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Original Research

Incontinence Is an Independent Risk Factor for Total Hip and Knee Arthroplasty

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ABSTRACT

Background: Urinary incontinence has been linked to worse postoperative pain, decreased physical function, and reduced quality of life in patients following total joint arthroplasty. The purpose of this study was to analyze whether incontinence is associated with increased postoperative medical and joint complications following primary total hip arthroplasty (THA) and total knee arthroplasty (TKA).

Methods: A retrospective cohort study was conducted using a national insurance database. Thirty-two thousand eight hundred eleven patients with incontinence who underwent primary THA were identified and matched 1:4 with 129,073 patients without incontinence. Ninety-one thousand nine hundred thirty-five patients with incontinence who underwent primary TKA were matched 1:4 with 367,285 patients without incontinence. Medical and joint complication rates at 90 days and 2 years, respectively, were then compared for patient cohorts using multivariable logistic regressions.

Results: Patients who underwent primary THA with incontinence had statistically higher rates of dislocation, periprosthetic fracture, aseptic revisions, and overall joint complications compared to controls. Patients who underwent primary TKA with incontinence had higher rates of mechanical failure, aseptic revision, and all-cause revision compared to controls.

Conclusions: This study demonstrated an association between patients with incontinence and higher rates of dislocation, periprosthetic fractures, aseptic revisions, and overall joint complications following primary THA compared to controls. Patients with incontinence experience higher rates of mechanical failure, aseptic revision, and all-cause revision following TKA compared to controls. As such, perioperative management of urinary incontinence may help mitigate the risk of postoperative complications.

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Introduction

Total joint arthroplasty (TJA) is a highly successful and cost-effective treatment for end-stage osteoarthritis. [1,2] TJA is one of the most common orthopaedic procedures done in the United States, with the annual volume of total hip arthroplasty (THA) and total knee arthroplasty (TKA) projected to grow to 635,000 and 1.26 million, respectively, by 2030. [3] While TJA is generally successful, there remains the risk of potentially serious complications following the procedure. [4,5]

Urinary incontinence, estimated to have a prevalence of 8.7% worldwide, has been linked to worse postoperative pain, decreased physical function, and reduced quality of life in patients who underwent TJA. [6-8] Additionally, urinary incontinence has been identified as a strong risk factor for urinary tract infection (UTI), and previous literature demonstrates that symptomatic UTI increases the risk of prosthetic joint infection (PJI) following TJA. [9,10] Incontinence is often addressed with behavioral treatment, pharmacologic therapy, device use, or surgery, aiming to either regain continence by addressing underlying causes or decreasing the frequency of episodes. [7] There is not a consensus on the perioperative use of indwelling Foley catheters during TJA, with some studies demonstrating that these catheters are unnecessary for orthopaedic procedures. [11,12] The diagnosis of urinary incontinence in patients undergoing TJA could influence the perioperative plan and often requires the use of a Foley catheter. [13]

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There is a paucity of literature, however, that has thoroughly evaluated the effect of urinary incontinence on postoperative TJA outcomes, regardless of catheter use. As such, the purpose of this study was to analyze whether incontinence is associated with increased postoperative medical and joint complications following primary THA and TKA. It was hypothesized that patients with incontinence would exhibit significantly higher postoperative complication rates than matched controls in patients undergoing TJA.

Material and methods

Data source and study design

Patient records were queried from the PearlDiver Mariner database (PearlDiver Inc., Colorado Springs, CO), a commercially available administrative claims database that contains deidentified patient data from inpatient and outpatient settings. The database contains the medical records of patients across the U.S. from 2010 through Q3 of 2021, which were collected by an independent data aggregator. This study utilized the "M157Ortho" data set within PearlDiver, which contains a random sample of 157 million patients. All health insurance payors are represented, including commercial, private, and government plans. Researchers extract data using Current Procedural Terminology (CPT) and International Classification of Diseases, Ninth and Tenth revision (ICD-9/ICD-10) codes. Institutional review board exemption was granted as provided data were deidentified and compliant with the Health Insurance Portability and Accountability Act. No outside funding was received for this study.

A retrospective cohort study was conducted to investigate if incontinence is associated with increased complication rates following primary THA and TKA. THA was defined with CPT-27130 and associated ICD-9 and ICD-10 procedural codes. In order to isolate primary THA, patients with prior records of hemiarthroplasty, revision surgery, or diagnosis codes reflecting the presence of an artificial hip joint were excluded. Additionally, patients with pathologic hip fractures, avascular necrosis of the hip, infectious processes of the hip, or conversion from prior hip surgery (ie, CPT-27132) at the time of the primary THA were excluded. Finally, patients with records of contralateral hemiarthroplasty or THA during the 2-year follow-up were also excluded to ensure postoperative complications were tied to the index THA.

TKA was defined with CPT-27447 and associated ICD-9 and ICD-10 procedural codes. To include only primary TKA, patients with a prior record of unicompartmental knee arthroplasty, other knee reconstructive procedures, revision arthroplasty, or diagnosis codes reflecting the presence of an artificial knee joint were excluded. Patients with knee infections and distal femur and/or proximal tibia fractures at the time of the primary TKA were also excluded. Patients with records of contralateral arthroplasty or TKA during the 2-year follow-up were also excluded to ensure postoperative complications were tied to the index TKA. To avoid excluding patients who experienced PJI and considering that codes for TKA (eg, CPT-27447) are used to bill for the second stage of a 2-stage revision TKA for infection, contralateral TKA without concomitant removal of an antibiotic spacer during the follow-up was excluded.

Patients with incontinence were identified by claims containing relevant ICD-9/ICD-10 diagnosis codes (eg, ICD-9-D-6256, ICD-10-D-N393). In order to limit potential transfer bias due to patients leaving or joining the data set during the study period, only patients with continuous database enrollment for at least 3 months before and 2 years after the index arthroplasty were included.

In order to control for confounding variables related to the treatment of incontinence, the use of multiple drug classes by patients within 180 days prior to and following the primary arthroplasty were identified. Specific drug classes queried included antimuscarinic, beta-3 agonists, alpha blockers, and duloxetine, using the drug group codes (eg, DRUG-DULOXETINE_HCL) including pertinent generic and brand names. Additionally, prior diagnosis of common causes and comorbidities of incontinence were queried using relevant ICD-9 and ICD-10 diagnosis codes. The specific illnesses queried included multiple sclerosis, spinal cord injury, Parkinson's disease, and prostate disease. All codes used to define inclusion and exclusion criteria are provided in Appendix A.1.

Demographic data and clinical characteristics

Baseline demographic data was obtained for all patient cohorts, including age and sex. Clinical characteristics obtained included length of stay (LOS) during the index arthroplasty procedure and the prevalence of diabetes mellitus, tobacco use, and obesity. Demographic data is shown in Table 1. For patients undergoing THA, patients with incontinence were statistically more likely to have multiple sclerosis and had a lower LOS. All other queried comorbidities were statistically similar between cohorts for those undergoing THA. For patients undergoing TKA, patients with incontinence had a statistically longer LOS, but all other queried comorbidities were statistically similar vs the matched control group.

Outcomes

Rates of medical complications during the index hospital encounter and within 90 days postoperatively were obtained. Medical complications queried included deep vein thrombosis, pulmonary embolism, acute kidney injury (AKI), acute myocardial infarction, blood transfusion, pneumonia (PNA), disruption of wound, and UTI. Codes used to define medical complications are outlined in Appendix B.1.

Joint complications were evaluated at 2 years postoperatively. For THA, specific complications queried included all-cause revision, PJI, prosthetic dislocation, and periprosthetic fracture. All-cause revision THA included revision of the femoral and/or acetabular components, liner exchange, implant removal, and insertion/removal of an antibiotic spacer. Hip PJI was defined as a 2-stage revision for PJI, with the second stage defined as a conversion of prior hip surgery (ie, CPT-27132 and associated ICD-9/10 codes) with concomitant removal of an antibiotic spacer. Codes used to define THA complications are provided in Appendix B.2.

For TKA, specific complications queried included manipulation under anesthesia and/or lysis of adhesions for knee stiffness, all-cause revision, PJI, aseptic loosening, and periprosthetic fracture. All-cause revision TKA included revision of the femoral and/or tibial components, implant removal, liner exchange, and insertion/removal of an antibiotic spacer. Knee PJI was defined as a 1-stage or 2-stage revision for PJI. Codes used to define TKA complications are provided in Appendix B.3.

Additionally, medical and joint complications were queried for both THA and TKA in cohorts separated by gender. The same complications were compared between females undergoing THA with and without incontinence, between females undergoing TKA with and without incontinence, between males undergoing THA with and without incontinence, and between males undergoing TKA with and without incontinence. Lastly, the medical and joint complications were compared between males and females undergoing THA with incontinence and between males and females undergoing TKA with incontinence.

Table 1
Demographies for THA and TKA patients by incontinence diagnosis.

Complication	Total hip arthroplasty					Total knee arthroplasty				
	Controls for incontinence (n = 129,073)		Incontinence (n = 32,811)			Control (n = 367,285)		Incontinence (n = 91,935)		
	count	%	count	%	*P*-value	count	%	count	%	*P*-value
Age (years), mean ± SD	69.1 ± 8.3	-	69.1 ± 8.3	-	.392	67.7 ± 8.5	-	67.7 ± 8.5	-	.881
Females	106,249	82.3%	26,988	82.3%	.792	313,556	85.4%	78,487	85.4%	.998
Obesity	61,426	47.6%	15,672	47.8%	.577	221,397	60.3%	55,425	60.3%	.969
Diabetes	58,914	45.6%	15,024	45.8%	.641	194,839	53.0%	48,775	53.1%	.980
Multiple sclerosis	71	0.1%	31	0.1%	**.015**	0	0.0%	0	0.0%	-
Parkinson's disease	104	0.1%	35	0.1%	.182	0	0.0%	0	0.0%	-
Prostate disease	4004	3.1%	1046	3.2%	.435	41	0.0%	16	0.0%	.176
Tobacco use	53,181	41.2%	13,575	41.4%	.578	140,735	38.3%	35,243	38.3%	.927
LOS (days), mean ± SD	2.76 ± 1.8	-	2.66 ± 1.7	-	**<.001**	16.3 ± 8.3	-	16.8 ± 8.8	-	**<.001**

Bolded values denote statistical significance as defined by *P*-values less than or equal to .05.

Statistical analysis

Statistical analyses were performed using the R statistical software (Version 4.1.0; R Project for Statistical Computing, Vienna, Austria) integrated within the PearlDiver software with an α set to 0.05. In order to reduce confounding bias, exact matching without replacement was performed to generate similar patient cohorts. For both THA and TKA, patients with incontinence were matched at a 1:4 ratio with controls based on the following parameters: age, sex, year of surgery, diabetes mellitus, obesity, multiple sclerosis, spinal cord injury, Parkinson's disease, prostate disease, use of an anti-muscarinic, use of a beta-3 agonist, use of an alpha blocker, and use of Duloxetine.

Categorical variables were compared with a chi-square test, and continuous variables were compared with Welch's t-test or the Mann-Whitney U test. Rates of postoperative complications after primary THA and TKA were compared using multivariable logistic regression adjusting for age, sex, tobacco use, and LOS. Odds ratios (ORs) with corresponding 95% confidence intervals (CIs) were calculated for each outcome.

Results

Joint complications

For patients undergoing THA, those with incontinence had statistically higher rates of dislocation (1.9% vs 1.5%, OR 1.36, 95% CI: 1.17-1.57), periprosthetic fracture (1.3% vs 1.1%, OR 1.31, 95% CI: 1.08-1.57), aseptic revisions (1.6% vs 1.4%, OR 1.27, 95% CI: 1.04-1.54), and overall joint complications (4.1% vs 3.6%, OR 1.24, 95% CI: 1.12-1.38) vs controls (Table 2). All other queried complications were higher in patients with incontinence, but these did not reach statistical significance. For patients undergoing TKA, those with incontinence had higher rates of broken internal prosthesis (0.2% vs 0.1%, OR 1.62, 95% CI: 1.14-2.30), mechanical failure (1.1% vs 0.9%, OR 1.19, 95% CI: 1.04-1.36), aseptic revision (1.5% vs 1.3%, OR 1.20, 95% CI: 1.06-1.36), and all-cause revision (2.0% vs 1.7%, OR 1.15, 95% CI: 1.04-1.28) (Table 2). All other queried complications, except for dislocation, were higher in patients with incontinence, but these did not reach statistical significance.

For females undergoing THA, those with incontinence had higher rates of dislocation (1.9% vs 1.6%, OR 1.23, 95% CI: 1.04-1.44) and aseptic revision (1.6% vs 1.5%, OR 1.28, 95% CI: 1.02-1.59) (Table 3). All other queried complications, except for septic revision, were higher in females with incontinence, but these did not reach statistical significance. For males undergoing THA, all queried complications, except for mechanical failure and septic revision, were higher in males with incontinence, but none reached statistical significance.

For females undergoing TKA, those with incontinence had higher rates of aseptic revision (1.5% vs 1.3%, OR 1.19, 95% CI: 1.04-1.35) (Table 4). All other queried complications, except for periprosthetic fracture, were higher in females with incontinence, but these did not reach statistical significance. For males undergoing

Table 2
Rates of joint complications within 2 years of THA and TKA in patients with incontinence vs controls.

Complication	Total hip arthroplasty					Total knee arthroplasty				
	Control (n = 129,073)		Incontinence (n = 32,811)		Statistical analysis	Control (11 = 367,285)		Incontinence (n = 91,935)		Statistical analysis
	n	%	n	%	OR (95% CI)	n	%	n	%	OR (95% CI)
Dislocation	2000	1.55	618	1.88	**1.36 (1.17-1.57)**					
Stiffness						13,936	3.79	3169	3.45	0.98 (0.91-1.06)
Periprosthetic fracture	1435	1.11	415	1.26	**1.31 (1.08-1.57)**	1359	0.37	380	0.41	0.99 (0.80-1.23)
Loosening	614	0.48	203	0.62	1.25 (0.92-1.69)	2231	0.61	706	0.77	1.16 (0.99-1.36)
Other mechanical complication	386	0.30	119	0.36	1.42 (0.95-2.08)	1972	0.54	583	0.63	1.10 (0.91-1.32)
Prosthetic instability						1534	0.42	435	0.47	1.17 (0.96-1.42)
Broken internal prosthesis	139	0.11	51	0.16	1.27 (0.63-2.35)	434	0.12	136	0.15	**1.62 (1.14-2.30)**
Mechanical failure	502	0.39	162	0.49	1.39 (0.99-1.95)	3410	0.93	991	1.08	**1.19 (1.04-1.36)**
Aseptic revision	1812	1.40	518	1.58	**1.27 (1.04-1.54)**	4756	1.29	1400	1.52	**1.20 (1.06-1.36)**
Septic revision	900	0.70	265	0.81	0.99 (0.75-1.29)	1544	0.42	421	0.46	1.05 (0.87-1.26)
All-cause revision	2712	2.10	783	2.39	1.16 (0.99-1.36)	6300	1.72	1821	1.98	**1.15 (1.04-1.28)**
All complications	4646	3.60	1355	4.13	**1.24 (1.12-1.38)**	20,413	5.56	5075	5.52	1.04 (0.98-1.11)

Bolded values denote statistical significance as defined by *P*-values less than or equal to .05.

Table 3
Rates of joint complications within 2 years of THA in female and male patients with incontinence vs controls.

Complication	Total hip arthroplasty													
	Females					Males					Females vs males				
	Control (n = 106,242)		Incontinence (n = 26,542)		Statistical analysis	Control (n = 22,822)		Incontinence (n = 5724)		Statistical analysis	Female (n = 6600)		Male (n = 6600)		Statistical analysis (ref group females)
	n	%	n	%	OR (95% Cl)	n	%	n	%	OR (95% Cl)	n	%	n	%	OR (95% Cl)
Dislocation	1700	1.60	494	1.86	**1.23 (1.04-1.44)**	300	1.31	104	1.82	1.46 (0.99-2.12)	137	1.02	128	0.96	1.07 (0.70-1.65)
Periprosthetic fracture	1255	1.18	346	1.30	1.22 (0.99-1.49)	179	0.78	64	1.12	1.44 (0.87-2.31)	89	0.66	70	0.52	1.08 (0.60-1.96)
Aseptic loosening / mechanical failure	879	0.83	273	1.03	1.23 (0.94-1.58)	187	0.82	67	1.17	0.93 (0.49-1.63)	74	0.64	74	0.55	0.92 (0.43 -2.00)
All-cause revision THA	2293	2.16	630	2.37	1.14 (0.95-1.36)	418	1.83	134	2.34	1.21 (0.79-1.80)	182	1.25	182	1.36	1.45 (0.88-2.42)
Aseptic revision	1556	1.46	425	1.60	**1.28 (1.02-1.59)**	256	1.12	84	1.47	1.38 (0.81-2.26)	112	0.84	106	0.79	1.09 (0.58-2.07)
Septic revision (PJI)	737	069	205	0.77	0.93 (0.68-1.25)	162	0.71	50	0.87	0.97 (0.47-1.84)	70	0.52	61	0.46	1.27 (0.85-1.85)

Bolded values denote statistical significance as defined by *P*-values less than or equal to .05.

Table 4
Rates of joint complications within 2 years of TKA in female and male patients with incontinence vs controls.

Complication	Total knee arthroplasty													
	Females					Males					Females vs males				
	Control (n = 313,533)		Incontinence (n = 78,384)		Statistical analysis	Control (n = 52,723)		Incontinence (n = 13,435)		Statistical analysis	Female (n = 13,385)		Male (n = 13,385)		Statistical analysis (ref group females)
	N	%	n	%	OR (95% Cl)	n	%	n	%	OR (95% Cl)	n	%	n	%	OR (95% Cl)
Postoperative stiffness[a]	12,378	3.95	2815	3.59	1.02 (0.94-1.1)	1558	2.96	352	2.62	1.01 (0.8-1.27)	433	3.23	345	2.58	1.17 (0.88-1.55)
Periprosthetic fracture	1238	0.39	355	0.45	0.89 (0.7-1.11)	121	0.23	24	0.18	0.57 (0.23-1.21)	64	0.48	23	0.17	**2.72 (1.16-7.2)**
Aseptic loosening / mechanical failure	4455	1.42	1333	1.70	1.12 (0.99-1.25)	743	1.41	206	1.53	1.13 (0.84-1.5)	205	1.53	199	1.49	1.02 (0.71-1.47)
All-cause revision TKA	5232	1.67	1505	1.92	1.1 (0.98-1.24)	1068	2.03	313	2.33	1.19 (0.92-1.54)	247	1.85	303	2.26	0.83 (0.59-1.17)
Aseptic revision	4.042	1.29	1182	1.51	**1.19 (1.04-1.35)**	714	1.35	216	1.61	1.35 (0.95-1.88)	191	1.43	210	1.57	1.1 (0.72-1.68)
Septic revision (PJI)	1190	0.38	323	0.41	0.93 (0.74-1.15)	354	0.67	97	0.72	1.02 (0.68-1.49)	56	0.42	93	0.69	**0.47 (0.25-0.86)**

Bolded values denote statistical significance as defined by *P*-values less than or equal to .05.
[a] Patients were considered to have post-operative stiffness with codes for manipulation under anesthesia and/or lysis of adhesions.

TKA, all queried complications, except for periprosthetic fracture, were higher in males with incontinence, but none of these reached statistical significance.

For females compared to males undergoing THA with incontinence, all queried complications, except for mechanical failure and septic revision, were higher in females, but none reached statistical significance (Table 3). For females compared to males undergoing TKA with incontinence, females had higher rates of periprosthetic fracture (0.48% vs 0.17%, OR 2.72, 95% CI: 1.16-7.20), while females had lower rates of septic revision (0.42% vs 0.69%, OR 0.47, 95% CI: 0.25-0.86). All queried complications, except for all-cause revision, were higher in females, but these did not reach statistical significance (Table 4).

Medical complications

For patients undergoing THA, those with incontinence had statistically higher rates of cardiac arrest (0.06% vs 0.05%, OR 2.29, 95% CI: 1.01-4.86), PNA (1.4% vs 1.2%, OR 1.31, 95% CI: 1.09-1.57), wound disruption (1.0% vs 0.7%, OR 1.39, 95% CI: 1.12-1.72), and UTI (7.4% vs 4.3%, OR 1.76, 95% CI: 1.61-1.92). All other queried complications were higher in patients with incontinence, but these did not reach statistical significance (Table 5). For patients undergoing TKA, those with incontinence had statistically higher rates of PNA (1.4% vs 1.0%, OR 1.32, 95% CI: 1.17-1.49) and UTI (7.4% vs 3.8%, OR 2.04, 95% CI: 1.93-2.15). All other queried complications were higher in patients with incontinence, but these did not reach statistical significance (Table 5).

For females undergoing THA, those with incontinence had statistically higher rates of UTI (8.0% vs 4.6%, OR 1.64, 95% CI: 1.49-1.80). For males undergoing THA, those with incontinence had statistically higher rates of wound disruption (1.1% vs 0.5%, OR 2.13, 95% CI: 1.23-3.58) and UTI (5.1% vs 3.0%, OR 1.39, 95% CI: 1.07-1.78) (Table 6).

For females undergoing TKA, those with incontinence had statistically higher rates of UTI (7.9% vs 4.1%, OR 1.88, 95% CI: 1.77-1.99). Additionally, females with incontinence had statistically lower odds of AKI (1.6% vs 1.4%, OR 0.78, 95% CI: 0.69-0.89) and blood transfusion (1.8% vs 1.6%, OR 0.82, 95% CI: 0.70-0.96) despite having higher rates in the matched cohort. For males undergoing TKA, those with incontinence had statistically higher rates of UTI (4.9% vs 2.4%, OR 1.69, 95% CI: 1.40-2.03) and PNA (1.7% vs 1.2%, OR 1.40, 95% CI: 1.05-1.86) (Table 7).

For females compared to males undergoing THA with incontinence, females had higher rates of UTI compared to males (9.5% vs 5.3%, OR 2.53, 95% CI: 1.93-3.35). All queried complications, except for deep vein thrombosis, were higher in females, but these did not reach statistical significance (Table 6). For females compared to males undergoing TKA with incontinence, females had higher rates of UTI (17.8% vs 9.8%, OR 2.15, 95% CI: 1.78-2.62), while females had lower rates of AKI (4.0% vs 7.1%, OR 0.57, 95% CI: 0.41-0.78) (Table 7).

Discussion

This study demonstrated that patients with incontinence were significantly more likely to experience joint complications following TJA. This may be explained in part by gender differences in incontinence. Urinary incontinence is much more likely in females, which may be a contributing factor to why aseptic revisions were more likely to occur in the incontinence cohorts in the present study. [14] Adult women are thirty times more likely to develop a UTI than males, with any UTI diagnosed in a male being considered complicated. [15] This study additionally supports this by demonstrating that females with incontinence are more likely than males with incontinence to develop UTIs postoperatively. Since females are more likely to acquire UTIs, this may increase the likelihood of infection at surrounding surgical sites and increase the risk of septic revisions.

This study also demonstrated that patients with incontinence undergoing TJA had significantly higher rates of multiple medical complications. This is consistent with previous literature demonstrating an increased risk of medical complications in patients with incontinence, such as UTI and heart failure. [16,17] John et al. also demonstrated that the presence of cardiovascular risk factors is associated with the development of urinary incontinence. [18] These findings may contribute as to why the present study demonstrated an increased risk of cardiac arrest in patients with incontinence following THA. Additionally, patients who have multiple sclerosis commonly experience urinary incontinence. [19] Likewise, patients with multiple sclerosis also have a higher risk of PNA, both of which were demonstrated to be significantly more likely in patients with incontinence in this study. [20] Patients with Parkinson's disease also experience incontinence throughout the course of their disease but are known to have higher rates of PNA and other medical complications as well. [21,22] These findings could help demonstrate that patients with incontinence could have underlying diseases that may also be associated with other complications postoperatively. As such, taking into consideration the diagnosis, etiology, and associations with urinary incontinence, it is vital to develop an appropriate perioperative plan and assess the risk of postoperative complications.

Table 5
Rates of medical complications within 2 years of THA and TKA in patients with incontinence vs controls.

Complication	Total hip arthroplasty					Total knee arthroplasty				
	Control (n = 129,073)		Incontinence (n = 32,811)		Statistical analysis	Control (n = 367,285)		Incontinence (n = 91,935)		Statistical analysis
	N	%	n	%	OR (95% Cl)	n	%	n	%	OR (95% Cl)
DVT	616	0.48	188	0.57	1.07 (0.80-1.43)	2104	0.57	591	0.64	1.02 (0.86-1.22)
PE	522	0.4	163	0.50	1.19 (0.86-1.64)	2063	0.56	652	0.71	1.13 (0.95-1.34)
AKI	2125	1.65	618	1.88	1.03 (0.86-1.23)	5810	1.58	1753	1.91	1.05 (0.94-1.17)
Cardiac arrest	63	0.05	19	0.06	**2.29 (1.01-4.86)**	145	0.04	55	0.06	1.35 (0.69-2.45)
Transfusion	2913	2.26	877	2.67	1.09 (0.91-1.30)	5861	1.60	1644	1.79	0.92 (0.80-1.06)
Pneumonia	1495	1.16	471	1.44	**1.31 (1.09-1.57)**	3747	1.02	1273	1.38	**1.32(1.17-1.49)**
Disruption of wound	942	0.73	329	1.00	**1.39 (1.12-1.72)**	3131	0.85	919	1.00	1.14(0.99-1.30)
UTI	5559	4.31	2454	7.48	**1.76 (1.61-1.92)**	14,059	3.83	6869	7.47	**2.04 (1.93-2.15)**
Readmission	4848	3.76	1575	4.80	0.92 (0.55-1.47)	1130	0.31	309	0.34	0.99 (0.75-1.32)

DVT, deep vein thrombosis; PE, pulmonary embolism.
Bolded values denote statistical significance as defined by *P*-values less than or equal to .05.

Table 6
Rates of medical complications within 2 years of THA in female and male patients with incontinence vs controls.

Complication	Total hip arthroplasty													
	Females					Males					Females vs males				
	Control (n =106,242)		Incontinence (n = 26,542)		Statistical analysis	Control (n = 22,822)		Incontinence (n = 5724)		Statistical analysis	Female (n = 6600)		Male (n = 6600)		Statistical analysis
	n	%	n	%	OR (95% CI)	n	%	n	%	OR (95% CI)	n	%	n	%	OR (95% CI)
Wound disruption	822	0.77	259	0.98	1.06 (0.83-1.35)	119	0.52	65	1.14	**2.13 (1.23-3.58)**	84	1.27	72	1.09	1.25 (0.692.30)
Urinary tract infection	4872	4.59	2122	7.99	**1.64 (1.49-1.80)**	686	3.01	291	5.08	**1.39 (1.07-1.78)**	628	9.52	351	5.32	**2.53 (1.93-3.35)**
Pneumonia	1207	1.14	360	1.36	1.06 (0.86- 1.31)	208	0.91	103	1.80	1.18 (0.78-1.75)	112	1.70	118	1.79	1.04 (0.63-1.74)
Deep vein thrombosis	483	0.45	154	0.58	0.95 (0.67-1.31)	133	0.58	32	0.56	0.67 (0.33-1.24)	30	0.45	40	0.61	0.67 (0.24-1.79)
Pulmonary embolism	432	0.41	137	0.52	1.12 (0.77-1.60)	90	0.39	26	0.45	1.08 (0.48-2.22)	35	0.53	28	0.42	1.01 (0.41-2.53)
Acute kidney injury	1572	1.48	442	1.67	0.85 (0.69-1.04)	553	2.42	162	2.83	0.88 (0.59-1.27)	145	2.20	192	2.91	1.14 (0.70-1.85)
Cardiac arrest	45	0.04	16	0.06	2.02 (0.84-4.62)	18	0.08	3	0.05	1.27 (0.06-10.53)	−1		−1		5.30 (0.33-174.68)
Blood transfusion	2548	2.40	735	2.77	0.98 (0.80-1.19)	364	1.59	125	2.18	0.99 (0.62-1.54)	180	2.73	144	2.18	0.89 (0.51-1.59)

Bolded values denote statistical significance as defined by *P*-values less than or equal to .05.

Table 7
Rates of medical complications within 2 years of TKA in female and male patients with incontinence vs controls.

Complication	Total knee arthroplasty													
	Females					Males					Females vs males				
	Control (n = 313,553)		Incontinence (n = 78,384)		Statistical analysis	Control (n = 53,723)		Incontinence (n = 13,435)		Statistical analysis	Female (n = 13,385)		Male (n = 13,385)		Statistical analysis
	n	%	n	%	OR (95% CI)	n	%	n	%	OR (95% CI)	n	%	n	%	OR (95% CI)
Wound disruption	2655	0.85	768	0.98	1.00 (0.86-1.16)	476	0.89	149	1.11	0.91 (0.63-1.28)	149	2.26	143	2.17	0.9 (0.58-1.41)
Urinary tract infection	12,774	4.07	6211	7.92	**1.88 (1.77-1.99)**	1285	2.39	651	4.85	**1.69 (1.40-2.03)**	1174	17.79	646	9.79	**2.15 (1.78-2.62)**
Pneumonia	3096	0.99	1041	1.33	1.06 (0.92- 1.22)	651	1.21	230	1.71	**1.40 (1.05-1.86)**	188	2.85	229	3.47	0.73 (0.5-1.06)
Deep vein thrombosis	1743	0.56	500	0.64	0.87 (0.71-1.05)	361	0.67	91	0.68	0.68 (0.42-1.06)	91	1.38	88	1.33	1.26 (0.72-2.21)
Pulmonary embolism	1765	0.56	554	0.71	1.08 (0.90-1.30)	298	0.55	98	0.73	1.00 (0.59-1.60)	90	1.36	90	1.36	1.36 (0.77-2.47)
Acute kidney injury	4530	1.44	1276	1.63	**0.78 (0.69-0.89)**	1280	2.38	476	3.54	1.10 (0.88-1.36)	265	4.02	468	7.09	**0.57 (0.41-0.78)**
Cardiac arrest	111	0.04	39	0.05	1.49 (0.74-2.82)	34	0.06	16	0.12		9	0.07	15	0.23	-
Blood transfusion	5118	1.63	1414	1.80	**0.82 (0.70-0.96)**	742	1.38	224	1.67	0.86 (0.60-1.19)	282	4.27	224	3.39	0.88 (0.55-1.39)
Readmission	991	0.32	261	0.33	0.83 (0.59-1.14)	139	0.26	48	0.36	1.41 (0.71-2.65)	68	1.03	65	0.98	1.39 (0.69-2.88)
Length of stay (n = days)	16.4		16.8		***P* < .001**	15.8		17.0	-	***P* < .001**	17.2		16.9		.117

Bolded values denote statistical significance as defined by *P*-values less than or equal to .05.

Indwelling urinary catheters or intermittent catheterization are often used to manage bladder-related problems, including urinary incontinence. [23,24] However, the use of indwelling urinary catheters can be linked to an increased risk of infection by allowing bacteria to enter the urinary tract, leading to catheter-associated UTIs. [25] These are specifically complicated UTIs that have significant antibiotic resistance. [25] Ma et al. also demonstrated that the use of indwelling Foley catheters may increase the risk of postoperative UTIs. [26] Likewise, Meddings et al. demonstrated that catheter use 48 hours postoperatively was associated with an increased risk of UTI, 30-day mortality, and a longer LOS. [27] However, the present study was unable to query whether an indwelling Foley catheter was used for each patient due to the Foley catheter being automatically bundled into the TJA procedure reimbursement. Therefore, the overall association between the use or omission of a urinary catheter during surgery for patients with incontinence and the development of postoperative UTIs in these patients was unable to be determined.

Interestingly, studies have demonstrated the utility of TJA in the reduction of urinary incontinence symptoms. Baba et al. demonstrated that an anterior approach during a THA improved postoperative urinary incontinence symptoms, potentially due to increased tension of pelvic floor muscles. [28] Okumura et al. also demonstrated that THA procedures benefit patients with urinary incontinence by decreasing bladder symptoms postoperatively. [29] Additionally, in female patients with preoperative incontinence undergoing THA, Tamaki et al. demonstrated improvement in symptoms in 64% of their cohort following the procedure. [30] With these results, Tamaki et al. suggested a possible relationship between hip joint and pelvic floor dysfunction. However, these benefits do not seem to be restricted to THA. Oncel et al. demonstrated that following TKA, female patients saw an improvement in urinary incontinence and overactive bladder symptoms, which they associated with increased mobility following the surgery. [31] In addition to the possible reduction of urinary incontinence symptoms following TJA, it may be further beneficial to the patient to optimize urinary incontinence symptoms prior to surgery. Treatment options include bladder retraining and avoidance of bladder stimulants, such as anticholinergic medications, if possible. [32] This preoperative management of urinary incontinence may help mitigate the risk of postoperative complications, while postoperative improvement of urinary incontinence may further benefit TJA patients, especially females.

Limitations

There are several limitations to this study. First, by only evaluating complications within 2 years, this analysis is limited to short-term outcomes. Furthermore, because continuous database enrollment for 2 years after TJA was required for inclusion, patients who died within 2 years after surgery were excluded. Therefore, these results may not be applicable to patients with a high post-injury mortality risk. The possibility of coding errors is inherent with any analysis of administrative claims data. However, such instances are rare and will make up only 0.7% of Medicare and Medicaid payments in 2021. [33] Additionally, this study did not query specific etiologies of incontinence, limiting the ability to determine the significance of urinary incontinence and its link to any underlying medical illnesses.

Conclusions

This study demonstrated an association between patients with incontinence and higher rates of dislocation, periprosthetic fractures, aseptic revisions, and overall joint complications following primary THA compared to controls. Additionally, patients with incontinence are more likely to experience higher rates of mechanical failure, aseptic revision, and all-cause revision following TKA compared to controls. As such, perioperative management of urinary incontinence may help mitigate some of the risk of postoperative complications.

Conflicts of interest

W. Sherman is a paid consultant for Stryker, is an editorial board member for Arthroplasty Today, and is a knee committee member of the American Academy of Orthopaedic Surgery. All other authors declare no potential conflicts of interest.

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CRediT authorship contribution statement

Jacob S. Budin: Writing – original draft, Methodology, Formal analysis, Data curation. **Timothy L. Waters:** Writing – original draft, Methodology, Formal analysis, Data curation. **Lacee K. Collins:** Writing – original draft, Formal analysis. **Matthew W. Cole:** Writing – review & editing. **Julianna E. Winter:** Writing – review & editing. **Bela P. Delvadia:** Writing – review & editing. **Michael C. Iloanya:** Writing – review & editing. **William F. Sherman:** Writing – review & editing, Conceptualization.

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Appendix A.1
Codes used to define inclusion/exclusion criteria and other demographic and clinical variables.

Diagnosis	ICD-10
Inclusion criteria	
THA	CPT-27130, ICD-9-P-8151, ICD-10-P-0SR9019, ICD-10-P-0SR901A, ICD-10-P-0SR901Z, ICD-10-P-0SR9029, ICD-10-P-0SR902A, ICD-10-P-0SR902Z, ICD-10-P-0SR9039, ICD-10-P-0SR903A, ICD-10-P-0SR903Z, ICD-10-P-0SR9049, ICD-10-P-0SR904A, ICD-10-P-0SR904Z, ICD-10-P-0SR9069, ICD-10-P-0SR906A, ICD-10-P-0SR906Z, ICD-10-P-0SR90J9, ICD-10-P-0SR90JA, ICD-10-P-0SR90JZ, ICD-10-P-0SRB019, ICD-10-P-0SRB01A, ICD-10-P-0SRB01Z, ICD-10-P-0SRB029, ICD-10-P-0SRB02A, ICD-10-P-0SRB02Z, ICD-10-P-0SRB039, ICD-10-P-0SRB03A, ICD-10-P-0SRB03Z, ICD-10-P-0SRB049, ICD-10-P-0SRB04A, ICD-10-P-0SRB04Z, ICD-10-P-0SRB069, ICD-10-P-0SRB06A, ICD-10-P-0SRB06Z, ICD-10-P-0SRB0J9, ICD-10-P-0SRB0JA, ICD-10-P-0SRB0JZ
TKA	CPT-27447, ICD-9-P-8154, ICD-10-P-0SRC069, ICD-10-P-0SRC06A, ICD-10-P-0SRC06Z, ICD-10-P-0SRC0J9, ICD-10-P-0SRC0JA, ICD-10-P-0SRC0JZ, ICD-10-P-0SRD069, ICD-10-P-0SRD06A, ICD-10-P-0SRD06Z, ICD-10-P-0SRD0J9, ICD-10-P-0SRD0JA, ICD-10-P-0SRD0JZ
Incontinence	ICD-9-D-6256, ICD-9-D-78760, ICD-9-D-78830, ICD-9-D-78831, ICD-9-D-78832, ICD-9-D-78833, ICD-9-D-78834, ICD-9-D-78838, ICD-9-D-78839, ICD-9-D-78891, ICD-10-D-N393, ICD-10-D-N3941, ICD-10-D-N3942, ICD-10-D-N3946, ICD-10-D-N39490, ICD-10-D-N39491, ICD-10-D-N39492, ICD-10-D-N39498, ICD-10-D-R159, ICD-10-D-R32, ICD-10-D-R3981
Exclusion criteria	
Prior hip hemiarthroplasty	CPT-27125
Presence of artificial hip joint	ICD-9-D-V4364, ICD-10-D-Z96641, ICD-10-D-Z96642, ICD-10-D-Z96643, ICD-10-D-Z96649
Avascular necrosis hip	ICD-9-D-73342, ICD-10-D-M87051, ICD-10-D-M87052, ICD-10-D-M87059
Conversion from prior hip surgery	CPT-27132
Pathologic fracture hip	ICD-9-D-73314, ICD-9-D-73315, ICD-10-D-M84459A, ICD-10-D-M84559A, ICD-10-D-M84659A
Septic arthritis hip	ICD-9-D-71105, ICD-9-D-71106, ICD-9-D-71145, ICD-9-D-71146, ICD-10-D-M00851, ICD-10-D-M00852, ICD-10-D-M00859
Presence of artificial knee joint	ICD-9-D-V4365, ICD-10-D-Z96651, ICD-10-D-Z96652, ICD-10-D-Z96653, ICD-10-D-Z96659
Unicompartmental knee arthroplasty	CPT-27446, ICD-10-P-0SRC0L9, ICD-10-P-0SRC0LA, ICD-10-P-0SRC0LZ, ICD-10-P-0SRC0M9, ICD-10-P-0SRC0MA, ICD-10-P-0SRC0MZ, ICD-10-P-0SRD0L9, ICD-10-P-0SRD0LA, ICD-10-P-0SRD0LZ, ICD-10-P-0SRD0M9, ICD-10-P-0SRD0MA, ICD-10-P-0SRD0MZ
Revision total knee arthroplasty	CPT-27440, CPT-27441, CPT-27442, CPT-27443, CPT-27445, CPT-27446, CPT-27486, CPT-27487, CPT-27488, ICD-9-P-0080, ICD-9-P-0081, ICD-9-P-0082, ICD-9-P-0083, ICD-9-P-0084, ICD-9-P-8155, ICD-9-P-8155, ICD-10-P-0SPC0JZ, ICD-10-P-0SPC0JZ
Knee infection	ICD-9-D-71106, ICD-10-D-M009, ICD-10-D-M00061, ICD-10-D-M00062, ICD-10-D-M00069, ICD-10-D-M00161, ICD-10-D-M00162, ICD-10-D-M00169, ICD-10-D-M00261, ICD-10-D-M00262, ICD-10-D-M00269, ICD-10-D-M00861, ICD-10-D-M00862, ICD-10-D-M00869, ICD-10-D-M01X61, ICD-10-D-M01X62, ICD-10-D-M01X69, ICD-10-D-M01X61, ICD-10-D-M01X62, ICD-10-D-M01X69, ICD-10-D-T8453XA, ICD-10-D-T8453XD, ICD-10-D-T8453XS, ICD-10-D-T8454XA, ICD-10-D-T8454XD, ICD-10-D-T8454X
Knee fracture	CPT-27487, ICD-9-D-82100, ICD-9-D-82110, ICD-9-D-82120, ICD-9-D-82123, ICD-9-D-82129, ICD-9-D-82130, ICD-9-D-82132, ICD-9-D-82133, ICD-9-D-82139, ICD-9-D-73316, ICD-9-D-73393, ICD-9-D-82300, ICD-9-D-82302, ICD-9-D-82310, ICD-9-D-82312, ICD-9-D-82380, ICD-9-D-82382, ICD-9-D-82390, ICD-9-D-82392, ICD-10-D-M84453A, ICD-10-D-M84453A, ICD-10-D-M84453A, ICD-10-D-M84453A, ICD-10-D-M84453A, ICD-10-D-S7290XC, ICD-10-D-S72409A, ICD-10-D-S72453A, ICD-10-D-S72456A, ICD-10-D-S72499A, ICD-10-D-S72409B, ICD-10-D-S72453B, ICD-10-D-M84469A, ICD-10-D-M84369A, ICD-10-D-S82109A, ICD-10-D-S82101A, ICD-10-D-S82831A, ICD-10-D-S82102A, ICD-10-D-S82832A, ICD-10-D-S82109B, ICD-10-D-S82109C, ICD-10-D-S82101B, ICD-10-D-S82831B, ICD-10-D-S82102B, ICD-10-D-S82832B, ICD-10-D-S82201A, ICD-10-D-S82401A, ICD-10-D-S82202A, ICD-10-D-S82402A, ICD-10-D-S82201B, ICD-10-D-S82201C, ICD-10-D-S82401B, ICD-10-D-S82202B, ICD-10-D-S82402B
Contralateral knee total or unicompartmental arthroplasty	ICD-10-P-0SRC0L9, ICD-10-P-0SRC0LA, ICD-10-P-0SRC0LZ, ICD-10-P-0SRC0M9, ICD-10-P-0SRC0MA, ICD-10-P-0SRC0MZ, ICD-10-P-0SRD0L9, ICD-10-P-0SRD0LA, ICD-10-P-0SRD0LZ, ICD-10-P-0SRD0M9, ICD-10-P-0SRD0MA, ICD-10-P-0SRD0M
Other	
Antimuscarinic	DRUG-DARIFENACIN_ER, DRUG-ENABLEX, DRUG-TOVIAZ, DRUG-OXYBUTYNIN_CHLORIDE, DRUG-OXYBUTYNIN_CHLORIDE_ER, DRUG-OXYTROL, DRUG-OXYTROL_FOR_WOMEN, DRUG-DITROPAN, DRUG-DITROPAN_XL, DRUG-SOLIFENACIN_SUCCINATE, DRUG-VESICARE, DRUG-TOLTERODINE_TARTRATE, DRUG-TOLTERODINE_TARTRATE_ER, DRUG-DETROL, DRUG-DETROL_LA, DRUG-TROSPIUM_CHLORIDE, DRUG-TRSOPIUM_CHLORIDE_ER, DRUG-SACTURA, DRUG-SANCTURA_XR
Beta-3 agonists	DRUG-MYRBETRIQ, DRUG-GEMTESA
Alpha blockers	DRUG-TAMSULOSIN_HCL, DRUG-FLOMAX, DRUG-ALFUZOSIN_HCL_ER, DRUG-UROXATRAL, DRUG-SILODOSIN, DRUG-RAPAFLO, DRUG-DOXAZOSIN_MESYLATE, DRUG-CARDURA, DRUG-CARDURA_XL
Duloxetine	DRUG-DULOXETINE_HCL, DRUG-CYMBALTA
Multiple sclerosis	ICD-9-D-340, ICD-10-D-G35
Spinal cord injury	ICD-10-D-S14109A, ICD-10-D-S34109A, ICD-10-D-S24109A, ICD-10-D-S14109S, ICD-10-D-S14109D, ICD-10-D-S14105A, ICD-10-D-S34139A, ICD-10-D-S24103A, ICD-10-D-S14101A, ICD-10-D-S24109S, ICD-10-D-S14105S, ICD-10-D-S24103S, ICD-10-D-S24102S, ICD-10-D-S24101A, ICD-10-D-S34109S, ICD-10-D-S14104A, ICD-10-D-S24102A, ICD-10-D-S14106A, ICD-10-D-S24109D, ICD-10-D-S24104S, ICD-10-D-S14105D, ICD-10-D-S24104A, ICD-10-D-S34109D, ICD-10-D-S14103A, ICD-10-D-S14104S, ICD-10-D-S14106S, ICD-10-D-S24103D, ICD-10-D-S34101A, ICD-10-D-S14107A, ICD-10-D-S14102A, ICD-10-D-S24102D, ICD-10-D-S14104D, ICD-10-D-S14107S, ICD-10-D-S24104D, ICD-10-D-S14106D, ICD-10-D-S14101D, ICD-10-D-S14101S, ICD-10-D-S14103S, ICD-10-D-S34105A, ICD-10-D-S14103D, ICD-10-D-S34102A, ICD-10-D-S34104A, ICD-10-D-S14107D, ICD-10-D-S34103A, ICD-10-D-S34139S, ICD-10-D-S34101S, ICD-10-D-S14102D, ICD-10-D-S34101D, ICD-10-D-S14102S, ICD-10-D-S24101S, ICD-10-D-S24101D, ICD-10-D-S34139D, ICD-10-D-S34102S, ICD-10-D-S34102D, ICD-10-D-S34104D, ICD-10-D-S34103D, ICD-10-D-S34103S, ICD-10-D-S34105D, ICD-10-D-S34104S, ICD-10-D-S34105S, ICD-10-D-S14108A, ICD-10-D-S14108S, ICD-10-D-S14108D
Parkinson's disease	ICD-10-D-G20
Prostate disease	ICD-10-D-N400, ICD-10-D-N401

(*continued on next page*)

Appendix A.1 (*continued*)

Diagnosis	ICD-10
Tobacco use	ICD-9-D-3051, ICD-9-D-V1582, ICD-10-D-F17220, ICD-10-D-F17221, ICD-10-D-F17223, ICD-10-D-F17228, ICD-10-D-F17229, ICD-10-D-F17290, ICD-10-D-F17291, ICD-10-D-F17293, ICD-10-D-F17298, ICD-10-D-F17299, ICD-10-D-Z720
Diabetes mellitus	ICD-9-D-24900:ICD-9-D-25099, ICD-9-D-7902, ICD-9-D-79021, ICD-9-D-79022, ICD-9-D-79029, ICD-9-D-7915, ICD-9-D-7916, ICD-10-D-E090:ICD-10-D-E139
Obesity	ICD-9-D-2780, ICD-9-D-27800, ICD-9-D-27801, ICD-9-D-27802, ICD-9-D-27803, ICD-10-D-E660:ICD-10-D-E669

Appendix B.1
Codes used to define medical complications.

Diagnosis	ICD-10
Blood transfusion	ICD-9-P-9904, ICD-10-P-3023, ICD-10-P-30230AZ, ICD-10-P-30230G0, ICD-10-P- 30230G2, ICD-10-P-30230G3, ICD-10-P-30230G4, ICD-10-P-30230H0, ICD-10-P-30230H1, ICD-10-P- 30230J0, ICD-10-P-30230J1, ICD-10-P-30230K0, ICD-10-P-30230K1, ICD-10-P-30230L0, ICD-10-P-30230L1, ICD- 10-P-30230M0, ICD-10-P-30230M1, ICD-10-P-30230N0, ICD-10-P-30230N1, ICD-10-P-30230P0, ICD-10-P- 30230P1, ICD-10-P-30230Q0, ICD-10-P-30230Q1, ICD-10-P-30230R0, ICD-10-P-30230R1, ICD-10-P- 30230S0, ICD-10-P-30230S1, ICD-10-P-30230T0, ICD-10-P-30230T1, ICD-10-P-30230V0, ICD-10-P- 30230V1, ICD-10-P-30230W0, ICD-10-P-30230W1, ICD-10-P-30230X0, ICD-10-P-30230X2, ICD-10-P- 30230X3, ICD-10-P-30230X4, ICD-10-P-30230Y0, ICD-10-P-30230Y2, ICD-10-P-30230Y3, ICD-10-P- 30230Y4, ICD-10-P-30233AZ, ICD-10-P-30233G0, ICD-10-P-30233G2, ICD-10-P-30233G3, ICD-10-P- 30233G4, ICD-10-P-30233H0, ICD-10-P-30233H1, ICD-10-P-30233J0, ICD-10-P-30233J1, ICD-10-P- 30233K0, ICD-10-P-30233K1, ICD-10-P-30233L0, ICD-10-P-30233L1, ICD-10-P-30233M0, ICD-10-P- 30233M1, ICD-10-P-30233N0, ICD-10-P-30233N1, ICD-10-P-30233P0, ICD-10-P-30233P1, ICD-10-P- 30233Q0, ICD-10-P-30233Q1, ICD-10-P-30233R0, ICD-10-P-30233R1, ICD-10-P-30233S0, ICD-10-P- 30233S1, ICD-10-P-30233T0, ICD-10-P-30233T1, ICD-10-P-30233V0, ICD-10-P-30233V1, ICD-10-P- 30233W0, ICD-10-P-30233W1, ICD-10-P-30233X0, ICD-10-P-30233X2, ICD-10-P-30233X3, ICD-10-P-30233X4, ICD-10-P-30233Y0, ICD-10-P-30233Y2, ICD-10-P-30233Y3, ICD-10-P-30233Y4, ICD-10-P- 30240AZ, ICD-10-P-30240G0, ICD-10-P-30240G2, ICD-10-P-30240G3, ICD-10-P-30240G4, ICD-10-P- 30240H0, ICD-10-P-30240H1, ICD-10-P-30240J0, ICD-10-P-30240J1, ICD-10-P-30240K0, ICD-10-P- 30240K1, ICD-10-P-30240L0, ICD-10-P-30240L1, ICD-10-P-30240M0, ICD-10-P-30240M1, ICD-10-P- 30240N0, ICD-10-P-30240N1, ICD-10-P-30240P0, ICD-10-P-30240P1, ICD-10-P-30240Q0, ICD-10-P- 30240Q1, ICD-10-P-30240R0, ICD-10-P-30240R1, ICD-10-P-30240S0, ICD-10-P-30240S1, ICD-10-P- 30240T0, ICD-10-P-30240T1, ICD-10-P-30240V0, ICD-10-P-30240V1, ICD-10-P-30240W0, ICD-10-P- 30240W1, ICD-10-P-30240X0, ICD-10-P-30240X2, ICD-10-P-30240X3, ICD-10-P-30240X4, ICD-10-P- 30240Y0, ICD-10-P-30240Y2, ICD-10-P-30240Y3, ICD-10-P-30240Y4, ICD-10-P-30243AZ, ICD-10-P- 30243G0, ICD-10-P-30243G2, ICD-10-P-30243G3, ICD-10-P-30243G4, ICD-10-P-30243H0, ICD-10-P- 30243H1, ICD-10-P-30243J0, ICD-10-P-30243J1, ICD-10-P-30243K0, ICD-10-P-30243K1, ICD-10-P-30243L0, ICD- 10-P-30243L1, ICD-10-P-30243M0, ICD-10-P-30243M1, ICD-10-P-30243N0, ICD-10-P-30243N1, ICD-10-P-30243P0, ICD-10-P-30243P1, ICD-10-P-30243Q0, ICD-10-P-30243Q1, ICD-10-P-30243R0, ICD-10-P- 30243R1, ICD-10-P-30243S0, ICD-10-P-30243S1, ICD-10-P-30243T0, ICD-10-P-30243T1, ICD-10-P- 30243V0, ICD-10-P-30243V1, ICD-10-P-30243W0, ICD-10-P-30243W1, ICD-10-P-30243X0, ICD-10-P- 30243X2, ICD-10-P-30243X3, ICD-10-P-30243X4, ICD-10-P-30243Y0, ICD-10-P-30243Y2, ICD-10-P- 30243Y3, ICD-10-P-30243Y4, ICD-10-P-30250G0, ICD-10-P-30250G1, ICD-10-P-30250H0, ICD-10-P- 30250H1, ICD-10-P-30250J0, ICD-10-P-30250J1, ICD-10-P-30250K0, ICD-10-P-30250K1, ICD-10-P-30250L0, ICD- 10-P-30250L1, ICD-10-P-30250M0, ICD-10-P-30250M1, ICD-10-P-30250N0, ICD-10-P-30250N1, ICD-10-P- 30250P0, ICD-10-P-30250P1, ICD-10-P-30250Q0, ICD-10-P-30250Q1, ICD-10-P-30250R0, ICD-10-P- 30250R1, ICD-10-P-30250S0, ICD-10-P-30250S1, ICD-10-P-30250T0, ICD-10-P-30250T1, ICD-10-P- 30250V0, ICD-10-P-30250V1, ICD-10-P-30250W0, ICD-10-P-30250W1, ICD-10-P-30250X0, ICD-10-P- 30250X1, ICD-10-P-30250Y0, ICD-10-P-30250Y1, ICD-10-P-30253G0, ICD-10-P-30253G1, ICD-10-P- 30253H0, ICD-10-P-30253H1, ICD-10-P-30253J0, ICD-10-P-30253J1, ICD-10-P-30253K0, ICD-10-P- 30253K1, ICD-10-P-30253L0, ICD-10-P-30253L1, ICD-10-P-30253M0, ICD-10-P-30253M1, ICD-10-P- 30253N0, ICD-10-P-30253N1, ICD-10-P-30253P0, ICD-10-P-30253P1, ICD-10-P-30253Q0, ICD-10-P- 30253Q1, ICD-10-P-30253R0, ICD-10-P-30253R1, ICD-10-P-30253S0, ICD-10-P-30253S1, ICD-10-P- 30253T0, ICD-10-P-30253T1, ICD-10-P-30253V0, ICD-10-P-30253V1, ICD-10-P-30253W0, ICD-10-P- 30253W1, ICD-10-P-30253X0, ICD-10-P-30253X1, ICD-10-P-30253Y0, ICD-10-P-30253Y1, ICD-10-P- 30260G0, ICD-10-P-30260G1, ICD-10-P-30260H0, ICD-10-P-30260H1, ICD-10-P-30260J0, ICD-10-P- 30260J1, ICD-10-P-30260K0, ICD-10-P-30260K1, ICD-10-P-30260L0, ICD-10-P-30260L1, ICD-10-P- 30260M0, ICD-10-P-30260M1, ICD-10-P-30260N0, ICD-10-P-30260N1, ICD-10-P-30260P0, ICD-10-P- 30260P1, ICD-10-P-30260Q0, ICD-10-P-30260Q1, ICD-10-P-30260R0, ICD-10-P-30260R1, ICD-10-P- 30260S0, ICD-10-P-30260S1, ICD-10-P-30260T0, ICD-10-P-30260T1, ICD-10-P-30260V0, ICD-10-P- 30260V1, ICD-10-P-30260W0, ICD-10-P-30260W1, ICD-10-P-30260X0, ICD-10-P-30260X1, ICD-10-P- 30260Y0, ICD-10-P-30260Y1, ICD-10-P-30263G0, ICD-10-P-30263G1, ICD-10-P-30263H0, ICD-10-P- 30263H1, ICD-10-P-30263J0, ICD-10-P-30263J1, ICD-10-P-30263K0, ICD-10-P-30263K1, ICD-10-P-30263L0, ICD- 10-P-30263L1, ICD-10-P-30263M0, ICD-10-P-30263M1, ICD-10-P-30263N0, ICD-10-P-30263N1, ICD-10-P- 30263P0, ICD-10-P-30263P1, ICD-10-P-30263Q0, ICD-10-P-30263Q1, ICD-10-P-30263R0, ICD-10-P- 30263R1, ICD-10-P-30263S0, ICD-10-P-30263S1, ICD-10-P-30263T0, ICD-10-P-30263T1, ICD-10-P- 30263V0, ICD-10-P-30263V1, ICD-10-P-30263W0, ICD-10-P-30263W1, ICD-10-P-30263X0, ICD-10-P-30263X1, ICD-10-P-30263Y0, ICD-10-P-30263Y1, ICD-10-P-30273H1, ICD-10-P-30273J1, ICD-10-P-30273K1, ICD-10-P- 30273L1, ICD-10-P-30273M1, ICD-10-P-30273N1, ICD-10-P-30273P1, ICD-10-P-30273Q1, ICD-10-P- 30273R1, ICD-10-P-30273S1, ICD-10-P-30273T1, ICD-10-P-30273V1, ICD-10-P-30273W1, ICD-10-P- 30277H1, ICD-10-P-30277J1, ICD-10-P-30277K1, ICD-10-P-30277L1, ICD-10-P-30277M1, ICD-10-P- 30277N1, ICD-10-P-30277P1, ICD-10-P-30277Q1, ICD-10-P-30277R1, ICD-10-P-30277S1, ICD-10-P- 30277T1, ICD-10-P-30277V1, ICD-10-P-30277W1, ICD-10-P-30280B1, ICD-10-P-30283B1
Pulmonary embolism	ICD-9-D-4151:ICD-9-D-4159, ICD-10-D-I26:ICD-10-D-I269
Acute kidney injury	ICD-9-D-5845, ICD-9-D-5846, ICD-9-D-5847, ICD-9-D-5848, ICD-9-D-5849, ICD-10-D-N17:ICD-10-D-N179
Myocardial infarction	ICD-9-D-410:ICD-9-D-41099, ICD-9-D-412:ICD-9-D-41299, ICD-10-D-I21:ICD-10-D-I2199, ICD-10-D-I22:ICD-10-D-I2299, ICD-10-D-I252
Deep vein thrombosis	ICD-9-D-4532, ICD-9-D-4533, ICD-9-D-4534, ICD-9-D-45382, ICD-9-D-45384, ICD-9-D-45385, ICD-9-D-45386, ICD-10-D-I26:ICD-10-D-I2699

Appendix B.2
Codes used to define total hip joint complications.

Diagnosis	ICD-10
Periprosthetic fracture	ICD-9-D-99644, ICD-10-D-M9701XA, ICD-10-D-M9702XA, ICD-10-D-T84040A, ICD-10-D-T84041A
All-cause revision THA	CPT-27132, CPT-27134, CPT-27137, CPT-27138, CPT-11981, CPT-27091, CPT-20680, ICD-9-P-0070, ICD-9-P-0071, ICD-9-P-0072, ICD-9-P-0073, ICD-9-P-8153, ICD-9-P-8456, ICD-9-P-8457, ICD-10-P-0SW908Z, ICD-10-P-0SW909Z, ICD-10-P-0SW90BZ, ICD-10-P-0SW90JZ, ICD-10-P-0SW938Z, ICD-10-P-0SW93JZ, ICD-10-P-0SW94JZ, ICD-10-P-0SW9X8Z, ICD-10-P-0SW9XJZ, ICD-10-P-0SWA0JZ, ICD-10-P-0SWA4JZ, ICD-10-P-0SWAXJZ, ICD-10-P-0SWB08Z, ICD-10-P-0SWB09Z, ICD-10-P-0SWB0BZ, ICD-10-P-0SWB0JZ, ICD-10-P-0SWB3JZ, ICD-10-P-0SWB48Z, ICD-10-P-0SWB4JZ, ICD-10-P-0SWBX8Z, ICD-10-P-0SWBXJZ, ICD-10-P-0SWE0JZ, ICD-10-P-0SWE4JZ, ICD-10-P-0SWEXJZ, ICD-10-P-0SWR0JZ, ICD-10-P-0SWRXJZ, ICD-10-P-0SWS0JZ, ICD-10-P-0SWS3JZ, ICD-10-P-0SWS4JZ, ICD-10-P-0SWSXJZ
Hip dislocation	ICD-9-D-99642, ICD-10-D-T84020A, ICD-10-D-T84021A
Aseptic loosening / Mechanical failure	ICD-9-D-99641, ICD-10-D-T84030A, ICD-10-D-T84031A
PJI[a]	ICD-9-D-99666, ICD-10-D-T8450XA, ICD-10-D-T8459XA

[a] Patients with PJI had to have both codes for PJI and revision in order to be included in the PJI group.

Appendix B.3
Codes used to define total knee joint complications.

Diagnosis	ICD-10
Periprosthetic fracture	ICD-9-D-99644, ICD-10-D-M9711XA, ICD-10-D-M9712XA, ICD-10-D-T84042A, ICD-10-D-T84043A
All-cause revision TKA	CPT-27486, CPT-27487, ICD-9-P-0080, ICD-9-P-0081, ICD-9-P-0082, ICD-9-P-0083, ICD-9-P-0084, ICD-10-P-0SWC0JZ, ICD-10-P-0SWD0JZ, ICD-10-P-0SWC0JC, ICD-10-P-0SWCXJZ, ICD-10-P-0SWD0JC, ICD-10-P-0SWV0JZ, ICD-10-P-0SWDXJZ, ICD-10-P-0SWW0JZ, ICD-10-P-0SWC09Z, ICD-10-P-0SWT0JZ, ICD-10-P-0SWD09Z, ICD-10-P-0SWU0JZ, CPT-27488, ICD-9-P-8006, ICD-10-P-0SPC0JZ, ICD-10-P-0SPD0JZ, CPT-11981, ICD-9-P-8456, ICD-10-P-0SHC08Z, ICD-10-P-0SHD08Z, ICD-10-P-0SRC0EZ, ICD-10-P-0SRD0EZ, CPT-27447, ICD-9-P-8154, ICD-10-P-0SRC0J9, ICD-10-P-0SRC0JA, ICD-10-P-0SRC0JZ, ICD-10-P-0SRD0J9, ICD-10-P-0SRD0JA, ICD-10-P-0SRD0JZ, CPT-11982, ICD-9-P-8457, ICD-10-P-0SPC08Z, ICD-10-P-0SPC0EZ, ICD-10-P-0SPD08Z, ICD-10-P-0SPD0EZ
Postoperative stiffness[a]	CPT-27570, CPT-29884
Aseptic loosening	ICD-9-D-99641, ICD-10-D-T84032A, ICD-10-D-T84033A
PJI[b]	ICD-9-D-99666, ICD-10-D-M01X61, ICD-10-D-M01X62, ICD-10-D-M01X69, ICD-10-D-T8453XA, ICD-10-D-T8453XD, ICD-10-D-T8453XS, ICD-10-D-T8454XA, ICD-10-D-T8454XD, ICD-10-D-T8454XS

[a] Patients were considered to have postoperative stiffness with codes for manipulation under anesthesia and/or lysis of adhesions.
[b] Patients had to have both codes for PJI and revision in order to be included in the PJI group.