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Long-Term Implant Survivorship and Modes of Failure in Simultaneous Concurrent Bilateral Total Knee Arthroplasty

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Abstract

Background—There is limited evidence describing long-term implant survivorship and modes of failure in simultaneous concurrent bilateral total knee arthroplasty (TKA).

Methods—We performed a retrospective review of 266 consecutive patients (532 knees) who underwent simultaneous concurrent bilateral TKA. We reviewed medical records for preoperative characteristics, perioperative complications, and revision surgeries. The primary outcome was TKA survivorship. Secondary outcomes included indication and type of revision surgery. We used the Kaplan-Meier method to estimate survivorship and characterize risk of revision up to 20 years post-TKA.

Results—Our cohort had median follow-up of 9.8 years (interquartile range, 3.9–15.9). Forty-four patients (17%) underwent revision. Revision was more common among younger and male patients. The cumulative incidence of first-time revision per knee (n = 532) was 1.27 per 100 component-years. Implant survival was 99% (confidence interval, 97%–99%) at 5 years, 92% (89%–95%) at 10 years, 83% (77%–87%) at 15 years, and 62% (50%–73%) at 20 years. Five and 10-year survivorship compared favorably to estimates of TKA survivorship in the literature. The cumulative incidence of revision surgery per patient was 1.91 per 100 component-years. Implant survival at 5-, 10-, 15-, and 20-year time points was 96% (CI, 92%–98%), 84% (77%–89%), 71% (62%–79%), and 59% (46%–70%), respectively. Aseptic loosening (40%), polyethylene wear (34%), and infection (11%) were the most common indications for revision.

Conclusion—Simultaneous concurrent bilateral TKA is associated with a higher risk of reoperation for the patient when both knees are evaluated but similar implant survivorship to the literature when each knee was evaluated in isolation.

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Dr Keeney was a health services researcher on the faculty at Dartmouth College and Dartmouth–Hitchcock Medical Center during the conception, data collection, and analysis of this project. He is now the Director of Health Care Research and Analytics at Berkley Medical Management Solutions, a W.R. Berkley company, and remains on the Dartmouth faculty.

Keywords

bilateral; total knee arthroplasty; TKA; long-term; implant survivorship

Total knee arthroplasty (TKA) is an accepted treatment option for patients struggling with severe pain secondary to osteoarthritis of the knee. It represents one of the most common elective surgical procedures performed in the United States [1]. Current estimates project the annual number of TKA procedures to approach nearly 1 million by 2030 [1]. National expenditures related to arthroplasty procedures are estimated around \$15 billion annually in the United States [2].

Patients diagnosed with bilateral knee osteoarthritis may undergo TKA on both knees, but controversies exist regarding risks and benefits, costs, timing, and overall safety of bilateral TKA [3,4]. To compound these uncertainties, bilateral TKA may be performed and defined in various ways, and the specific time interval between each TKA is not always clear in the literature [4]. Bilateral TKA procedures completed during the same admission, under the same anesthetic, may be performed in 2 different ways. It is not always clear in the literature whether a single surgical team performed one side followed by the other (simultaneous sequential bilateral TKA) or 2 surgical teams operated concurrently (simultaneous concurrent bilateral TKA) [4]. Bilateral TKA may also be performed in a staged manner where one knee is replaced on a different day, during the same admission or delayed for several weeks to months after the initial procedure to allow for recovery between surgeries. Simultaneous concurrent bilateral TKA allows patients to undergo a shorter operative time compared to a single surgeon performing sequential TKAs under the same anesthetic, while still allowing for a single recovery. Prior studies have demonstrated high patient satisfaction with bilateral TKA, and similar or lower costs compared to staged procedures [5–8]. Bilateral TKA research generally focuses on short-term outcomes and demonstrates higher perioperative complication rates [1,5,7,9–11]. Most prior studies that include long-term follow-up of bilateral TKAs have either investigated simultaneous sequential bilateral TKA procedures or compared differences in implant type or techniques between knees in the same patient [12–15]. This is the first study we are aware of that looks at long-term follow-up of simultaneous concurrent bilateral TKA.

There is a paucity of data available on long-term outcomes following simultaneous concurrent bilateral TKA. This lack of evidence limits the ability of surgeons to counsel patients regarding realistic long-term expectations after undergoing simultaneous concurrent bilateral TKA. The objective of this study is to characterize long-term outcomes following simultaneous concurrent bilateral TKA, with focus on survivorship and modes of failure. We hypothesize that our bilateral TKA cohort will demonstrate similar long-term outcomes when compared to those of unilateral TKAs in the literature.

Methods

Institutional review board approval was obtained before the initiation of this study.

Study Population

We performed a follow-up cohort study of 266 consecutive patients (532 knees) who were originally assessed for perioperative complications after simultaneous concurrent bilateral TKA [9]. All patients underwent surgery between January 1994 and June 2000 at an academic tertiary care facility. We included the entire cohort in our retrospective chart review.

Operative and Postoperative Procedures

Bilateral TKA procedures were performed concurrently by separate surgical teams under a single anesthetic. Multiple orthopedic surgeons experienced in TKA were included in the study. A variety of implants from a single proprietary vendor (Johnson and Johnson, Warsaw, IN) were used including cruciate-retaining, posterior-stabilized, and rotating-platform types. All tibial components and the majority of femoral components were fixed with cement, and patellar resurfacing was performed in all cases. All patients participated in a standard postoperative TKA clinical pathway appropriate to the time period and were discharged to home or a rehabilitation facility.

Outcomes

The primary outcome of the study was implant survivorship defined by the cumulative incidence of revision. We considered a revision to be any procedure that involved removal of an implant (polyethylene insert, patellar component, femur, or tibia). Patients were censored at death or last documented physical encounter at our institution. Secondary outcomes included reason for revision, which included aseptic loosening, infection, polyethylene wear, instability, fracture, pain, or other (including failure of implant, failure of ingrowth, patellofemoral problems), and subsequent type of revision surgery procedure performed.

Data Sources

We extracted information on the 266 patients from the electronic medical record. Age, sex, body mass index (BMI), smoking status, TKA implant type, and perioperative complications were recorded previously by Bullock et al [9]. Information on preoperative medical comorbidities in the form of Charlson Comorbidity Index or American Society of Anesthesiologists score was not accessible in our electronic medical record from the time period of these patient's preoperative assessments. We reviewed operative reports and clinic notes for date of surgery, confirmation that a bilateral procedure was performed, incidence of revision, indication for subsequent procedures, number of additional procedures performed, and revision laterality when applicable. The medical record was also reviewed to confirm when a patient was lost to follow-up. Death information was corroborated by web-based public obituary records when necessary.

Statistical Analysis

We used the chi-square test for univariate comparisons of our categorical variables (preoperative characteristics, perioperative complications, and implant type), based on whether or not patients underwent revision. We then performed time-to-event analyses, using the Kaplan-Meier survival method to estimate univariate implant survival and risk of

revision for bilateral TKA patients (n = 266) on a per-knee basis and on a per-patient basis. Implant survival estimates and 95% confidence intervals (CIs) were calculated in both analyses. By measuring implant survival both per knee and per patient, we were able to better interpret and compare our findings to implant survivorship and risk of revision described after unilateral TKA in the existing literature. The per-knee analysis better captures implant survival, whereas the per-patient analysis better conveys the risk of return to the operating room for the patient. Both concepts are deemed important to patients for decision-making.

Risk of revision was estimated at 1-, 5-, 10-, 15-, and 20-year time points. We evaluated the association between risk factors and the risk of revision surgery per patient using Cox proportional hazards regression to generate hazard ratios (HRs). We included the following preoperative covariates in the model: age (younger than 60, 60–70, 70–80, 80 or older), BMI (<25, 25–30, 30–35, 35–40, >40), sex, and current smoking status (yes/no). A *P* value of .05 was used to indicate statistical significance in the regression model. We conducted all analyses in Stata 15.1 (StataCorp LLC, College Station, TX).

Descriptive statistics were used to present modes of failure and type of surgery performed on a per-knee basis. Modes of failure were summarized for knees that underwent a revision procedure (involving removal of the polyethylene, patella, tibia, or femur components). Type of surgery was presented for any surgical intervention following the initial primary TKA procedure.

Results

Our cohort had a median follow-up of 9.8 years (interquartile range, 3.9–15.9). The mean age and BMI for the cohort at the time of surgery were 67.6 years (standard deviation [SD], 10.3) and 32.3 kg/m² (SD, 6.8), respectively. At the time of retrospective review in 2018, 154 patients (58%) were confirmed to be deceased. Forty-four patients (17%) underwent at least 1 revision procedure (18 bilateral, 10 right-side only, and 16 left-side only). In these cases, mean time to revision was 9.7 years (SD, 4.3). Revision was more common among younger and male patients (Table 1).

The cumulative incidence of first-time revision among all knees (n = 532) was 1.27 per 100 component-years. Based on the Kaplan-Meier estimate, percent survival for a specific knee was 99% (95% CI, 97%–99%) at 5 years, 92% (95% CI, 89%–95%) at 10 years, 83% (95% CI, 78%–87%) at 15 years, and 62% (95% CI, 48%–72%) at 20 years (Fig. 1). This was associated with a risk of revision of 0.2% at 1 year, 2% at 5 years, 8% at 10 years, 17% at 15 years, and 38% at 20 years (Table 2).

The cumulative incidence of a revision surgery in either knee among bilateral TKA patients was 1.91 per 100 person-years. Based on the Kaplan-Meier estimate, percent survival for either knee at 5-, 10-, 15-, and 20-year time points was 96% (95% CI, 92%–98%), 84% (95% CI, 77%–89%), 71% (95% CI, 62%–79%), and 59% (95% CI, 46%–70%), respectively (Fig. 2). This was associated with a risk of revision of 0.4% at 1 year, 4% at 5 years, 16% at 10 years, 29% at 15 years, and 41% at 20 years (Table 2).

In the adjusted Cox proportional hazards regression model, only older age (HR, 0.66; 95% CI, 0.44–0.99; $P=.042$) and female sex (HR, 0.33; 95% CI, 0.17–0.62; $P=.001$) were significantly protective against revision. The risk of revision decreased across increasing age categories with patients younger than 60 at the highest risk of revision and patients over 80 at the lowest risk of revision. There were no revision surgeries in patients over age 80 ($n = 29$) despite these patients living on average an additional 7.5 years beyond surgery. The 1-year mortality rate for these extreme elderly patients was 13.8%. BMI and smoking status were not associated with revision.

Of the 62 incident revisions, 39% were for aseptic loosening, 35% for wear of the polyethylene component, and 10% for infection (Table 3). Isolated patellofemoral problems were uncommon ($n = 4$) and were most often treated by patellar revision and polyethylene exchange (3). As seen in Table 4, the most frequently performed revision procedure was exchange of the polyethylene component ($n = 21$) followed by all-component revision TKA (17). Additional procedures included 6 revisions of the femoral component and polyethylene and 4 revisions of the tibial component and polyethylene. Three knees underwent explant removal of all components: 2 knees had an antibiotic cement spacer for confirmed infection and 1 knee had aseptic loosening with initial concern for infection. Additional infection cases were treated by arthroscopic irrigation and debridement without exchange of polyethylene ($n = 2$), irrigation and debridement with polyethylene exchange (2), and open irrigation debridement without polyethylene exchange (1). Twenty knees underwent at least 2 revision procedures. These cases were most often associated with infection. One patient underwent 5 procedures related to infected TKA and ultimately underwent above-knee amputation.

Discussion

There is limited evidence that specifically examines outcomes after simultaneous concurrent bilateral TKA. Two surgical teams completing TKA procedures at the same time, on the same patient, may introduce additional complexity and risk. We sought to examine whether these perceived drawbacks manifested as differences in TKA survivorship. We analyzed simultaneous concurrent bilateral TKA in 266 patients in the context of existing knowledge on TKA implant survivorship.

The cumulative incidence of revision surgery on a per-knee basis among our study population (1.27 per 100 component-years) compares favorably to overall TKA revision rates in a systematic review including national reports of international joint registries that identified a mean revision rate of 1.26 per 100 component-years [16]. The authors who studied the registry data concluded that revision rates of approximately 6% at 5 years and 12% at 10 years should be expected [16]. Our results showed lower rates of revision at both time points—1.5% and 7.7%, respectively. These results are also consistent with a large administrative database study of 301,955 TKA patients who identified a frequency of revision of 4.0% at 5 years and 8.9% at 9 years [17]. In contrast, our data demonstrated higher rates of revision compared to multiple retrospective studies [18–20]. The discrepancy between population-level and single-center data is consistent with prior accounts and may be at least partially due to selection bias [21]. Longer-term implant survivorship was 83% at 15

years and 62% at 20 years in our cohort. This varies substantially compared to a recent comprehensive systematic review and meta-analysis of case series and national registry reports from Australia and Finland which demonstrated 15-year and 20-year TKA survivorship of 93% and 90% in the registry data vs 96% and 92% in the case series data, respectively [22]. Differences in patient population may contribute to limits in the generalizability of the findings of this study to ours as the Finnish and Australian registry patients may not be representative of our cohort. The discrepancy is more heavily influenced by diminishing strength of our Kaplan-Meier estimates at those time points given the effects of loss to follow-up and mortality in our cohort, with median follow-up of 9.8 years and only 49% of patients completing longer than 10 years of follow-up. Furthermore, some authors suggest the Kaplan-Meier method overestimates the risk of revision after TKA especially in studies with long follow-up durations [23]. By design, this form of analysis estimates the time to a distinct event that will ultimately occur for all subjects. It does not account for additional competing risks that could preempt the event of interest and thereby impact the probability of that event [23].

We also examined implant survivorship and risk of revision surgery on a per-patient basis, as this was felt to represent important clinical information to patients. Conceptually, the risk of revision surgery in a bilateral TKA patient should be higher than that of a unilateral TKA patient based on double the exposure of 2 knee arthroplasties. In our cohort, the risk of revision surgery in either knee was 4% at 5 years, 16% at 10 years, 29% at 15 years, and 41% at 20 years, all higher than the risk of revision surgery on a per-knee basis. By comparing the risk of revision on a per-knee basis to a per-patient basis, we can infer that patients undergoing bilateral TKA likely have a higher risk of returning to the operating room but can expect similar survivorship of each implant relative to unilateral TKAs. This is valuable information when counseling patients with bilateral knee osteoarthritis.

Patient age was found to impact the risk of revision surgery for bilateral TKA patients. Younger patients were at increased risk of revision surgery, consistent with multiple prior studies [17,19,20]. No patients over the age of 80 underwent revision surgery. However, it is important to note that 1-year mortality was high for this subgroup. We hypothesize that the physiologic demand of 2 simultaneous surgeries is likely not safe in this population. It is now better understood that patients in this age range are at higher risk of perioperative morbidity and mortality [24], and we no longer consider simultaneous concurrent bilateral TKA in this patient cohort. The higher rate of revision in young patients may be attributable to increased activity level and thereby an increased demand placed on their implants. Additionally, older patients are less likely to outlive or wear out their implants and need revision. Similar to other studies, sex was another significant determinant in the risk of revision surgery for bilateral TKA patients with female patients less likely to require revision [17,20,25]. Contrary to other studies [26,27], we did not find an association between BMI and revision. This may be due to a limited number of patients at each BMI category.

The most common indications for revision in our population were aseptic loosening (39%), polyethylene wear (35%), and infection (10%). These figures are in agreement with those of other studies involving TKAs performed during the late 1990s [28,29]. Modes of failure

have changed alongside dramatic advances in implant technology. More recent studies involving newer implants and techniques have identified infection, stiffness, and instability as the dominant indications for revision surgery with polyethylene-related causes in the minority [30–33]. This shift is likely due to changes in polyethylene content and processing with the transition away from gamma sterilization in air to gamma sterilization in an inert gas or vacuum which occurred concurrently in the late 1990s [34,35].

We acknowledge several limitations of our study. First, this is a retrospective follow-up cohort study without a comparison group. This introduces the potential for bias and limits the strength of our conclusions about our bilateral TKA patients relative to unilateral TKA patients. Second, this is a single-institution study involving patients who underwent surgery 15 to 20 years ago and may not be generalizable to a modern cohort of bilateral TKA patients based on demographic factors and advances in implant and medical technology. Third, due to the limitations of our electronic medical record of that time period, we lack detailed information on medical comorbidities as well as technique, specifically in regard to hybrid fixation with a cemented tibia and uncemented femur, and implants, particularly the type of polyethylene component. Fourth, the loss to follow-up in our population is fairly significant and limits the strength of our point estimates despite the use of the Kaplan-Meier method for survival analysis. However, most unfunded long-term studies over multiple decades of follow-up face similar issues, which are challenging to avoid. Despite these limitations, our study has several strengths. We continued the analysis of an established research population. Our definition and classification of simultaneous concurrent bilateral TKA was explicitly clear and has not been previously reported on in the long term to our knowledge. The results add to the limited evidence on long-term outcomes following simultaneous concurrent bilateral TKA.

Conclusion

Within the first 10 years, simultaneous concurrent bilateral TKA is associated with a slightly higher risk of reoperation for the patient but similar implant survivorship in each knee compared to existing estimates of TKA survivorship in the literature. This is consistent with an additive effect associated with double the exposure related to having 2 knee arthroplasties. Inconsistent with recent studies involving modern cohorts, polyethylene wear and aseptic loosening were the most common causes of failure in our study. We believe simultaneous concurrent bilateral TKA remains a reliable option in select patients, specifically those who can tolerate the increased physiologic demand of 2 surgical procedures during a single anesthetic. Surgeons may be able to provide patients reassurance that they are not compromising implant survivorship when undergoing simultaneous concurrent bilateral TKA.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1. Kaplan-Meier plot depicting survival estimate for time to revision surgery per knee in 532 knees (266 patients). TKA, total knee arthroplasty; CI, confidence interval.

Fig. 2. Kaplan-Meier plot for incident revision of either knee after bilateral TKA per patient (N = 266).

Table 1

Unadjusted Preoperative Characteristics and Incidence of Perioperative Complications in Simultaneous Concurrent Bilateral TKA Patients by Revision Status.

Variable	No Revision (N = 222)	Revision (N = 44)	P Value
Age			.001
Younger than 60	35 (16%)	17 (38%)	
60–70	71 (32%)	14 (32%)	
70–80	87 (39%)	13 (30%)	
80 or older	29 (13%)	0 (0%)	
Sex			.013
Male	88 (40%)	27 (61%)	
Female	134 (60%)	17 (39%)	
Body mass index			.494
<25	30 (14%)	2 (5%)	
25–30	76 (34%)	16 (36%)	
30–35	51 (23%)	10 (23%)	
35–40	36 (16%)	8 (18%)	
40+	29 (13%)	8 (18%)	
Current smoker	17 (8%)	1 (2%)	.181
Perioperative complication			
Myocardial infarction	5 (2%)	0 (0%)	.308
Gastrointestinal bleed	4 (2%)	1 (2%)	.853
Wound infection	0 (0%)	1 (2%)	.026
Deep venous thrombosis	5 (2%)	0 (0%)	.308
Pulmonary embolism	1 (0.5%)	0 (0%)	.651
TKA implant type, right	No revision (n = 238)	Revision (n = 28)	.330
Posterior-stabilized	186 (78%)	23 (82%)	
Cruciate-retaining	35 (15%)	5 (18%)	
Rotating-platform	17 (7%)	0(0%)	
TKA implant type, left	No revision (n = 232)	Revision (n = 34)	.257
Posterior-stabilized	195 (84%)	26 (76%)	
Cruciate-retaining	33 (14%)	6(18%)	
Rotating-platform	4(2%)	2 (6%)	

TKA, total knee arthroplasty.

Table 2

Risk of Revision Surgery After Bilateral TKA at 1-, 5-, 10-, 15-, and 20-Year Time Points Based on Kaplan-Meier Survival Estimates for Incident Revision in Either Knee per Patient vs per Knee.

Time	Per Patient			Per Knee		
	Risk of Revision (%)	Lower 95% CI	Upper 95% CI	Risk of Revision (%)	Lower 95% CI	Upper 95% CI
1 y	0.4	0.1	2.7	0.2	0.03	1.3
5 y	3.9	2.0	7.7	1.5	0.6	3.4
10 y	15.7	10.8	22.6	7.7	5.2	11.1
15 y	28.8	21.5	38.0	17.3	13.0	22.7
20 y	41.4	30.3	54.5	37.6	27.0	50.5

TKA, total knee arthroplasty; CI, confidence interval.

Table 3

Indications for Revision TKA (N = 62).

Indication	N (%)
Aseptic loosening	24 (39)
Polyethylene wear	22 (35)
Infection	6 (10)
Fracture	3 (5)
Instability	2 (3)
Pain	2 (3)
Other	2 (3)
Missing	1 (2)

TKA, total knee arthroplasty.

Table 4

Reoperation Procedures (N = 63).

Procedure	N (%)
Polyethylene exchange	21 (33)
Revision (complete)	17 (27)
Revision (polyethylene, femur)	6 (10)
Revision (polyethylene, tibia)	4 (6)
Explant, placement of antibiotic spacer	3 (5)
Patellar revision with polyethylene exchange	3 (5)
Arthroscopic irrigation and debridement	2 (3)
Irrigation and debridement with polyethylene exchange	2 (3)
Distal femur replacement	1 (2)
Irrigation and debridement	1 (2)
Polyethylene exchange and synovectomy	1 (2%)
Removal of patellar component	1 (2%)

Includes type of procedure performed for the first reoperation after the primary TKA per knee. Information was missing for 1 knee. A total of 63 knees underwent at least 1 surgical intervention. One patient underwent mini-incision irrigation and debridement with retention of all components.