D-T8131XA, D-T8131XD, D-T8131XS, D-T8132XA, D-T8132XD, D-T8132XS, D-T8133XA, DT8133XD, D-T8133XS
		P-0SRC06A		D-5846	
		P-0SRC06Z	Tobacco related disorder	D-5847	Hematoma
		P-0SRC0J9	Z87891	D-5848	D-99811, D-99812, D-99813, D-D7801, D-D7802, DD7821, D-D7822, D-E3601, D-E3602, D-E89810, DE89811, D-G9731, D-G9732, D-G9751, D-G9752, DH59111, D-H59112, D-H59113, D-H59119, D-H59121, DH59122, D-H59123, D-H59129, D-H59311, D-H59312, DH59313, D-H59319, D-H59321, D-H59322, D-H59323, DH59329, D-H9521, D-H9522, D-H9541, D-H9542, DI97410, D-I97411, D-I97418, D-I9742, D-I97610, DI97611, D-I97618, D-I97620, D-J9561, D-J9562, D-J95830, D-J95831, D-K9161, D-K9162, D-K91840, D-K91841, D-L7601, D-L7602, D-L7621, D-L7622, D-M96810, DM96811, D-M96830, D-M96831, D-N9961, D-N9962, DN99820, D-N99821, D-T888XXA
		P-0SRC0JA		D-5849	
		P-0SRC0JZ	Obesity	D-N17	Wound complication
		P-0SRD069	E660, E6601	D-N179	D-99883, D-99832, D-99830, D-T8131XA, D-T8131XD, D-T8131XS, D-A4852, D-B871
		P-0SRD06A	E6609, E661		
		P-0SRD06Z	E662, E668	Cardiac arrest	
		P-0SRD0J9	E669, Z6830	D-4275	
		P-0SRD0JA	Z6831, Z6832	D-42741	
		P-0SRD0JZ	Z6833, Z6834	D-I46	
		P-0SRT0J9	Z6835, Z6836	D-I469	
		P-0SRT0JA	Z6837, Z6838		
		P-0SRT0JZ	Z6839	Cerebrovascular accident	
		P-0SRU0J9		D-I97821	
		P-0SRU0JA		D-43491	
		P-0SRU0JZ			
		P-0SRV0J9		Opioid use	
		P-0SRV0JA		USC-02211	
		P-0SRV0JZ		USC-02212	
		P-0SRW0J9		USC-02214	
		P-0SRW0JA		USC-02221	
		P-0SRW0JZ		USC-02222	
				USC-02232	
				Cannabis use, abuse, or dependence	Surgical site infection
				D-F12120, D-F12121, D-F12122, D-F12129, D-F12150, D-F12151, D-F12159, D-F12180, D-F12188, D-F1219, D-F1220, D-F12220, D-F12222, D-F12229, D-F1223, DF12250, D-F12251, D-F12259, D-F12280, D-F12288, DF1229, D-F1290, D-F12920, D-F12921, D-F12922, DF12929, D-F1293, D-F12950, D-F12951, D-F12959, DF12980, D-F12988, D-F1299, D-F1210, D-30430, D-30431, D-30432, D-30520, D-30521, D-30522	D-T814, D-T814XXA, D-T814XXD, D-M86:D-M869, D-M868X0, D-M868X1, D-M868X2, D-M868X3, D-M868X4, D-M868X5, D-M868X6, D-M868X7, D-M868X8, D-M868X9, D-T814XXS, D-99851, D-99859, D-99666, D-99667, D73001, D-73011, D-73021, D-73081, D-73091
				Pulmonary embolism	
				D-4151	
				D-4159	
				D-I26	
				D-I269	
				Sepsis	
				D-99591	
				D-A419	
				Myocardial infarction	
				D-41000, D-41001, D-41002, D-41010, D-41011, D-41012, D-41020, D-41021, D-41022, D-41030, D-41031, D41032,	

Appendix 1 ICD and CPT Codes Used. (*continued*)

Unicompartmental Knee Arthroplasty	High Tibial Osteotomy	Total Knee Arthroplasty	Comorbidity Codes	Medical Complication Codes	Surgical Complication Code
				D-41040, D-41041, D-41042, D-41050, D-41051, D-41052, D-41080, D-41081, D-41082, D-41090, D-41091, D-41092, D-I2101, D-I2102, D-I2109, D-I2111, D-I2119, D-I2121, D-I2129, D-I213, D-I214, D-I219, DI21A1, D-I21A9, D-I220, D-I221, D-I222, D-I228, D-I229	
				Deep vein thrombosis	
				D-45340, D-I82409, D-45341, D-I82419, D-I82429, DI82439, D-I824Y9, D-45341, D-I82419, D-I82429, D-I82439, D-I824Y9, D-45381, D-I82619, D-45382, D-I82629, D45383, D-I82609, D-45384, D-I82A19, D-45385, D-I82B19, D-45386, D-I82C19, D-45387, D-I82290, D-45389, DI82890, D-4539, D-I8291, D-41512, D-I2690, D-41513, D-I2692, D-41519, D-I2699	
				Nerve injury	
				D-9550, D-9551, D-9552, D-9553, D-9554, D-9555, D-9556, D-9557, D-9558, D-9559, D-9074, D-S440, DS4400, D-S4400XA, D-S4400XD, D-S4400XS, D-S4401, DS4401XA, D-S4401XD, D-S4401XS, D-S4402, D-S4402XA, D-S4402XD, D-S4402XS, D-S441, D-S4410, D-S4410XA, D-S4410XD, D-S4410XS, D-S4411, D-S4411XA, D-S4411XD, D-S4411XS, D-S4412, D-S4412XA, D-S4412XD, D-S4412XS, D-S442,D-S4420, D-S4420XA, D-S4420XD, D-S4420XS, D-S4421, D-S4421XA, D-S4421XD, D-S4421XS, D-S4422, D-S4422XA, D-S4422XD, D-S4422XS, D-S443, D-S4430, D-S4430XA, D-S4430XD, D-S4430XS, D-S4431, DS4431XA, D-S4431XD, D-S4431XS, D-S4432, D-S4432XA, D-S4432XD, D-S4432XS, D-S444, D-S4440, D-S4440XA, D-S4440XD, D-S4440XS, D-S4441, D-S4441XA, D-S4441XD, D-S4441XS, D-S4442, D-S4442XA, D-S4442XD, D-S4442XS, D-S445, D-S4450, D-S4450XA, D-S4450XD, D-S4450XS, D-S4451, D-S4451XA, D-S4451XD, D-S4451XS, D-S4452, D-S4452XA, D-S4452XD, D-S4452XS, D-S448, D-S448X, D-S448X1, D-S448X1A, D-S448X1D, D-S448X1S, DS448X2, D-S448X2A, D-S448X2D, D-S448X2S, D-S448X9, D-S448X9A, D-S448X9D, D-S448X9S, D-S449, D-S4490, D-S4490XA, D-S4490XD, D-S4490XS, D-S4491, D-S4491XA, D-S4491XD, D-S4491XS, D-S4492, D-S4492XA, D-S4492XD, D-S4492XS	
				Pneumonia	
				D-4800:D-4809, D-481, D-4820, D-4821, D-48230, D48231, D-48232, D-48239, D-48240, D-48241, D-48242, D-48249, D-48281, D-48282, D-48283, D-48284, D-48289, D-4829, D-4830, D-4831, D-4838, D-4841, D-4843, D4845, D-4846, D-4847, D-4848, D-485, D-486, DJ12:D-J189	