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SYMPOSIUM: LEARNING FROM LARGE-SCALE ORTHOPAEDIC DATABASES

What Are the Frequency, Associated Factors, and Mortality of Amputation and Arthrodesis After a Failed Infected TKA?

Min-Sun Son PhD, Edmund Lau MS, Javad Parvizi MD, Michael A. Mont MD, Kevin J. Bozic MD, MBA, Steven Kurtz PhD

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Abstract

Background For patients with failed surgical treatment of an infected TKA, salvage operations such as arthrodesis or above-knee amputation (AKA) may be considered. Clinical and institutional factors associated with AKA and arthrodesis after a failed TKA have not been investigated in a large-scale population, and the utilization rate and trend of these measures are not well known.

Questions/purposes (1) How has the frequency of arthrodesis and AKA after infected TKA changed over the last 10 years? (2) What clinical or institutional factors are associated with patients undergoing arthrodesis or AKA? (3) What is the risk of mortality after arthrodesis or AKA?

Methods The Medicare 100% National Inpatient Claims Database was used to identify 44,466 patients 65 years of age or older who were diagnosed with an infected TKA and who underwent revision between 2005 and 2014 based on International Classification of Diseases, 9th Revision, Clinical Modification codes. Overall, 1182 knee arthrodeses and 1864 AKAs were identified among the study population. One year of data before the index infection-related knee revision were used to examine patient demographic, institutional, and clinical factors, including comorbidities, hospital volumes, and surgeon volumes. We developed Cox regression models to investigate the risk of arthrodesis, AKA, and death as outcomes. In addition, the year of the index revision was included as a covariate to determine if the risk of subsequent surgical interventions was changing over time. The risk of mortality was also assessed as the event of interest using a similar multivariate Cox model for each patient group (arthrodesis, AKA) in addition to those who underwent additional revisions but who did not undergo either of the salvage procedures.

Results The number of arthrodesis (hazard ratio [HR], 0.90, $p < 0.001$) and amputation (HR, 0.95, $p < 0.001$) procedures showed a declining trend. Clinical factors associated with arthrodesis included acute renal failure (HR, 1.22 [1.06–1.41], $p = 0.006$), obesity (HR, 1.58 [1.35–1.84], $p < 0.001$), and having additional infection-related revisions (HR for 2+ additional revisions, 1.36 [1.13–1.64], $p = 0.001$). Higher Charlson comorbidity score (HR for a score of 5+ versus 0, 2.56 [2.12–3.14], $p < 0.001$), obesity (HR, 1.14 [1.00–1.30], $p = 0.044$), deep vein thrombosis (HR, 1.34 [1.12–1.60], $p = 0.001$), and additional revisions (HR for 2+ additional revisions, 2.19 [1.91–2.49], $p < 0.001$) were factors associated with AKA,

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M.-S. Son (✉), E. Lau
Exponent Inc, 149 Commonwealth Drive, Menlo Park, CA 94025, USA
e-mail: mson@exponent.com

J. Parvizi
Rothman Institute at Thomas Jefferson University, Philadelphia, PA, USA

M. A. Mont
Cleveland Clinic, Cleveland, OH, USA

K. J. Bozic
Dell Medical School at The University of Texas at Austin, Austin, TX, USA

S. Kurtz
Exponent, Inc, Philadelphia, PA, USA

which in turn was an independent risk factor for mortality. The risk of death increased with amputation after adjusting for age, comorbidities, and other factors (HR, 1.28 [1.20–1.37], $p < 0.001$), but patients who received arthrodesis did not show a change in mortality compared with the patients who did not receive arthrodesis or amputation (HR, 1.00 [0.91–1.10], $p = 0.971$).

Conclusions The findings of this study suggest that clinicians may be more aggressively attempting to preserve the knee even in the face of chronic prosthetic joint infection but also show that a greater number of revisions is associated with a greater risk of subsequent AKA or arthrodesis. The results also suggest that recommending centers with a high volume of joint arthroplasties may be a way to reduce the risk of the salvage procedures.

Level of Evidence Level III, therapeutic study.

Introduction

Prosthetic joint infection (PJI) is a serious complication of TKA and is the most common reason for revision [2]. Despite best efforts, the recurrence of infection is not uncommon, occurring in 8% to 16% of patients treated for PJI [10, 22], and salvage operations such as arthrodesis or above-knee amputation (AKA) may be considered after other treatment options have been exhausted [16, 17]. Arthrodesis and AKA present obvious disadvantages as salvage procedures for patients because they are associated with poor function and substantial activity limitations in this patient population. Fedorka et al. [6] reported that only half of the patients who received an AKA could walk, confirming results from other studies [8, 21]. In a recent study comparing the outcome of arthrodesis and AKA, arthrodesis was shown to have a higher risk of postoperative infection compared with AKA [4], possibly as a result of the presence of hardware in the knee. In addition, the possibility of nonunion can lead to failure of this operation [23], and patients after arthrodesis have been reported to experience persistent pain and impairment of quality of life [14, 20].

Despite such severe consequences, few studies have investigated the frequency of receiving an arthrodesis or AKA or the risk factors associated with these procedures. The studies that have been conducted primarily focus on the functional outcome rather than risk factors and are mostly based on a single-institution series with a small sample size as a result of the rarity of performing such salvage procedures [4, 8, 15, 21]. Understanding risk factors is informative in formulating a preventive care plan and can provide insight into identifying any institutional or systemic measures that can be implemented to reduce the risk of these procedures.

Therefore, we asked: (1) How has the frequency of arthrodesis and AKA after infected TKA changed over the last 10 years? (2) What clinical or institutional factors are associated with patients undergoing arthrodesis or AKA? (3) What is the risk of mortality after arthrodesis or AKA?

Materials and Methods

Data Sources

For this study, the Medicare Inpatient Claims Database was used to identify a cohort of patients who received infection-related revision TKAs from January 1, 2005, through December 31, 2014. In addition, patients who subsequently underwent AKA and/or arthrodesis were identified. The hospital data were accessed in the Medicare limited data set (LDS) format, which represents the fee-for-service claims submitted by hospitals to the Centers for Medicare & Medicaid Services for processing and does not include claims associated with beneficiaries enrolled in health maintenance organizations (HMOs) and other private health insurance plans. Each beneficiary in these LDS files is identified by a synthetic but unique number, allowing tracking of the individual patient for any subsequent complications.

Revision knee arthroplasties, AKA, and arthrodesis were identified using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) procedure codes. Patients had to be 65 years of age or older at the time of the revision and residing within the 50 United States. Periprosthetic joint infection was identified by the diagnosis code 996.66 on the same record as the revision. In addition, each beneficiary must have been enrolled in Medicare for at least 1 year before admission for the index revision knee arthroplasty. This preoperative, 1-year look-back period was used to identify prior morbidities and capture diagnoses and procedures performed before the revision for establishing the general health status of the patient at the time of the surgery. The primary TKA that led to the infection-related index revision could be more than 1 year before the index revision. Patients entered the cohort continuously during the study period, starting on January 1, 2005, and were followed until the end of the study period (December 31, 2014), patient's death, or patient's withdrawal from Medicare, which included withdrawal from conventional fee-for-service Medicare and enrollment in Medicare-HMO programs, where claims are not submitted to the Centers for Medicare & Medicaid Services. The patient's status was tracked using the matching 2005 to 2014 Medicare annual enrollment files, which provide age, resident state, entitlement status, and other enrollment information. Patients younger than 65 years old, those

residing outside of the 50 states, or those enrolled in Medicare-HMO programs were excluded from this study.

The Medicare LDS hospital data identified 93,345 infection-related knee revisions from 2005 to 2014. After applying the exclusions and accounting for multiple revisions per patient, 44,466 patients remained, which included 41,420 patients who neither received arthrodesis nor amputation, 1182 who received arthrodesis, and 1864 who received an AKA. A small fraction of the revision arthroplasty cohort patients (approximately 0.25%) received arthrodesis and ultimately an AKA. These patients were analyzed as part of the AKA group to avoid including them in both the arthrodesis and AKA groups. Total hospital charges, Medicare payments, and total lengths of stay of the first infection-related revision were also examined and reported.

Determining Risk and Associated Factors

The two primary clinical outcomes were knee arthrodesis and AKA. The patient's recurring need for additional revision and mortality were also studied. The Cox proportional hazard regression was used to evaluate the relative risk of knee arthrodesis and AKA after the initial revision knee arthroplasty. Death is a strong competing risk for these patients and many patients did not survive the followup period. Thus, the cumulative incidence function (CIF) extension of the conventional Cox model was used to evaluate the relative risk of these clinical outcomes. Amputation is also treated as a competing risk for additional revision or arthrodesis. Death before the end of the study and without first experiencing the arthrodesis or amputation is a competing risk censoring, which was separately identified from right-censoring as a result of end of study for the CIF calculation. For descriptive purposes, conventional survival plots were also generated using cause-specific hazard estimation. The factors evaluated included the patient's age, sex, race, resident census region, economic status using state Medicare buy-in as a proxy, and overall health status as captured by the Charlson Comorbidity Index. Specific comorbidity indicators for diabetes, obesity, heart failure, pulmonary disease, and acute renal failure were included to capture the effects beyond the overall health status characterized by the Charlson Index. Institutional factors included were hospital ownership (eg, private), bed size, teaching or nonteaching status, and urban/rural location. In addition, two volume measures treated as proxy variables for experience were included, quantifying the approximate annual joint arthroplasty procedures performed at the facility and performed by the physician for Medicare patients.

The data and results reported in our study were processed and analyzed using SAS® 9.4 statistical software (SAS® Institute Inc, Cary, NC, USA). P-values < 0.05 were considered statistically significant.

Results

Frequency of Above-Knee Amputation and Arthrodesis

In the years examined (2005–2014), the number of arthrodesis and amputation procedures showed a declining trend despite the increase in infection-related revisions. In 2005, there were 4147 infection-related revisions, of which 253 eventually required amputation, and 169 had arthrodesis. In 2013, by contrast, there were 4854 PJI revisions but only 129 amputations and 73 arthrodeses. Adjusted for other factors, the risk for arthrodesis decreased from year to year (hazard ratio [HR], 0.90 [0.88–0.92], $p < 0.001$) and similarly also for amputation (HR, 0.95 [0.93–0.97], $p < 0.001$). One year after the infection-related revision knee arthroplasty, the risk for arthrodesis and amputation were both at approximately 2.5%, as shown in a plot of the unadjusted CIF for arthrodesis and amputation (Fig. 1). The risk for amputation was higher than arthrodesis in later years, leveling off at 7% compared with 4% for arthrodesis at 10 years. Of all infection-related revisions identified in the study period, 14,625 of 44,466 (30%) patients underwent an additional surgery (amputation, arthrodesis, or another revision), which included AKA in 1864 of 44,466 (4%) and arthrodesis in 1182 of 44,466 (3%) (Table 1). The median time from the first index infection-related revision to arthrodesis and AKA was 6 and 11 months, respectively.

Factors Associated With Above-Knee Amputation and Arthrodesis

Sex, age, residence region, and the patient's eligibility for state buy-in of Medicare (as a proxy for economic status) are factors associated with AKA (HR for female [sex], 0.81 [0.74–0.90], $p < 0.001$; HR for 70–74 years versus 65–69 [age], 0.85 [0.75–0.96], $p = 0.009$; HR for Midwest versus South [residence region], 0.83 [0.73–0.95], $p = 0.005$; HR for Medicare buy-in, 1.74 [1.54–1.97], $p < 0.001$), whereas arthrodesis was only associated with state buy-in of Medicare (HR, 1.65 [1.43–1.93], $p < 0.001$) (Table 2). Patients who received aid to pay for Medicare had a much greater risk of receiving either an AKA or an arthrodesis. Institution-related factors at the time of the index revision were not associated factors for arthrodesis with the exception of the volume of total joint arthroplasties (TJAs) performed in the hospital (HR for increment of 100 TJAs per hospital, 0.96 [0.94–0.99], $p = 0.018$). For AKA,

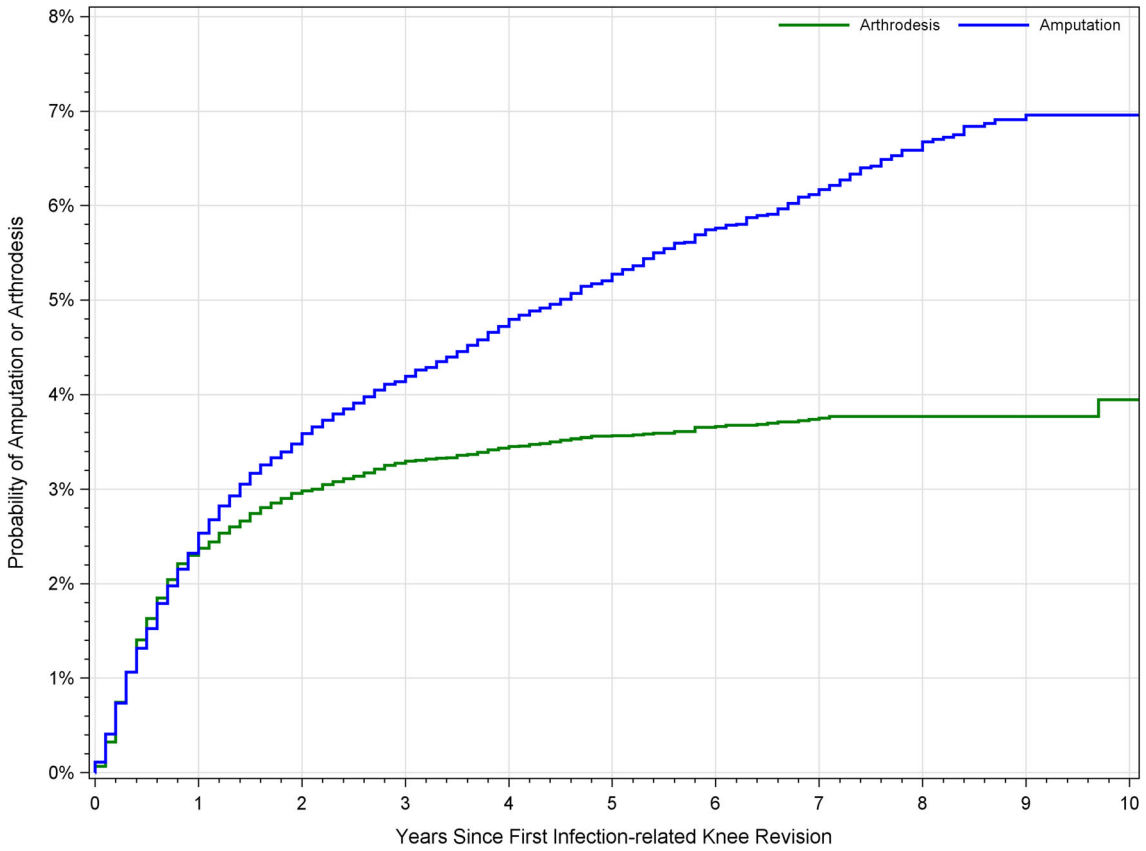

Fig. 1 Cumulative incidence function for amputation and arthrodesis after infection-related knee revision is presented.

hospital size as well as hospital and surgeon volume of TJAs were associated hospital-related factors (HR for 500+ versus < 150 hospital bed size, 1.29 [1.08–1.54], p = 0.005; HR for increment of 100 TJAs per hospital, 0.96 [0.94–0.98], p < 0.001; HR for increment of 100 TJAs per surgeon, 0.99 [0.98–1.00], p = 0.010). The results showed that larger hospital size and hospitals with larger TJA volume were associated with a reduced risk of a patient receiving AKA. In addition, having a higher Charlson Index score at the time of the index revision (HR for a score of 5+ versus 0, 2.56 [2.12–3.14], p < 0.001) or having additional revisions (HR for 2+ versus 0 additional revision, 2.19 [1.91–2.49], p < 0.001) was a strong risk factor for AKA. Other comorbidities that resulted in a higher risk of amputation were deep vein thrombosis (HR, 1.34 [1.12–1.60, p = 0.001] and obesity (HR, 1.14 [1.00–1.30], p = 0.044). For arthrodesis, increased risk was associated with acute renal failure (HR, 1.22 [1.06–1.41], p = 0.006). Risk of arthrodesis also increased with additional revisions (HR for 2+ versus 0 additional revision, 1.36 [1.13–1.64], p = 0.001) and obesity (HR, 1.58 [1.35–1.84], p < 0.001) but did not increase with the Charlson Index. The risk of receiving amputation and arthrodesis procedures was much higher if additional revisions were performed.

Mortality and Above-Knee Amputation, Arthrodesis, and Additional Revisions

The risk of death increased with amputation and decreased with additional revisions after adjusting for age, comorbidities, and other factors (Table 3). Patients who received amputation had 28% higher mortality risk than those who did not receive either salvage procedure (HR, 1.28 [1.20–1.37], p < 0.001). In contrast, patients who received arthrodesis did not show a change in mortality compared with the patients who did not receive arthrodesis or amputation (HR, 1.00 [0.91–1.10], p = 0.971; Fig. 2). Patients who received one additional revision had a 27% lower risk of death (HR, 0.73 [0.70–0.75], p < 0.001), and those who received two or more additional revisions had a 34% lower mortality risk (HR, 0.66 [0.61–0.70], p < 0.001). The mean survival time for patients who did not undergo amputation or arthrodesis was 6.8 years compared with 5.7 years for the amputation group and 6.6 years for the arthrodesis group.

Table 1. Revision knee arthroplasty with infection patient characteristics, 2005–2014

Patient characteristic	Amputated	Arthrodesis	None
Sex			
Male	960 (52%)	537(45%)	19,863 (48%)
Female	904 (48%)	645 (55%)	22,557 (52%)
Age groups (years)			
65–69	606 (33%)	352 (30%)	11,881 (29%)
70–74	459 (25%)	325 (27%)	10,629 (26%)
75–79	401 (22%)	272 (23%)	9279 (22%)
80–84	262 (14%)	158 (13%)	6221 (15%)
85+	136 (7%)	75 (6%)	3410 (8%)
Race			
White	1620 (87%)	1020 (86%)	37,225 (90%)
Black	180 (10%)	114 (10%)	2751 (7%)
Others	64 (3%)	48 (4%)	1444 (3%)
Region			
Midwest	485 (26%)	346 (29%)	11,551 (28%)
Northeast	263 (14%)	222 (19%)	6955 (17%)
South	847 (45%)	463 (39%)	16,088 (39%)
West	269 (14%)	151 (13%)	6826 (16%)
Charlson Index			
0	417 (22%)	339 (29%)	14,262 (34%)
1–2	751 (40%)	491 (42%)	17,137 (41%)
3–4	422 (23%)	245 (21%)	6838 (17%)
5+	274 (15%)	107 (9%)	3183 (8%)
Additional revisions			
0	1153 (62%)	763 (65%)	29,841 (72%)
1	432 (23%)	299 (25%)	8934 (22%)
2+	279 (15%)	120 (10%)	2645 (6%)
Total	1864	1182	41,420
Age (years)* (mean ± SD)	74 ± 7	74 ± 6	74 ± 7
Length of stay (days)* (mean ± SD)	10 ± 8	9 ± 8.5	7.5 ± 7
Hospital charge* (mean ± SD)	USD 99,605 ± 92,635	USD 90,166 ± 86,353	USD 84,838 ± 82,547
Centers for Medicare & Medicaid Services payment* (mean ± SD)	USD 22,173 ± 15,502	USD 21,465 ± 20,877	USD 19,982 ± 14,598
Followup period (years) (mean ± SD)	4 ± 3	5 ± 3	4 ± 3

* At the time of the initial revision.

Discussion

Salvage procedures such as arthrodesis or AKA are occasionally needed for patients with persistent infection who are not candidates for reconstruction. Clinical and institutional factors associated with these drastic procedures after a failed TKA have not been investigated in a large-scale population, and the utilization rate, trend, and mortality risk of these drastic measures are not well known. Understanding the frequency and factors associated with the need for salvage operations provides payers with helpful information and may also help physicians decide on treatment options and recommend preventive measures. In this study, we showed that the number of AKA and arthrodesis procedures has declined in the past decade and that various clinical and institutional factors are associated with these procedures. In addition, the mortality risk was determined to be higher for patients with AKA, whereas patients with arthrodesis were not associated with a lower or higher risk of mortality.

Limitations of the study include using the Medicare administrative claims data that are based on a patient population older than 65 years and in which clinical information is limited to the diagnosis and procedures

Table 2. Hazard ratios and 95% confidence intervals comparing the risk of receiving an amputation or arthrodesis

Patient demographic factors	Level	Amputation			Arthrodesis		
		HR	(95% CI)	p value	HR	(95% CI)	p value
Patient demographic factors							
Sex	Male	1.00	–	–	1.00	–	–
	Female	0.81	(0.74–0.90)	< 0.001	0.98	(0.87–1.11)	0.781
Age (years)	65–69	1.00	–	–	1.00	–	–
	70–74	0.85	(0.75–0.96)	0.009	1.07	(0.92–1.24)	0.386
	75–79	0.84	(0.74–0.96)	0.012	1.03	(0.88–1.20)	0.720
	80–84	0.86	(0.73–1.01)	0.058	0.93	(0.77–1.13)	0.477
	85+	0.89	(0.73–1.07)	0.208	0.87	(0.67–1.14)	0.309
Race	White	1.00	–	–	1.00	–	–
	Black	1.09	(0.91–1.30)	0.351	1.15	(0.94–1.41)	0.165
	Other	0.79	(0.62–1.00)	0.052	1.03	(0.77–1.37)	0.848
Medicare Buy-in	No buy-in	1.00	–	–	1.00	–	–
	Buy-in	1.74	(1.54–1.97)	< 0.001	1.65	(1.35–1.84)	< 0.001
Resident region	South	1.00	–	–	1.00	–	–
	Midwest	0.83	(0.73–0.95)	0.005	1.05	(0.90–1.24)	0.514
	Northeast	0.78	(0.66–0.94)	0.005	1.15	(0.94–1.41)	0.176
	West	0.80	(0.68–0.95)	0.011	0.79	(0.64–0.96)	0.018
Year	2005–2014	0.95	(0.94–0.97)	< 0.001	0.90	(0.88–0.92)	< 0.001

Hospital factors	Level	Amputation			Arthrodesis		
		HR	(95% CI)	p value	HR	(95% CI)	p value
Institutional factors							
Type	Nonteaching	1.00	–	–	1.00	–	–
	Teaching	0.95	(0.85–1.07)	0.411	1.00	(0.86–1.16)	0.990
Region	Urban	1	–	–	1.00	–	–
	Rural	1.06	(0.90–1.24)	0.516	0.98	(0.79–1.21)	0.837
Ownership	Private	1.00	–	–	1.00	–	–
	Nonprofit	1.08	(0.96–1.23)	0.207	1.03	(0.87–1.23)	0.723
	Public	1.09	(0.93–1.27)	0.296	0.88	(0.70–1.10)	0.247
Bed size	1–149	1.00	–	–	1.00	–	–
	150–299	1.10	(0.93–1.30)	0.248	0.94	(0.77–1.15)	0.551
	300–499	1.30	(1.09–1.54)	0.003	1.07	(0.87–1.31)	0.537
	500+	1.29	(1.08–1.54)	0.005	1.06	(0.84–1.32)	0.643
Hospital volume	Additional 100/year	0.96	(0.94–0.98)	< 0.001	0.96	(0.94–0.99)	0.018
Surgeon volume	Additional 10/year	0.99	(0.98–1.00)	0.010	0.99	(0.98–1.00)	0.101

Comorbidities	Level	Amputation			Arthrodesis		
		HR	(95% CI)	p value	HR	(95% CI)	p value
Patient clinical factors							
Charlson Index	00	1.00	–	–	1.00	–	–
	1–2	1.36	(1.19–1.56)	< 0.001	1.06	(0.91–1.23)	0.475
	3–4	1.86	(1.59–2.17)	< 0.001	1.26	(1.05–1.52)	0.015
	5+	2.56	(2.12–3.14)	< 0.001	0.89	(0.89–1.50)	0.271
Additional revisions	0	1.00	–	–	1.00	–	–
	1	1.14	(1.03–1.28)	0.015	1.17	(1.02–1.34)	0.022
	2+	2.19	(1.91–2.49)	< 0.001	1.36	(1.13–1.64)	0.001

Table 2. continued

Comorbidities	Level	Amputation			Arthrodesis		
		HR	(95% CI)	p value	HR	(95% CI)	p value
Acute myocardial infarction	Y	0.98	(0.76–1.27)	0.894	0.90	(0.62–1.31)	0.589
Acute renal failure	Y	1.10	(0.99–1.23)	0.080	1.22	(1.06–1.41)	0.006
Deep vein thrombosis	Y	1.34	(1.12–1.60)	0.001	0.93	(0.72–1.22)	0.612
Diabetes	Y	1.09	(0.98–1.21)	0.104	1.13	(0.98–1.30)	0.085
Obesity	Y	1.14	(1.00–1.30)	0.044	1.58	(1.35–1.84)	< 0.001
Pulmonary embolism	Y	0.92	(0.66–1.30)	0.640	1.19	(0.80–1.76)	0.389
Pneumonia	Y	1.11	(0.95–1.29)	0.182	0.83	(0.67–1.03)	0.086

HR = hazard ratio; CI = confidence interval; Y = yes.

Table 3. Hazard ratios and 95% confidence intervals of amputation, arthrodesis, and additional revisions for risk of mortality

Treatment	Level	Death		
		HR	(95% CI)	p value
Outcome	None	1.00	–	–
	Amputation	1.28	(1.20–1.37)	< 0.001
	Arthrodesis	1.00	(0.91–1.10)	0.971
Additional revisions	0	1.00	–	–
	1	0.73	(0.70–0.75)	< 0.001
	2+	0.66	(0.61–0.70)	< 0.001

HR = hazard ratio; CI = confidence interval.

listed on the record based on the ICD-9-CM codes. Specifically, the database does not provide information regarding the side of the knee on which the procedures are performed and therefore requires the assumption that the knee revised for infection is the knee that was either amputated or had an arthrodesis procedure. This assumption is reasonable given the drastic measures of amputation and arthrodesis, which are considered last resort measures for PJI after performing a revision. In addition, the revisions identified in the database do not indicate whether the patient received a single-stage or two-stage revision; a two-stage revision would have most likely been considered as two separate revisions. In defining the arthrodesis and AKA patient groups, the small number of patients who received an arthrodesis followed by an AKA were assigned to the AKA patient group; these patients were approximately 0.25% of the overall number of patients, and not including them in the arthrodesis group is not expected to change the results of the study. The risk factors for amputation and arthrodesis were also based on comorbidities that were identifiable using ICD codes only and did not consider other important clinical factors such as bone quality, patient mobility, or patient response to antimicrobial treatment. Perhaps one of the most important limitations of the database is the lack of microbiology data, namely the type of infecting organism, that is known to influence the outcome of surgical procedures for infection [7, 13]. The results of this study should be understood with this limitation but may aid surgeons in identifying high-risk patients.

The Medicare population included in the study received more AKA procedures compared with arthrodeses, and the risk of receiving either operation decreased over time. These findings suggest that clinicians may be more aggressively attempting to preserve the knee even in the face of chronic PJI. This result is in agreement with a study by Carr et al. [4] that showed an increasing trend toward AKA compared with arthrodesis. Although poor functional outcomes of AKA have been widely reported [6, 8, 21], patients with persistent infection have limited options; the relative increase of AKA compared with arthrodesis may be the result of the similarly unsatisfactory outcome of arthrodesis [20] and reported patient satisfaction of AKA despite poor functional outcomes [9].

Multiple clinical and institutional factors were found to be associated with the risk of receiving an AKA or

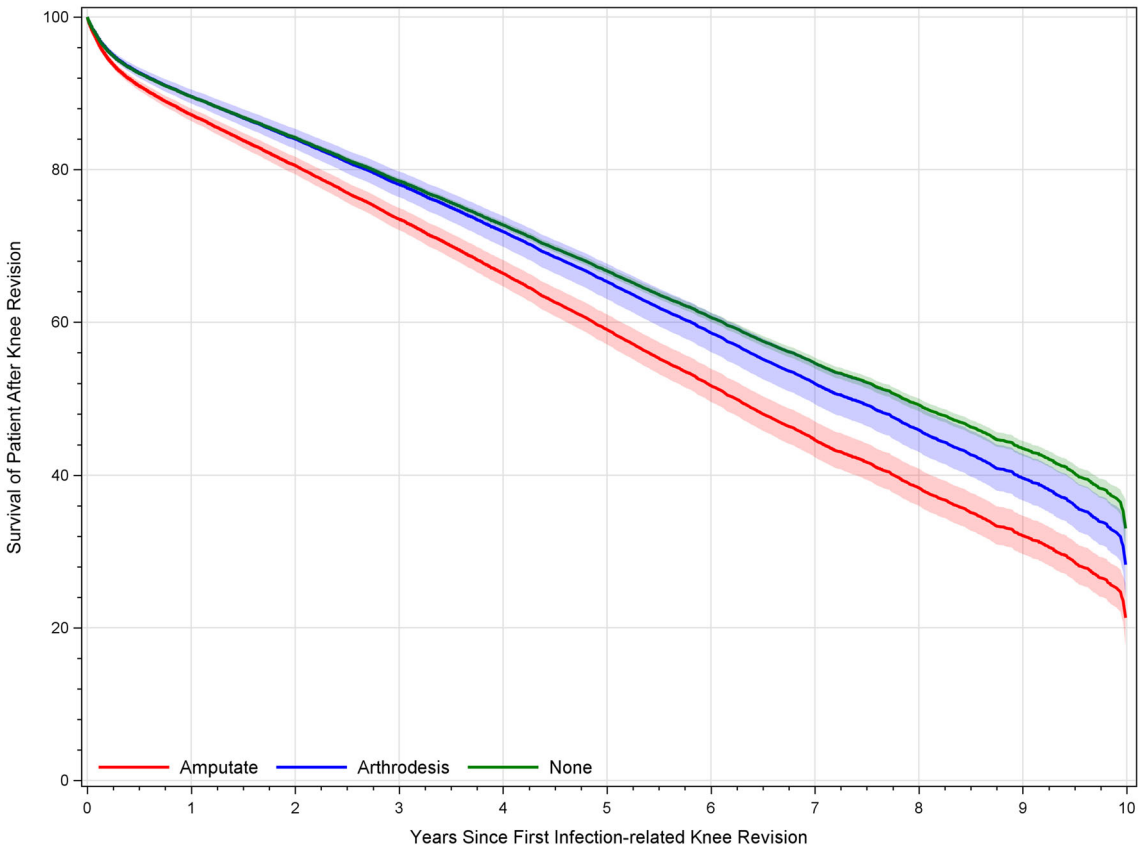

Fig. 2 The percentage of patient survival after the initial infection-related knee revision is shown for patients who received an amputation or arthrodesis in addition to patients who did not receive either of these salvage operations.

arthrodesis, including Medicare buy-in, hospital volume of TJA, obesity, and additional revisions. Medicare buy-in status and obesity have also been shown to be risk factors for developing PJI after a primary TKA, indicating that patients who are at a higher risk of developing PJI in the first place continue to be at high risk for recurrent infection [11, 12, 18, 19]. The outcome of surgical intervention appears to be better in institutions that perform a higher volume of arthroplasty or infection-related revisions. This result suggests that such institutions are capable of providing better care and should be recommended for management of complex PJI. Other studies have also shown that better outcomes occur in hospitals that conduct a higher number of lower extremity joint arthroplasties [1, 3]. High-volume hospitals are advantageous with respect to having access to multidisciplinary teams, including plastic surgeons, infectious disease consultants, and surgeon specialists who may not always be available at lower volume hospitals. Such factors may contribute to lowering the risk of AKA and arthrodesis. In addition, understanding the clinical factors associated with AKA and arthrodesis such as obesity and renal failure may help clinicians identify high-risk patients to monitor them more closely after an infection-related revision or guide physicians to address these comorbidities before subjecting patients to these salvage operations.

Mortality risk among this cohort of patients undergoing infection-related knee revision showed several revealing patterns. Patients who had to be amputated, with or without any additional revisions, showed worse survival, which is in agreement with previous studies indicating poor functional outcomes for patients undergoing AKA [3, 5, 18]. Interestingly, patients who had additional attempts at treatment for the recurrent infection were associated with a lower risk of death despite being also a strong factor for amputation. This result also indicates that although the risk of amputation is high with additional revisions, if the revision is successful, the patient will have a higher chance of survival. Arthrodesis did not have any effect on survival. The cause of death is not available from the Medicare data, but one can suspect a loss of functionality, decreased quality of life, and reduced mobility associated with amputation may have contributed toward an increased risk of death. Although both arthrodesis and AKA may be considered to have poor functional outcomes [4, 6, 8, 14, 20, 21, 23] with some studies showing

arthrodesis as having higher failure rates, the difference in the mortality risk between the two procedures may be the result of the mental well-being of the patient. In a study comparing AKA and arthrodesis outcomes, Chen et al. showed that the patients with arthrodesis had better mental scores, most likely because they preserved their leg [5]. Further investigation is necessary to understand whether the lower mortality of patients undergoing arthrodesis is the result of the procedure itself or whether other clinical factors such as the mental well-being or rehabilitation methods of the patient have an effect.

The data from the Medicare population over the last decade demonstrate that there has been a reduction in the risk of patients receiving a salvage operation such as arthrodesis or amputation. These results indicate that clinicians have been increasingly more successful with attempts of additional revisions. However, this study also indicates that additional revisions are associated with increased risk of AKA and arthrodesis. Another important finding is the lower risk of AKA and arthrodesis being associated with institutions that perform a higher volume of arthroplasty or infection-related revisions, suggesting that such institutions that are capable of providing better care should be recommended for management of complex PJI. Data from examining the mortality risk of patients with AKA or arthrodesis indicate that those who receive AKA are at a higher risk of death, whereas receiving an arthrodesis did not have any effect on patient survival. If a salvage operation is determined to be necessary, the patient and clinician need to consider the advantages and disadvantages of an AKA versus arthrodesis. In this decision, the mortality risk results presented in this study can be considered in conjunction with known functional and clinical outcomes of each procedure.

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