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Original Research

Patients With Lymphedema are at Increased Risk of Complication After Total Knee Arthroplasty: A Population Level Study

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ABSTRACT

Background: Lymphedema, a chronic disorder characterized by abnormal lymphatic fluid buildup, most commonly affects the lower extremities. Limited literature exists regarding the impact of lymphedema on outcomes following primary total knee arthroplasty (TKA). This study examined the effect of lymphedema's impact on complications and early revision-free survivorship following primary TKA using population-level data. We hypothesized that patients with preoperative lymphedema would have higher complication and revision rates.

Methods: Patients undergoing TKA for osteoarthritis between 2009 and 2020 were identified from a national claims database. Those with preoperative lymphedema were matched 1:1 to contemporaries without lymphedema using propensity score matching. Comparisons between matched and unmatched cohorts were performed using Chi-square and independent t-tests, while Cox proportional hazards models assessed revision risk.

Results: Of the 530,938 TKA patients, 1.05% (n = 5602) had preoperative lymphedema. Matched analysis showed lymphedema had higher 90-day rates of periprosthetic joint infection (2.9% vs 1.4%, $P < .001$), superficial surgical site infection (2.3% vs 1.6%, $P = .007$), wound complications (2.4% vs 1.7%, $P = .013$), and pulmonary embolism (6.6% vs 4.6%, $P < .001$). At 2 years, lymphedema was associated with increased risk of all-cause (hazard ratio (HR) = 1.42, $P < .001$) and septic revisions (HR = 1.88, $P < .001$) but not aseptic revisions (HR = 0.99, $P = .929$).

Conclusions: Preoperative lymphedema is associated with increased 90-day rates of periprosthetic joint infection and superficial surgical site infection, wound complications, and pulmonary embolism after primary TKA. Although aseptic revision risk was not increased, the association with higher all-cause and septic revisions warrants attention. These findings emphasize the need for aggressive counseling and preoperative optimization before TKA in lymphedema patients.

Introduction

Total knee arthroplasty (TKA) is a common procedure indicated for the definitive treatment of severe, symptomatic osteoarthritis (OA) of the knee. While complication rates have decreased from historic standards following TKA [1], periprosthetic joint infection (PJI) continues to be a devastating complication with a reported incidence rate between 0.3% and 1.9% [2]. While risk factors for PJI such as obesity, diabetes mellitus, and renal disease have been well described, there is a relative paucity of literature regarding the association between PJI and lymphedema.

Lymphedema is a chronic disease characterized by impaired lymphatic drainage and subsequent accumulation of fluid in the interstitium [3]. Lymphedema can occur as a primary disease due to abnormal lymphatic development or as a secondary pathology associated with the damage or obstruction of previously normal lymphatic vessels caused by disease processes, recurrent infections, trauma, surgery, or radiation treatment [3]. In arthroplasty, small, single-institutional series have linked lymphedema to higher rates of complications following TKA, including increased rates of PJI and superficial wound infections.

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While informative, the existing literature regarding lymphedema and outcomes following TKA is limited by small numbers of included patients from single institutions [4,5]. Therefore, there is a need for population-level data to clarify and confirm the results of these prior investigations. Therefore, the purpose of this study was to examine the influence of lymphedema on outcomes following primary TKA using a large national database. Preoperative lymphedema was hypothesized to be associated with increased complication and revision rates.

Material and methods

Data source

This study utilized data from the Merative MarketScan Commercial Claims and Encounters database, which also includes the Medicare Supplemental and Coordination of Benefits database (Merative, Ann Arbor, MI). This dataset encompasses insurance claims from both commercial and Medicare health plans across the United States, covering approximately 250 million patient records. Procedural and diagnostic data were extracted using the Ninth and Tenth Revisions of the International Classification of Diseases (ICD-9 and ICD-10) as well as Current Procedural Terminology (CPT) codes (Appendix A-D). Since the dataset is fully deidentified, the study was deemed exempt from institutional review board approval.

Study design and patient selection

Patients who underwent primary TKA for OA between January 1, 2009, and December 31, 2020, were identified using CPT code 27447 and OA-related ICD-9/10 codes as listed in Appendix A (n = 815,850). To ensure accurate reporting, patients with records indicating bilateral TKA were excluded to avoid potential complications from the contralateral procedure due to inconsistent laterality designators in the database (n = 121,134). Additionally, patients under 18 years of age (n = 233) and patients without a diagnosis of primary OA (n = 23,330) were excluded. Furthermore, patients with an additional diagnosis of traumatic arthritis (n = 2530), rheumatoid arthritis (n = 72,635), or a history of a fracture around the knee (n = 315) were excluded. Finally, individuals with less than 90 days of follow-up (n = 64,735) were excluded. Thus, the final cohort consisted of 530,938 patients (Fig. 1).

Propensity score matching was used to divide the study population into 2 cohorts. The control cohort consisted of patients without a presurgical diagnosis of lymphedema, while the lymphedema cohort included patients with a presurgical diagnosis of lymphedema. Matching was performed in a 1:1 ratio based on age, sex, Elixhauser comorbidities, Elixhauser Comorbidity Index (ECI), active smoking status, prior ischemic stroke, and prior myocardial infarction. This resulted in a final matched cohort of 5596 patients in each group.

Baseline patient data and comorbidities

Baseline characteristics, including sex, age, active smoking, and alcohol use, were collected along with major comorbidities, such as congestive heart failure, rheumatoid arthritis, diabetes, liver disease, renal failure, obesity, and neurological disorders. The overall comorbidity burden was quantified using the ECI for each patient [6]. Patient comorbidities were determined using ICD-9 and ICD-10 codes assigned to insurance claims within 1 year of the index TKA (Appendix B).

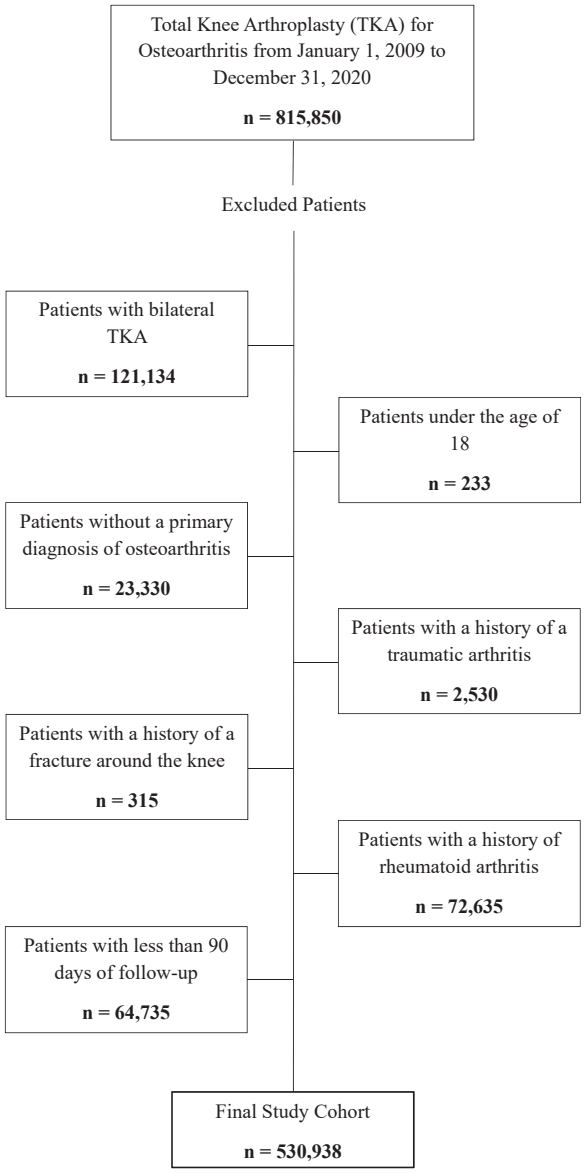

Figure 1. Study population exclusion criteria flow chart.

Study outcomes

The outcomes evaluated were 90-day complication rates and 2-year survivorship outcomes. Complications assessed included PJI, septic revision, superficial surgical site infections (SSIs), wound complications, periprosthetic fractures, sepsis, hematoma, deep vein thrombosis, pulmonary embolism (PE), myocardial infarction, and pneumonia (Appendix C). The number of readmissions within 90 days and the number of aseptic revision surgeries were also recorded.

Extended length of stay was defined as hospital admission exceeding 2 days postindex surgery. Survivorship at 2 years free from all-cause revision, septic revision, and aseptic revision was evaluated. These outcomes were identified using ICD-9, ICD-10, and CPT codes for revision TKA, cross-referenced with primary and secondary diagnosis codes to establish the indication for revision (Appendix D). We utilized published methodology for the identification of septic and aseptic revision procedures [7].

Data analyses

Patient characteristics and comorbidities in the unmatched and matched cohorts were compared using Chi-square tests for categorical variables and independent 2-sample t-tests for continuous variables. Ninety-day complications were also compared using Chi-square tests. Kaplan–Meier curves were constructed to evaluate 2-year survivorship free from all-cause revision, septic revision, and aseptic revision. Hazard ratios (HRs) for revision surgeries were calculated using Cox proportional hazards models, adjusting for clinically relevant covariates. The proportional hazards assumption was tested to ensure model validity. Statistical significance was set at a P value of <0.05 for all tests.

Results

Patient demographic characteristics and comorbidities

Of the included 530,938 patients who were initially included, 5602 patients had a presurgical diagnosis of lymphedema (1.05%). Prior to matching, the lymphedema cohort was older (64 vs 63, $P <$ .001), less often men (28.8% vs 41.1%, $P <$ .001), and had higher comorbid burden (ECI 5.46 vs 3.17, $P <$ .001). Specifically, the lymphedema cohort had higher rates of obesity, alcohol use disorder, congestive heart failure, diabetes mellitus, renal failure, liver disease, and neurological disorders. However, there were more smokers in the control group (6.7% vs 6.0%, $P <$ .001).

After matching, there were matched cohorts consisting of 5596 patients with and without lymphedema. Matching provided well-balanced cohorts with no significant differences in age, sex, ECI, or individual comorbidities (Table 1).

Ninety-Day complication outcomes

Within 90 days of surgery, patients in the lymphedema cohort experienced significantly higher rates of complications compared to the control group. The incidence of PJI was 2.9% in the lymphedema cohort, compared to 1.4% in the control group ($P = .001$). Similarly, the rates of SSI and wound complications were higher in the lymphedema group (2.3% vs 1.6%, $P = .007$ and 2.4% vs 1.7%, $P = .013$, respectively). Other notable differences included a higher incidence of hematoma (1.2% vs 0.6%, $P = .004$), PE (6.6% vs 4.6%, $P <$ .001), and extended length of stay (9.3% vs 8.2%, $P = .038$) in the lymphedema cohort.

Table 2
Ninety-Day complication outcomes.

Complications	Control N = 6993 (%)	Lymphedema N = 6993 (%)	P value[a]
PJI	77 (1.4)	160 (2.9)	**<0.001**
SSI	87 (1.6)	127 (2.3)	**0.007**
Wound complications	95 (1.7)	133 (2.4)	**0.013**
Periprosthetic Fx	7 (0.1)	8 (0.1)	1.000
Hematoma	35 (0.6)	65 (1.2)	**0.004**
DVT	28 (0.5)	36 (0.6)	0.380
PE	257 (4.6)	372 (6.6)	**<0.001**
MI	117 (2.1)	122 (2.2)	0.794
PNA	41 (0.7)	25 (0.4)	0.064
Readmissions	122 (2.2)	109 (1.9)	0.425
Extended LOS	460 (8.2)	523 (9.3)	**0.038**
Aseptic revision surgery	2984 (53)	2980 (53)	0.955

Fx, Fracture; DVT, deep venous thrombosis; MI, myocardial infarction; PNA, pneumonia; LOS, length of stay.
Bolded P values indicate statistical significance ($P < 0.05$).
[a] Pearson's Chi-squared test.

No significant differences were observed for periprosthetic fractures (0.1% vs 0.1%, $P = 1.000$, or other major complications such as deep vein thrombosis, myocardial infarction, or pneumonia. There were also no significant differences between the 2 groups for readmissions or aseptic revision surgery within 90 days of index surgery (Table 2).

Two-year survivorship

At 2 years, Kaplan–Meier survivorship free from all-cause revision was 94.3% in the lymphedema group vs 96.0% in the control group (Fig. 2). Survivorship free from septic revision was 96.4% vs 98.2%, respectively (Fig. 3). There was no notable difference in aseptic revision (Fig. 4). In multivariable Cox proportional hazards analysis, lymphedema was associated with a significantly increased risk of all-cause revision (HR: 1.42, 95% confidence interval (CI): 1.18-1.72), and septic revision (HR: 1.88, 95% CI: 1.45-2.44). There was no significant difference in aseptic revision risk (HR: 0.99, 95% CI: 0.74-1.31) (Table 3).

Discussion

The aim of this study was to examine 90-day complication outcomes and 2-year survivorship following primary TKA in

Table 1
Patient demographic characteristics and comorbidities: Unmatched and matched cohorts.

Total, n	Unmatched cohorts			Matched cohorts		
	Control (525,336)	Lymphedema (5602)	P value[a]	Control (5596)	Lymphedema (5596)	P value[a]
Age, Mean (range)	63 (19, 100)	64 (25, 94)	**<0.001**	65 (19, 94)	64 (25, 94)	0.297
Sex			**<0.001**			0.616
Men	215,707 (41.1)	1615 (28.8)		1591 (28.4)	1615 (28.9)	
Women	309,629 (58.9)	3987 (71.2)		4005 (71.6)	3981 (71.1)	
Elixhauser index (mean, sd)	3.17 (2.35)	5.46 (3.23)	**<0.001**	5.4 (3.3)	5.4 (3.2)	0.820
Obesity (n,%)	104,398 (19.9)	2357 (42.1)	**<0.001**	2392 (42.7)	2352 (42.0)	0.456
Active smoking (n,%)	35,162 (6.69)	334 (5.96)	**0.031**	293 (5.24)	332 (5.93)	0.118
Alcohol use disorder (n,%)	9307 (1.77)	153 (2.73)	**<0.001**	139 (2.48)	153 (2.73)	0.441
CHF (n,%)	30,812 (5.87)	921 (16.4)	**<0.001**	915 (16.4)	915 (16.4)	>0.999
Diabetes (n,%)	158,628 (30.2)	2263 (40.4)	**<0.001**	2319 (41.4)	2259 (40.4)	0.257
Renal failure (n,%)	27,449 (5.23)	687 (12.3)	**<0.001**	689 (12.3)	685 (12.2)	0.931
Liver disease (n,%)	31,919 (6.08)	686 (12.2)	**<0.001**	674 (12.0)	683 (12.2)	0.817
Neurological disorders (n,%)	19,087 (3.63)	414 (7.39)	**<0.001**	411 (7.34)	413 (7.38)	0.971

CHF, congestive heart failure.
Bolded P values indicate statistical significance ($P < 0.05$).
[a] Welch 2-Sample t-test; Pearson's Chi-squared test.

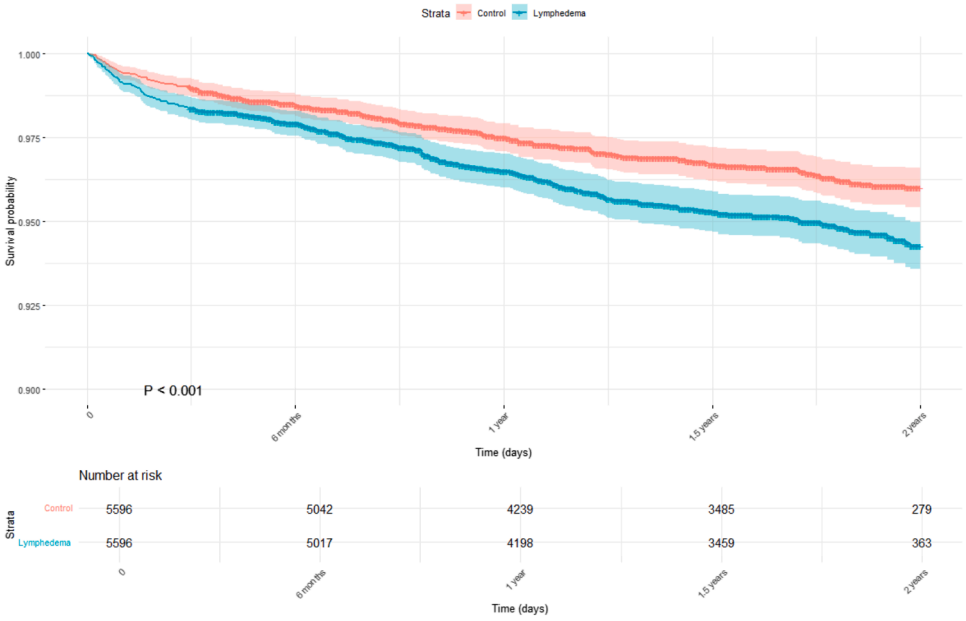

Figure 2. Two-year survivorship free of all-cause revision.

patients with lymphedema using population-level data from a national database. The results demonstrate that patients with lymphedema undergoing TKA are at significantly higher risk for postoperative complications compared to those without lymphedema. After appropriate matching, which balanced the cohorts for age, sex, and comorbidities, the lymphedema group had a higher incidence of PJI, SSI, wound complications, hematoma, and PE within 90 days of surgery. Perhaps more importantly, lymphedema was found to compromise 2-year survivorship, with significantly lower rates of survivorship free of all-cause and septic revision.

The study's results are consistent with smaller, single-institution studies of patients undergoing primary TKA. Prior studies have reported high infection rates in this population. Shrader et al. Reported infection in 19% of patients (superficial and deep infections in 12% and 7%, respectively) among 63 individuals undergoing primary TKA [5]. Cusma et al. similarly reported a 9% infection rate and 9% revision/reoperation rate in a cohort of 67 patients with preoperative lymphedema [4]. Kolz et al., in a larger series of 432 patients, reported significantly higher rates of SSIs in patients with lymphedema compared to controls, with an infection rate of 9.7% vs 1.0%, respectively, as well as increased readmissions [8]. In contrast, our study found more modest rates of PJI in the lymphedema group (2.9%), though this remained significantly higher than in comorbidity-matched controls (1.4%). At 2 years, we also found that lymphedema was associated with an 88% increased hazard of septic revision. Similarly, and perhaps not

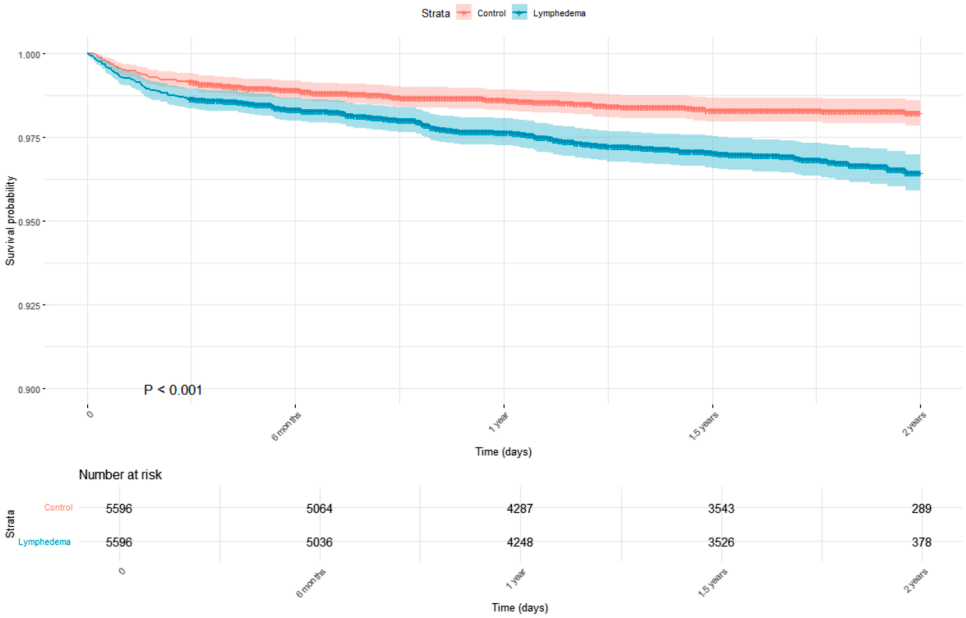

Figure 3. Two-year survivorship free of septic revision.

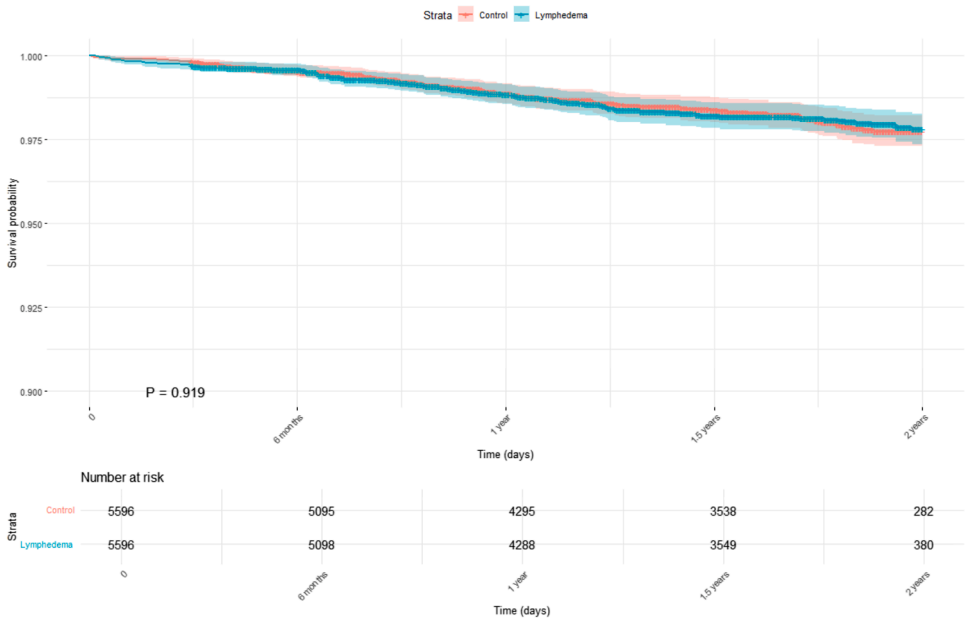

Figure 4. Two-year survivorship free of aseptic revision.

surprisingly, our results indicated that wound complications were higher in patients with lymphedema. This is consistent with findings from prior authors who also reported elevated rates of wound complications in this population.

An important finding of this study is the lower 2-year survivorship free of all-cause revision in patients with lymphedema. As noted above, this difference was largely due to an increased rate of septic revision. Patients with lymphedema had a significantly higher hazard of septic revision (HR: 1.88, 95% CI: 1.45-2.44), while the risk of aseptic failure was not significantly different between groups (HR: 0.99, 95% CI: 0.74-1.31). The overall risk of all-cause revision was also increased in the lymphedema group (HR: 1.42, 95% CI: 1.18-1.72).

Given the significant morbidity posed by PJI and the difficulty associated with infection eradication in patients with decreased local immune response due to fluid retention, these findings warrant consideration and recognition. These findings highlight the importance of thorough preoperative risk assessment and vigilant postoperative management for patients with lymphedema undergoing TKA.

The association between infection and lymphedema is likely due to a combination of systemic inflammation and the unique pathophysiology of the disease [9]. Lymphedema induces chronic inflammation, which not only disrupts normal immune function but also fosters a proinflammatory environment that impairs wound healing and tissue repair [10]. Additionally, lymphedema leads to fibrosis of the skin and subcutaneous tissues, which compromises the integrity of the skin barrier, making it more susceptible to bacterial invasion [11].

To combat this heightened risk, a multidisciplinary approach is essential. Collaboration between orthopaedic surgeons, vascular specialists, and lymphedema therapists can optimize preoperative and postoperative care. The use of compression therapy, including compression stockings both before and after surgery, can aid in reducing fluid accumulation and improving lymphatic flow, which may help mitigate infection risk [12]. Additionally, emerging techniques such as micro lymphatic surgery may help to restore lymphatic function in severe cases and could be considered prior to TKA in high-risk patients to reduce complications and improve surgical outcomes [13,14].

The present study substantially expands upon the available data regarding TKA and lymphedema by utilizing population-level data to report on a much larger cohort of patients than has previously been studied. Despite this obvious strength, there are limitations to consider. Database studies are inherently limited by the validity and accuracy of diagnostic codes. Therefore, it is possible that some patients with lymphedema were not identified as such if not properly coded. Furthermore, the database limits the

Table 3
Cox proportional hazards model for all-cause revision and septic revision.

Characteristic	All-cause revision			Septic revision			Aseptic revision		
	HR[a]	95% CI	*P* value[b]	HR[a]	95% CI	*P* value[b]	HR[a]	95% CI	*P* value[b]
Lymphedema	1.42	1.18, 1.72	**<.001**	1.88	1.45, 2.44	**<.001**	0.99	0.74, 1.31	.929
Men	1.67	1.38, 2.02	**<.001**	2.31	1.80, 2.97	**<.001**	1.00	0.73, 1.37	.985
BMI >35	1.43	1.18, 1.74	**<.001**	1.53	1.20, 1.97	**.001**	1.29	0.96, 1.74	.097
Diabetes Mellitus	1.40	1.15, 1.71	**.001**	1.70	1.29, 2.24	**<.001**	1.10	0.81, 1.48	.546
Chronic kidney disease	1.24	1.00, 1.55	.053	1.60	1.21, 2.11	**.001**	0.79	0.54, 1.16	.237
Depression	1.40	1.15, 1.71	**.001**	1.45	1.12, 1.88	**.006**	1.32	0.98, 1.78	.072

BMI, body mass index; SD, standard deviation.
Bolded *P* values indicate statistical significance ($P < 0.05$).
[a] Adjusted hazard ratio.
[b] Wald Test.

evaluation of the severity of a patient's lymphedema. Although this may still be difficult to quantify during clinical evaluation, the degree of lymphedema and skin integrity could affect patient outcomes following TKA. The lower rate of wound complications and infections in our study, compared with smaller single-institution reports, may reflect over-diagnosis of lymphedema in the database. Similarly, the study design does not allow us to know preoperative optimization strategies. It is possible that appropriate optimization (or lack thereof) could influence our results.

Conclusions

Patients with lymphedema undergoing primary TKA are at increased risk for early postoperative complications—including PJI, wound complications, and PE—as well as reduced revision-free survivorship at 2 years. These findings, drawn from a large, national database, reinforce lymphedema as a clinically meaningful risk factor for complications following primary TKA. Given the heightened susceptibility to infection and wound-related morbidity, lymphedema should be carefully considered during preoperative risk stratification and surgical planning. Multidisciplinary optimization and tailored postoperative care may help mitigate these risks and improve outcomes for this vulnerable patient population.

Conflicts of interest

Ajay Premkumar is a paid consultant for Accupredict, Smith & Nephew, Stryker, Osgenic, and Naviswiss.

Jacob M. Wilson is a paid consultant for Zimmer Biomet.

The other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2025.101900.

CRediT authorship contribution statement

Bryce T. Hrudka: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Evan Bailey:** Writing – review & editing, Writing – original draft. **Alyssa Woltemath:** Writing – review & editing, Writing – original draft, Conceptualization. **Grayson Nour:** Writing – review & editing, Writing – original draft. **Ajay Premkumar:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Jacob M. Wilson:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

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Appendix A
Procedure and exclusion codes.

Procedure type	CPT codes		Definition
TKA	27447		**TKA**
Exclusion Criteria (ICD 9 and 10 Codes)			
Traumatic arthritis of knee	ICD-9	716.16	Traumatic arthropathy, unspecified knee
	ICD-10	M17.3	Unilateral post-traumatic osteoarthritis of knee
Rheumatoid arthritis	ICD-9	714	Rheumatoid arthritis and other inflammatory polyarthropathies
	ICD-10	M05.06	Felty's syndrome, knee
		M05.16	Rheumatoid lung disease with rheumatoid arthritis of knee
		M05.26	Rheumatoid vasculitis with rheumatoid arthritis of knee
		M05.36	Rheumatoid heart disease with rheumatoid arthritis of knee
		M05.46	Rheumatoid myopathy with rheumatoid arthritis of knee
		M05.56	Rheumatoid polyneuropathy with rheumatoid arthritis of knee
		M05.86	Other rheumatoid arthritis with rheumatoid factor of knee
		M06.06	Rheumatoid arthritis without rheumatoid factor, knee
		M06.26	Rheumatoid bursitis, knee
		M06.36	Rheumatoid nodule, knee
		M06.86	Other specified rheumatoid arthritis, knee
Fractures involving knee	ICD-9	821	Fracture of other and unspecified parts of femur
		823	Fracture of tibia and fibula
	ICD-10	S72.4	Fracture of lower end of femur
		S82.1	Fracture of upper end of tibia

Appendix B
Comorbidity ICD codes.

Comorbidity	ICD code		Description
Active smoking	ICD-9	305.1	Tobacco use disorder
		V15.82	Personal history of tobacco use
	ICD-10	F17	Nicotine dependence
		Z87.891	Personal history of nicotine dependence
Obesity	ICD-9	278.00	Obesity, unspecified
		278.01	Morbid obesity
		278.02	Overweight
		278.03	Obesity hypoventilation syndrome
		V85.30 to V85.45	Body mass index 30.0-30.9, adult to body mass index 70 and over, adult
	ICD-10	E66	Overweight and obesity
		Z68.3	Body mass index 30-39, adult
		Z68.4	Body mass index 40 or greater, adult
Hypertension	ICD-9	401 to 405	Hypertensive disease
	ICD-10	I10 to I16	Hypertensive disease
Diabetes	ICD-9	250	Diabetes mellitus
	ICD-10	E10	Type 1 diabetes mellitus
		E11	Type 2 diabetes mellitus
		E13	Other specified diabetes mellitus
Rheumatic disease	ICD-9	446	Polyarteritis nodosa and allied conditions
		701.0	Circumscribed scleroderma
		710.0	Systemic lupus erythematosus
		710.1	Systemic sclerosis
		710.2	Sicca syndrome
		710.3	Dermatomyositis
		710.4	Polymyositis
		710.8	Other specified diffuse diseases of connective tissue
		710.9	Unspecified diffuse connective tissue disease
		711.2	Arthropathy in Behcet's syndrome
		714	Rheumatoid arthritis and other inflammatory polyarthropathies
		719.3	Palindromic rheumatism
		720	Ankylosing spondylitis and other inflammatory spondylopathies
		725	Polymyalgia rheumatica
		728.5	Hypermobility syndrome
		728.89	Other disorders of muscle, ligament, and fascia
		729.30	Panniculitis, unspecified site
	ICD-10	L94.0	Localized scleroderma [morphea]
		L94.1	Linear scleroderma
		L94.3	Sclerodactyly
		M05	Rheumatoid arthritis with rheumatoid factor
		M06	Other rheumatoid arthritis
		M08	Juvenile arthritis
		M12.0	Chronic postrheumatic arthropathy [Jaccoud]
		M12.3	Palindromic rheumatism
		M30	Polyarteritis nodosa and related conditions
		M31.0	Hypersensitivity angiitis
		M31.1	Thrombotic microangiopathy
		M31.2	Lethal midline granuloma
		M31.3	Wegener's granulomatosis
		M32	Systemic lupus erythematosus
		M33	Dermatopolymyositis
		M34	Systemic sclerosis [scleroderma]
		M35	Other systemic involvement of connective tissue
		M45	Ankylosing spondylitis
		M46.1	Sacroiliitis, not elsewhere classified
		M46.8	Other specified inflammatory spondylopathies
		M46.9	Unspecified inflammatory spondylopathy
Atrial fibrillation	ICD-9	427.31	Atrial fibrillation
	ICD-10	I489.1	Unspecified atrial fibrillation
Coronary artery disease	ICD-9	410 to 414	Ischemic heart disease
	ICD-10	I20 to I25	Ischemic heart disease
Renal disease	ICD-9	403	Hypertensive renal disease
		404	Hypertensive heart and renal disease
		585	Chronic renal failure
		586	Renal failure, unspecified
		587	Renal sclerosis, unspecified
		5880	Renal osteodystrophy
		V42.0	Kidney replaced by transplant
		V45.11	Renal dialysis status
		V45.12	Noncompliance with renal dialysis
		V56	Encounter for dialysis and dialysis catheter care
	ICD-10	I12.0	Hypertensive chronic kidney disease with stage 5 chronic kidney disease or end stage renal disease
		I13.1	Hypertensive heart and chronic kidney disease without heart failure
		N18	Chronic kidney disease

Appendix B (*continued*)

Comorbidity	ICD code		Description
		N19	Unspecified kidney failure
		N25.0	Renal osteodystrophy
		Z49	Encounter for car involving renal dialysis
		Z94.0	Kidney transplant status
		Z99.2	Dependence on renal dialysis
Lung disease	ICD-9	416.8	Other chronic pulmonary heart diseases
		416.9	Chronic pulmonary heart disease, unspecified
		490	Bronchitis, not specified as acute or chronic
		491	Chronic bronchitis
		492	Emphysema
		493	Asthma
		494	Bronchiectasis
		495	Extrinsic allergic alveolitis
		496	Chronic airways obstruction, not elsewhere classified
		500	Coalworkers' pneumoconiosis
		501	Asbestosis
		502	Pneumoconiosis due to other silica or silicates
		503	Pneumoconiosis due to other inorganic dust
		504	Pneumopathy due to inhalation of other dust
		505	Pneumoconiosis, unspecified
		506.4	Chronic respiratory conditions due to fumes and vapors
		508.1	Chronic and other pulmonary manifestations due to radiation
		508.8	Respiratory conditions due to other specified external agents
	ICD-10	I27.8	Other specified pulmonary heart diseases
		I27.9	Pulmonary heart disease, unspecified
		J40	Bronchitis, not specified as acute or chronic
		J41	Simple and mucopurulent chronic bronchitis
		J42	Unspecified chronic bronchitis
		J43	Emphysema
		J44	Other chronic obstructive pulmonary disease
		J45	Asthma
		J47	Brochiectasis
		J60	Coalworker's pneumoconiosis
		J61	Pneumoconiosis due to asbestos and other mineral fibers
		J62	Pneumoconiosis due to dust containing silica
		J63	Pneumoconiosis due to other inorganic dusts
		J64	Unspecified pneumoconiosis
		J65	Pneumoconiosis associated with tuberculosis
		J66	Airway disease due to specific organic dust
		J67	Hypersensitivity pneumonitis due to organic dust
		J68.4	Chronic respiratory conditions due to chemicals, gases, fumes and vapors
		J70.1	Chronic and other pulmonary manifestations due to radiation
		J70.3	Chronic drug-induced interstitial lung disorders
Liver disease	ICD-9	070.22	Chronic viral hepatitis B with hepatic coma without hepatitis delta
		070.23	Chronic viral hepatitis B with hepatic coma with hepatitis delta
		070.32	Chronic viral hepatitis B without mention of hepatic coma without mention of hepatitis delta
		070.33	Chronic viral hepatitis B without mention of hepatic coma with mention of hepatitis delta
		070.44	Chronic hepatitis C with hepatic coma
		070.54	Chronic hepatitis C without mention of hepatic coma
		070.6	Unspecified viral hepatitis with hepatic coma
		070.9	Unspecified viral hepatitis without mention of hepatic coma
		456.0	Esophageal varices with bleeding
		456.1	Esophageal varices without mention of bleeding
		456.2	Esophageal varices in diseases classified elsewhere, with bleeding
		570	Acute and subacute necrosis of liver
		571	Chronic liver disease and cirrhosis
		572.2	Hepatic encephalopathy
		572.3	Portal hypertension
		572.4	Hepatorenal syndrome
		572.8	Other sequelae of chronic liver disease
		573.3	Hepatitis, unspecified
		573.4	Hepatic infarction
		573.8	Other specified disorders of liver
		573.9	Unspecified disorder of liver
		V427	Liver replaced by transplant
	ICD-10	B18	Chronic viral hepatitis
		I85	Esophageal varices
		I86.4	Gastric varices
		K70	Alcoholic liver disease
		K71.1	Toxic liver disease with hepatic necrosis
		K71.3	Toxic liver disease with chronic persistent hepatitis
		K71.4	Toxic liver disease with chronic lobular hepatitis

(*continued on next page*)

Appendix B (*continued*)

Comorbidity	ICD code		Description
		K71.5	Toxic liver disease with chronic active hepatitis
		K71.7	Toxic liver disease with fibrosis and cirrhosis of liver
		K72	Hepatic failure, not elsewhere classified
		K73	Chronic hepatitis, not elsewhere classified
		K74	Fibrosis and cirrhosis of liver
		K76.0	Fatty (change of) liver, not elsewhere classified
		K76.2	Central hemorrhagic necrosis of liver
		K76.3	Infarction of liver
		K76.4	Peliosis hepatis
		K76.5	Hepatic veno-occlusive disease
		K76.6	Portal hypertension
		K76.7	Hepatorenal syndrome
		K76.8	Other specified diseases of liver
		K76.9	Liver disease, unspecified
		Z94.4	Liver transplant status
Congestive heart failure	ICD-9	398.91	Rheumatic heart failure (congestive)
		402.01	Malignant hypertensive heart disease with heart failure
		402.11	Benign hypertensive heart disease with heart failure
		402.91	Unspecified hypertensive heart disease with heart failure
		404.01	Hypertensive heart and chronic kidney disease, malignant, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified
		404.03	Hypertensive heart and chronic kidney disease, malignant, with heart failure and with chronic kidney disease stage V or end stage renal disease
		404.11	Hypertensive heart and chronic kidney disease, benign, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified
		404.13	Hypertensive heart and chronic kidney disease, benign, with heart failure and chronic kidney disease stage V or end stage renal disease
		404.91	Hypertensive heart and chronic kidney disease, unspecified, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified
		404.93	Hypertensive heart and chronic kidney disease, unspecified, with heart failure and chronic kidney disease stage V or end stage renal disease
		425.4	Other primary cardiomyopathies
		425.5	Alcoholic cardiomyopathy
		425.8	Cardiomyopathy in other diseases classified elsewhere
		425.9	Secondary cardiomyopathy, unspecified
		428	Heart Failure
	ICD-10	I09.81	Rheumatic heart failure
		I09.9	Rheumatic heart disease, unspecified
		I11.0	Hypertensive heart disease with heart failure
		I13.0	Hypertensive heart and chronic kidney disease with heart failure and stage 1 through stage 4 chronic kidney disease, or unspecified chronic kidney disease
		I13.2	Hypertensive heart and chronic kidney disease with heart failure and with stage 5 chronic kidney disease, or end stage renal disease
		I25.5	Ischemic cardiomyopathy
		I42	Cardiomyopathy
		I43	Cardiomyopathy in diseases classified elsewhere
		I50	Heart failure

Appendix C
Complication diagnosis.

Complication ICD codes	
ICD Codes	Description
Surgical complication	
PJI	
ICD-9 codes	
711.06	Pyogenic arthritis, lower leg
996.66	Infection and inflammatory reaction due to internal joint prosthesis
996.67	Infection and inflammatory reaction due to other internal orthopaedic device, implant, and graft
ICD-10 codes	
T81.4	Infection following a procedure
T84.5	Infection and inflammatory reaction due to internal joint prosthesis
T84.7	Infection and inflammatory reaction due to other internal orthopaedic prosthetic devices, implants and grafts
SSI	
ICD-9 codes	
682.6	Cellulitis and abscess of leg, except foot
ICD-10 codes	
T81.41	Infection following a procedure, superficial incisional surgical site
T81.49	Infection following a procedure, other surgical site
Wound complications	
ICD-9 codes	
998.3	Disruption of wound
998.83	Nonhealing surgical wound
ICD-10 codes	
T81.3	Disruption of wound
Periprosthetic fracture	
ICD-9 codes	
733.1	Pathologic fracture, unspecified site
733.81	Malunion of fracture
733.82	Nonunion of Fracture
821	Fracture of other and unspecified parts of femur
822	Fracture of patella
823	Fracture of tibia and fibula
996.44	Periprosthetic fracture around prosthetic joint
ICD-10 codes	
M97	Periprosthetic fracture around internal prosthetic joint
S72	Fracture of femur
S72.4	Fracture of lower end of femur
S82.0	Fracture of patella
Hematoma	
ICD-9 codes	
998.12	Hematoma complicating a procedure
ICD-10 codes	
T84.83	Hemorrhage due to internal orthopaedic prosthetic device, implants and grafts
L76.32	Postprocedural hematoma of skin and subcutaneous tissue following other procedure
Medical complications	
Pneumonia/influenza	
ICD-9 codes	
480-488	Pneumonia and influenza
ICD-10 codes	
J09-J18	Influenza and pneumonia
Sepsis	
ICD-9 codes	
038	Septicemia
995.91	Sepsis
ICD-10 codes	
A41.9	Sepsis, unspecified organism
T81.44	Sepsis following a procedure
Cardiac	
ICD-9 codes	
393-398	Chronic rheumatic heart disease
402	Hypertensive heart disease
410-414	Ischemic heart disease
420-429	Other forms of heart disease
ICD-10 codes	
I05-I09	Chronic rheumatic heart diseases
I11	Hypertensive heart disease
I20-I25	Ischemic heart diseases
I30-I5A	Other forms of heart disease
Deep vein thrombosis	
ICD-9 codes	
453	Other venous embolism and thrombosis
ICD-10 codes	
I82	Other venous embolism and thrombosis

(*continued on next page*)

Appendix C (*continued*)

Complication ICD codes	
ICD Codes	Description
Pulmonary embolism	
ICD-9 codes	
415.1	Pulmonary embolism
ICD-10 codes	
I26	Pulmonary embolism

Appendix D
Septic revision.

Septic revision = revision TKA CPT codes + ICD codes below		
ICD-10 codes:	Definition	Approximate ICD-9 equivalent
A40.8	Other streptococcal sepsis	038.0
A41.01	Sepsis due to Methicillin-susceptible Staphylococcus aureus	038.11
A41.02	Sepsis due to Methicillin-resistant Staphylococcus aureus	038.12
A41.1	Sepsis due to other specified staphylococcus	038.19
A41.51	Sepsis due to Escherichia coli [E. coli]	038.42
A41.81	Sepsis due to Enterococcus	038.8
A41.9	Sepsis, unspecified organism	038.9, 995.91
A49.01	Methicillin-susceptible Staphylococcus aureus infection, unspecified site	041.11
A49.02	Methicillin-resistant Staphylococcus aureus infection, unspecified site	041.12
B95.4	Other streptococcus as the cause of diseases classified elsewhere	041.09
B95.61	Methicillin-susceptible Staphylococcus aureus infection as the cause of diseases classified elsewhere	041.11
B95.62	Methicillin-resistant Staphylococcus aureus infection as the cause of diseases classified elsewhere	041.12
B95.8	Unspecified staphylococcus as the cause of diseases classified elsewhere	041.10
B96.20	Unspecified Escherichia coli [E. coli] as the cause of diseases classified elsewhere	041.49
L02.415	Cutaneous abscess of right lower limb	682.6
L02.416	Cutaneous abscess of left lower limb	
M00	Pyogenic arthritis	711
M86	Osteomyelitis	730
T81.4	Infection following a procedure	998.59
T83.511	Infection and inflammatory reaction due to indwelling urethral catheter	996.64
T83.518	Infection and inflammatory reaction due to other urinary catheter	
T83.598	Infection and inflammatory reaction due to other prosthetic device, implant and graft in urinary system	996.65
T84.5	Infection and inflammatory reaction due to internal joint prosthesis	996.66
T84.620	Infection and inflammatory reaction due to internal fixation device of right femur	996.67
T84.621	Infection and inflammatory reaction due to internal fixation device of left femur	
T84.69	Infection and inflammatory reaction due to internal fixation device of other site	
T84.7	Infection and inflammatory reaction due to other internal orthopaedic prosthetic devices, implants and grafts	
T85.7	Infection and inflammatory reaction due to other internal prosthetic devices, implants and grafts	996.69
Z47.3	Aftercare following explantation of joint prosthesis	V54.82
Z86.14	Personal history of Methicillin-resistant Staphylococcus aureus infection	V12.04