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Incidence, outcomes and risk factors of postoperative urinary retention in patients undergoing primary total knee arthroplasty: a national inpatient sample database study

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Abstract

Background Postoperative urinary retention (POUR) was reported as a common complication in patients undergoing primary total knee arthroplasty (pTKA), but descriptions of its prevalence and negative outcomes vary widely and remain inadequately studied.

Methods A retrospective cohort study was conducted using the National Inpatient Sample database from 2005 to 2014. The annual incidence, baseline characteristics, and inpatient outcomes of POUR after pTKA were recorded. Logistic regression analysis was performed to estimate potential predictors of POUR. Statistical significance was defined as $P < 0.01$.

Results A total of 1,228,621 patients undergoing pTKA were identified. The incidence of POUR after pTKA is increasing annually from 2005 (1.51%, 95%CI 1.44-1.59%) to 2014 (2.29%, 95%CI 2.21-2.37%), and the cumulative incidence of POUR was 1.91% (95%CI 1.89-1.93%). POUR was significantly associated with higher Charlson Comorbidity Index and Elixhauser Comorbidity Index scores, and higher medical costs. In patients experiencing pTKA, the Top 5 most significant risk factors for developing POUR were male gender (odds ratio [OR] = 3.40; 95% confidence interval [CI] 3.30–3.51; $P < 0.0001$), fluid and electrolyte disorders (OR = 2.02; 95% CI 1.94–2.10; $P < 0.0001$), age over 60 (OR = 1.97; 95% CI 1.89–2.05; $P < 0.0001$), paralysis (OR = 1.78; 95% CI 1.46–2.17; $P < 0.0001$), and psychoses (OR = 1.57; 95% CI 1.43–1.72; $P < 0.0001$). Although POUR did not result in higher inpatient mortality (0.1% vs. 0.07%, $P = 0.1242$), it may be associated with the occurrence of other complications such as acute myocardial infarction (0.42% vs. 0.20%, $P < 0.0001$), pulmonary embolism and infarction (0.80% vs. 0.42%, $P < 0.0001$), acute renal failure (6.06% vs. 1.49%,

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$P < 0.0001$), deep venous thrombosis (0.71% vs. 0.45%, $P < 0.0001$), acute posthemorrhagic anemia (28.89% vs. 19.45%, $P < 0.0001$), and infection (0.29% vs. 0.15%, $P < 0.0001$).

Conclusions Although POUR has no effect on inpatient mortality, our large-scale national study provides new insights that it increases postoperative complications and impairs clinical outcomes. Given the increasing incidence of POUR, early identification of high-risk patients, particularly those with identified comorbidities, should be prioritized. Preventive strategies, such as optimized perioperative fluid management, may help mitigate the risk of POUR. Future research should focus on developing preventive strategies to mitigate its impact.

Keywords Comorbidities, National inpatient sample, Outcomes, Postoperative complications, Postoperative urinary retention, Total knee arthroplasty

Introduction

Postoperative urinary retention (POUR) is a common complication after many surgical procedures [1–4]. It has been defined as the inability to void in the presence of a full bladder (400–600 mL for an adult) and is associated with the detrusor failing to contract effectively and/or the bladder outlet failing to relax [5, 6]. Because patients undergoing orthopedic surgeries have relatively more severe postoperative pain and more frequent use of epidural analgesics and opioids, it has been reported that these patients also have a relatively higher risk (8–55%) of developing POUR as compared with other surgical patients, for example, 4–6% in the general surgical population [5, 7–11].

The volume of total knee arthroplasty (TKA), one of the most frequently performed orthopedic surgeries, has increased rapidly during the past decade [12–14]. According to Sloan et al., [15] the volume of primary TKA (pTKA) procedures in 2030 is projected to be 1.67 million in the United State. Despite the increasing skill shown when operating this procedure, the reported occurrences of POUR after total joint arthroplasty (TJA) range widely from 0 to 75% [5, 7–11]. Resulting from impairment of urinary tract innervation, surgical trauma or the side effect of spinal anesthesia, the occurrence of POUR after pTKA has also been identified as a risk factor of urinary tract infection or bacteremia, which might subsequently result in periprosthetic joint infection [16, 17]. Meanwhile, patients developing POUR after joint replacement surgeries are at higher risk of negative consequences, such as unnecessary bladder pain or discomfort, prolonged hospitalizations, and an additionally 44% increased healthcare costs, heightening the burdens of treatment and nursing management, and underscoring the urgent need for effective preventive and management strategies [3, 18, 19].

Several studies have investigated the incidence and risk factors of POUR after TJA, and multiple predictors such as age and spinal anesthesia were identified [4, 5, 8, 11, 17, 18, 20–22]. However, descriptions of the prevalence and negative outcomes vary widely and are difficult to interpret and compare, because of the diverse definitions of POUR and study designs [5, 21]. Moreover, some of these differences need to be estimated on larger samples. To our knowledge, few studies have evaluated the incidence and outcomes of POUR in patients undergoing pTKA, and discussions have instead focused on TJA samples or patients undergoing total hip arthroplasty. A better understanding of these risk factors may help guide preventive strategies, such as early bladder scanning protocols, tailored anesthetic approaches, and optimized postoperative monitoring, potentially reducing complications and healthcare burden associated with POUR. Thus, we aim to: (1) determine the incidence and trends of POUR after pTKA, (2) identify patient- and hospital-related risk factors associated with POUR, and (3) evaluate the impact of POUR on postoperative complications and healthcare resource utilization. By addressing these with a nationwide large sample database, our findings may inform strategies for risk stratification and perioperative management in this patient population. Based on the existing literature, we hypothesize that: (1) the incidence of POUR may keep increasing in patients undergoing pTKA, (2) elder age, male gender and some comorbidities may be associated with an increased risk of POUR, and (3) POUR may be linked to other postoperative complications and heavier medical costs.

Methods

This retrospective cohort study was conducted using the National Inpatient Sample (NIS) database, which is maintained by the Agency for Healthcare Research and Quality and recognized as the largest national database in the United States [23, 24]. Unlike single-center or small-cohort studies, the NIS database provides a diverse patient population across various hospital settings, improving the generalizability of our findings. Additionally, the use of administrative data also allows for efficient analysis of hospital outcomes and trends over time, facilitating a comprehensive evaluation of POUR after pTKA. We investigated patients who underwent pTKA from 2005 to 2014 in the United States, as this period provided a consistent coding framework under the International Classification of Diseases, Ninth Revision (ICD-9)

system before the transition to ICD-10 in late 2015. This approach ensured uniformity in POUR identification and comorbidity classification while allowing for long-term trend analysis. Given that our primary aim was to assess associations rather than produce national estimates, unweighted analyses were performed. This approach is consistent with prior NIS-based studies focused on evaluating risk factors rather than projecting population-level incidence or prevalence. According to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9 CM) procedure code 81.54, we identified patients undergoing pTKA, and a total of 1,228,621 patients undergoing pTKA were included in the study, excluding 258 of those with missing data. The identified patients were then divided into two groups based on the presence of POUR (ICD-9 codes 788.20/788.21/788.29). In accordance with ICD-9 coding, POUR was defined as the accumulation of urine within the bladder because of the inability to urinate or incomplete emptying of the bladder after surgery. We excluded patients diagnosed with urinary retention preoperatively, as well as those with missing data (Fig. 1). In our study, the primary outcome was the postoperative outcomes in pTKA patients with POUR, evaluated by comparing complications, length of stay, and hospital costs between patients with and without POUR. The incidence of POUR after pTKA, and risk factors associated with POUR development, were the secondary outcomes. Patients who died during hospitalization were included in the analysis. For outcomes related to the completion of hospital stay, these patients were censored at the time of their death. This means that the length of stay (LOS) for deceased patients was counted only up to the point of death, and they were not included in subsequent analyses that required discharge data.

Categorical variables such as grouped age (categorized as < 40 years, 41–50 years, 51–60 years, 61–70 years, and > 70 years), gender, and race were evaluated using the chi-square test. Continuous variables including age, body mass index (BMI), Charlson Comorbidity Index (CCI), Elixhauser Comorbidity Index (ECI), length of stay, and total medical cost were evaluated via the Wilcoxon rank-sum test. Therein, the CCI, which is an index aggregating the prognostic burden of comorbid diseases, was used to predict 1-year mortality, whereas the ECI was used to evaluate the risks of death and hospital readmission. [25a]

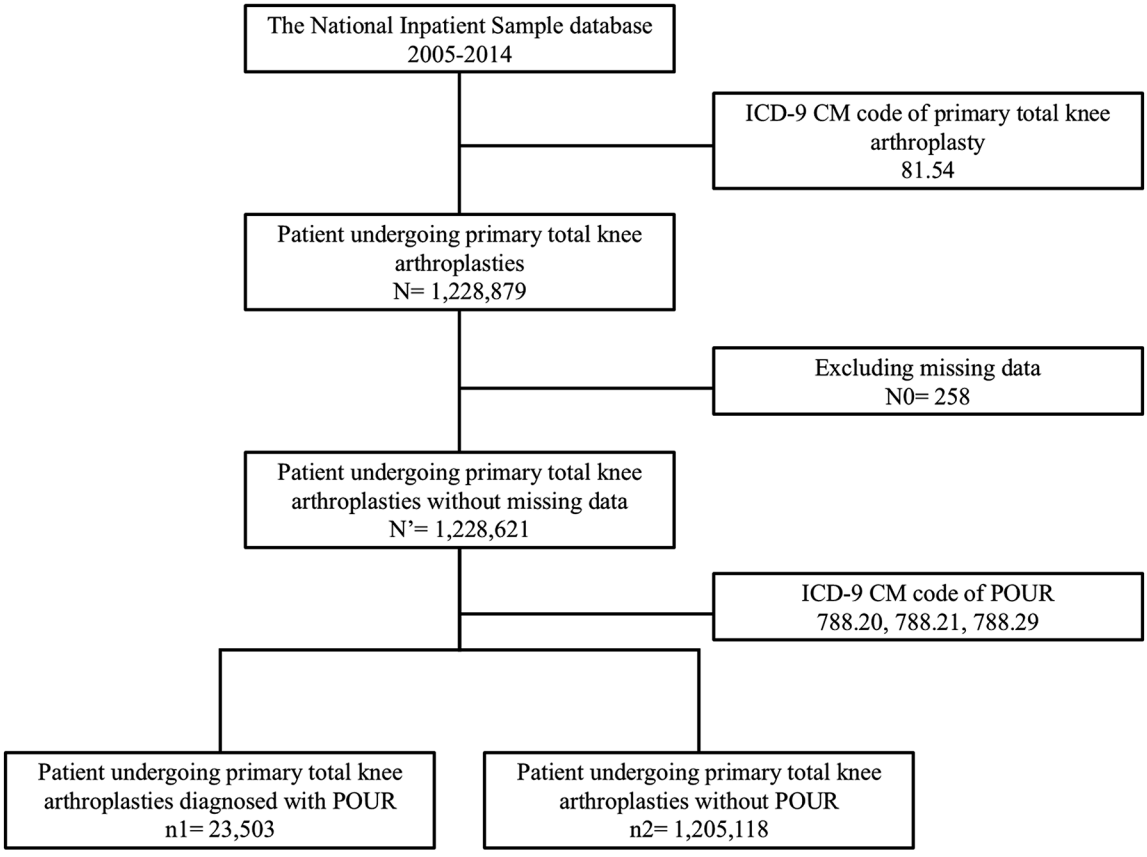

Fig. 1 Flowchart of the study population. Abbreviations: ICD-9 CM: International Classification of Diseases, Ninth Revision, Clinical Modification; POUR: postoperative urinary retention

Complications were categorized into major and minor based on clinical significance and the required level of intervention (Supplementary materials: ICD-9 codes of complications). This classification was aligned with commonly used frameworks in the literature. [25b] Furthermore, the potential predictors of POUR were identified via logistic regression analysis. Given the large sample size available in the NIS database, a formal power analysis was not performed. A total of 23,503 POUR cases ensures the robustness of our logistic regression model, supporting the validity of our multivariable analysis. Stepwise selection was used to determine the final model, with covariates included based on clinical relevance and statistical significance ($p < 0.01$). The model adjusted for patient demographics (BMI), comorbid conditions (acquired immune deficiency syndrome, drug abuse, and peptic ulcer disease), hospital characteristics (hospital regions). Only those factors with a $P < 0.01$ were retained in the final model. No multicollinearity was observed in all logistic regression models, all the GVIF and GVIF^(1/(2Df)) were below 2. To reduce the likelihood of Type I errors given the large sample size of our study, $P < 0.01$ was defined as the level of statistical significance. The analyses were conducted using R 4.2.4 (R development core team, University of Auckland, New Zealand).

Results

Patient characteristics and hospital conditions

As shown in Table 1, the average age of patients undergoing pTKA in the POUR group was significantly older compared with those who did not develop POUR (71 vs. 66, $P < 0.0001$). Notably, over half of the POUR group were aged ≥ 70 years (52.43% vs. 35.12%, $P < 0.0001$), and nearly two-thirds were male (64.83% vs. 36.59%, $P < 0.0001$). Patients who developed POUR were more frequently White compared to those who did not develop POUR (86.44% vs. 83.32%, $P < 0.0001$). Geographic differences were also observed, hospitals in the northeast (17.33% vs. 16.37%, $P < 0.0001$) and Midwest (34.27% vs. 27.31%, $P < 0.0001$) regions were significantly more prevalent in the POUR group as well. These differences may reflect geographic variation in patient characteristics or institutional practices related to bladder management protocols. While the median CCI and ECI scores were similar between groups, certain individual comorbidities were more prevalent in the POUR group. This suggests that POUR risk may be more closely related to specific conditions rather than the overall comorbidity burden quantified by these indices. On the other hand, alcohol abuse was significantly more prevalent in the POUR group compared to the non-POUR group, as was fluid and electrolyte disorders and other conditions, such as diabetes mellitus (DM), depression, and psychoses. No significant difference was observed between patients with POUR and without POUR in AIDS, drug abuse, liver diseases, or peptic ulcer diseases excluding bleeding. The small sample size in the underweight BMI category limits conclusions about this subgroup. However, our primary findings focus on the robust associations observed in higher BMI strata (obese classes I–III), which constituted > 90% of the cohort.

Cumulative incidence of POUR after pTKA

The incidence of POUR after pTKA increased annually from 2005 to 2014, as shown in Fig. 2; Table 2. The tend of POUR after pTKA was gradually increasing, from 2005 (1.51%, 95%CI 1.44-1.59%) to 2014 (2.29%, 95%CI 2.21-2.37%), and the cumulative incidence was 1.91% (95%CI 1.89-1.93%). A year-by-year analysis demonstrated an upward trend, with the most notable increases observed between 2009 and 2010, suggesting that POUR had become a more frequent postoperative complication in pTKA patients over time and potentially reflecting evolving surgical practices, patient characteristics, or changes in perioperative management.

Predictors for developing POUR after pTKA

As illustrated in Table 3, several factors were independently associated with the development of POUR. Male gender was considered to be the strongest demographic predictor, with more than threefold increased odds (odds ratio [OR] = 3.40; 95% confidence interval [CI] 3.30–3.51; $P < 0.0001$). Age greater than 60 years, larger hospital bed size, and admission to teaching hospital were identified as factors associated with a higher likelihood of POUR as well. In contrast, Black (OR = 0.88; 95% CI 0.83–0.94; $P = 0.0001$) and Hispanic (OR = 0.78; 95% CI 0.72–0.84; $P < 0.0001$) races were identified as negative predictors for the development of POUR, as compared with White race. On the other hand, among the perioperative comorbidities, the presence of fluid and electrolyte disorders was the strongest predictor of POUR (OR = 2.02; 95% CI 1.94–2.10; $P < 0.0001$), followed by psychoses (OR = 1.57; 95% CI 1.43–1.72; $P < 0.0001$) and weight loss (OR = 1.53; 95% CI 1.25–1.88; $P < 0.0001$). Interestingly, obesity (OR = 0.88; 95% CI 0.83–0.92; $P < 0.0001$) was identified as a factor associated with a lower likelihood of POUR. While several predictors of POUR were identified in our analysis, it is important to distinguish between statistical significance and clinical relevance. Given the large sample size of the NIS database, even small effect sizes may be statistically significant, but not necessarily clinically meaningful. It is essential to consider both statistical significance and effect size when interpreting these findings. While variables with small effect sizes may not significantly alter clinical practice, those with larger effect sizes could guide patient screening and management strategies.

Table 1 Patient characteristics and comorbidities of those developed and did not develop postoperative urinary retention after primary total knee arthroplasty

	POUR[a]	No POUR	*P* value
Age	71(64–77)	66(59–74)	< 0.0001
Age group			
≤ 40	97(0.41%)	8,635(0.72%)	
41–50	629(2.68%)	69,279(5.75%)	
51–60	3,157(13.43%)	277,381(23.03%)	< 0.0001
61–70	7,298(31.05%)	426,088(35.38%)	
≥ 71	12,322(52.43%)	423,045(35.12%)	
Gender (Female)	8,264(35.17%)	762,658(63.41%)	< 0.0001
BMI[b]			
< 19	< 10(0.27%)	209(0.18%)	
19–24	30(1.36%)	1,066(0.94%)	
25–29	172(7.81%)	6,668(5.85%)	0.0005
30–39	1,205(54.75%)	61,621(54.06%)	
≥ 40	788(35.8%)	44,425(38.97%)	
Race			
White	16,869(86.44%)	840,717(83.32%)	
Black	1,103(5.65%)	74,557(7.39%)	
Hispanic	808(4.14%)	53,830(5.34%)	< 0.0001
Asian or Pacific Islander	235(1.2%)	12,648(1.25%)	
Native American	85(0.44%)	4,833(0.48%)	
Other	415(2.13%)	22,386(2.22%)	
CCI[c]	4(3–5)	4(3–4)	< 0.0001
ECI[d]	0(-1-3)	0(-2-0)	< 0.0001
Region			
Northeast	4,073(17.33%)	197,331(16.37%)	
Midwest	8,054(34.27%)	329,064(27.31%)	< 0.0001
South	8,040(34.21%)	443,948(36.84%)	
West	3,336(14.19%)	234,775(19.48%)	
Comorbidities			
AIDS[e]	< 10(0.03%)	212(0.02%)	0.3186
Alcohol abuse	310(1.32%)	9,390(0.78%)	< 0.0001
Deficiency anemia	4,095(17.42%)	153,258(12.72%)	< 0.0001
ARTH[f]	760(3.23%)	45,494(3.78%)	< 0.0001
Chronical blood loss anemia	530(2.26%)	19,422(1.61%)	< 0.0001
CHF[g]	1,023(4.35%)	29,724(2.47%)	< 0.0001
CPD[h]	3,621(15.41%)	175,089(14.53%)	0.0002
Coagulopathy	945(4.02%)	21,426(1.78%)	< 0.0001
Depression	2,597(11.05%)	145,704(12.09%)	< 0.0001
Diabetes	5,084(21.63%)	235,014(19.5%)	< 0.0001
DMCX[i]	706(3%)	19,393(1.61%)	< 0.0001
Drug abuse	95(0.4%)	4,957(0.41%)	0.9064
Hypertension	16,821(71.57%)	808,664(67.1%)	< 0.0001
Hypothyroidism	3,159(13.44%)	183,588(15.23%)	< 0.0001
Liver disease	229(0.97%)	9,949(0.83%)	0.0141
Lymphoma	72(0.31%)	2,673(0.22%)	0.0081
Fluid and electrolyte disorders	3,672(15.62%)	94,574(7.85%)	< 0.0001
Metastatic cancer	30(0.13%)	863(0.07%)	0.0024
Other neurological disorders	1,273(5.42%)	43,519(3.61%)	< 0.0001
Obesity	4,231(18%)	246,901(20.49%)	< 0.0001
Paralysis	130(0.55%)	3,046(0.25%)	< 0.0001
PVD[j]	765(3.25%)	22,908(1.9%)	< 0.0001
Psychoses	617(2.63%)	22,975(1.91%)	< 0.0001

Table 1 (continued)

	POUR[a]	No POUR	*P* value
Pulmonary circulation disorders	371(1.58%)	10,866(0.9%)	< 0.0001
Renal failure	1,815(7.72%)	41,986(3.48%)	< 0.0001
Solid tumor without metastasis	178(0.76%)	4,885(0.41%)	< 0.0001
Peptic ulcer disease excluding bleeding	< 10(0.02%)	257(0.02%)	1
Valvular disease	1,208(5.14%)	42,775(3.55%)	< 0.0001
Weight loss	112(0.48%)	2,514(0.21%)	< 0.0001

a: postoperative urinary retention; b: body mass index; c: Charlson comorbidity index; d: Elixhauser comorbidity index; e: acquired immune deficiency syndrome; f: rheumatoid arthritis/collagen vascular diseases; g: congestive heart failure; h: chronic pulmonary disease; i: diabetes with chronical complications; j: peripheral vascular disorders

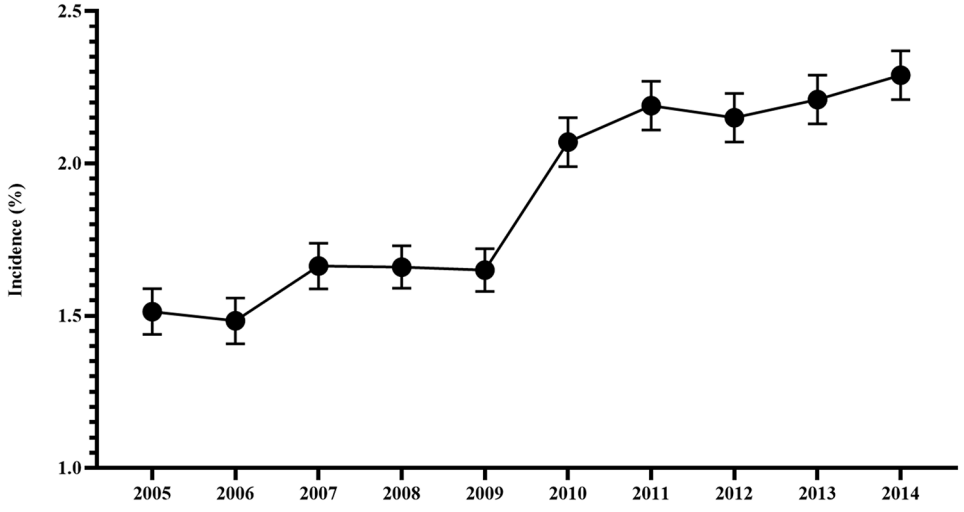

Fig. 2 The incidence of postoperative urinary retention after primary total knee arthroplasty from 2005 to 2014. pTKA: primary total knee arthroplasty

Table 2 Annual and cumulative incidence of postoperative urinary retention after primary total knee arthroplasty

Year	POUR[a]	No POUR	Incidence (%, 95% CI[b])
2005	1,542	100,343	1.51 (1.44–1.59)
2006	1,519	100,899	1.48 (1.41–1.56)
2007	1,894	111,899	1.66 (1.59–1.74)
2008	2,092	123,941	1.66 (1.59–1.73)
2009	2,022	120,847	1.65 (1.58–1.72)
2010	2,755	130,240	2.07 (1.99–2.15)
2011	2,934	130,815	2.19 (2.11–2.27)
2012	2,709	123,525	2.15 (2.07–2.23)
2013	2,923	129,575	2.21 (2.13–2.29)
2014	3,113	133,034	2.29 (2.21–2.37)
			Cumulative incidence
Total	23,503	1,205,118	1.91 (1.89–1.93)

a: postoperative urinary retention; b: confidence interval

Postoperative outcomes

As shown in Table 4, we detected an approximate twofold increase in the possibility of experiencing major postoperative complications in the POUR group (1.29% vs. 0.69%, $P < 0.0001$), including acute myocardial infarction (0.42% vs. 0.2%, $P < 0.0001$) and pulmonary embolism and infarction (0.80% vs. 0.42%, $P < 0.0001$). Moreover, patients in the POUR group might have a more than twofold increase in the possibility of developing minor postoperative complications (47.77% vs. 21.75%, $P < 0.0001$), deep venous thrombosis (0.71% vs. 0.45%, $P < 0.0001$), acute renal failure (6.06% vs. 1.49%, $P < 0.0001$), acute posthemorrhagic anemia (28.89% vs. 19.45%, $P < 0.0001$), and infection (0.29% vs. 0.15%, $P < 0.0001$). While these associations do not imply causality, they highlight a consistent pattern of poorer postoperative outcomes among patients with POUR. In addition, total inpatient costs ($44,338 vs. $41,228, $P < 0.0001$) were significantly higher in those who developed POUR after pTKA. In contrast, no significant difference was detected in inpatient mortality rate (0.1% vs. 0.07%, $P = 0.1242$) between patients with POUR and those without POUR.

Discussion

During the past several decades, pTKA has ranked as one of the top five most performed as well as the top five fastest growing surgeries each year in the United States, yet POUR remains a significant concern [26, 27]. According to the results of our study, with a substantial growth in procedural volume of pTKA between 2005 and 2014, the incidence of POUR in patients undergoing this procedure

Table 3 Predictors of postoperative urinary retention in patients undergoing total knee arthroplasty

Values	OR[a]	CI[b]	*P* value
Age > 60	1.97	1.89–2.05	< 0.0001
Male	3.40	3.30–3.51	< 0.0001
Race			
White			
Black	0.88	0.83–0.94	0.0001
Hispanic	0.78	0.72–0.84	< 0.0001
Asian or Pacific Islander	0.95	0.84–1.09	0.4821
Native American	0.96	0.77–1.19	0.6927
Other	0.96	0.87–1.06	0.4382
Hospital bed size			
Small			
Medium	1.12	1.07–1.17	< 0.0001
Large	1.07	1.03–1.12	0.0004
Teaching status			
Non-teaching hospital			
Teaching hospital	1.20	1.16–1.23	< 0.0001
Location			
Rural			
Urban	1.06	1.01–1.11	0.0227
Comorbidities			
Fluid and electrolyte disorders	2.02	1.94–2.10	< 0.0001
Paralysis	1.78	1.46–2.17	< 0.0001
Psychoses	1.57	1.43–1.72	< 0.0001
Weight loss	1.53	1.25–1.88	< 0.0001
Renal failure	1.41	1.33–1.50	< 0.0001
Coagulopathy	1.39	1.28–1.50	< 0.0001
Deficiency anemia	1.39	1.34–1.44	< 0.0001
Other neurological disorders	1.38	1.30–1.48	< 0.0001
DMCX[c]	1.37	1.26–1.49	< 0.0001
Chronical blood loss anemia	1.36	1.23–1.50	< 0.0001
Pulmonary circulation disorders	1.34	1.19–1.50	< 0.0001
Metastatic cancer	1.30	0.86–1.94	0.2099
Solid tumor without metastasis	1.24	1.05–1.46	0.0120
Valvular disease	1.21	1.13–1.29	< 0.0001
CHF[d]	1.18	1.10–1.27	< 0.0001
Alcohol abuse	1.16	1.03–1.31	0.0173
PVD[e]	1.13	1.04–1.23	0.0028
Depression	1.13	1.08–1.19	< 0.0001
Lymphoma	1.11	0.86–1.44	0.4058
CPD[f]	1.11	1.07–1.16	< 0.0001
Hypothyroidism	1.10	1.05–1.15	< 0.0001
Hypertension	1.06	1.03–1.10	0.0002
Diabetes	1.05	1.02–1.09	0.0045
ARTH[g]	1.01	0.93–1.10	0.7936
Obesity	0.88	0.83–0.92	< 0.0001

a: odd ratios; b: confidence interval; c: diabetes with chronical complication; d: congestive heart failure; e: peripheral vascular disorders; f: chronic pulmonary disease; g: rheumatoid arthritis/collagen vascular diseases

has been increasing as well. Interestingly, we found the occurrence of POUR to be lower than in previous studies, which might be attributed to our larger sample that included patients of all ages as well as the different definitions of POUR between ICD-9 codes [3, 5, 8, 11, 18, 28]. This methodological variation likely accounts for the observed differences and highlights the importance of standardized diagnostic criteria in future research. Although the overall incidence has been reported relatively lower (1.91%) in our study, the increasing trend of POUR warrants ongoing attention, as it still affects a substantial number of patients.

According to our study, patient characteristics such as older age, male gender, BMI, and White race were related to the development of POUR, supported by some but not all previous studies [5, 11, 20, 29, 30]. In a study conducted by Lawrie et al., [20] no significant difference was found in age, sex, or BMI, whereas Griesdale et al. [30] came to the same conclusion on age and BMI but considered male gender to be associated with the development of POUR. However, in our study, older age was identified as an independent predictor, and male gender was the strongest predictor for developing POUR. While our study did not directly examine the underlying mechanisms, several physiological factors may contribute to this association. For example, prostate enlargement and differences in urethral anatomy and hormones could predispose male patients to urinary retention. To our knowledge, analgesic and anesthetic agents had longer durations of action in older patients, leading to a higher risk of developing negative urodynamic effects [31]. In addition, the use of different types of procedures and anesthesia might have contributed to the different conclusions reached among these studies, which warrants further study based on more specific conditions such as the different types and routes of anesthesia administration. Regional variations in POUR rates may reflect differences in institutional protocols for bladder management, variations in surgical and anesthetic practices, or differences in patient characteristics across geographic areas. Few studies have analyzed those regional disparities, existing in perioperative care, including pain management strategies and catheterization practices, which may contribute to the observed differences in POUR incidence. However, due to the limitations of the NIS database, we cannot directly assess these factors, and future research is warranted to explore the underlying causes of these geographic disparities.

In this study, we found that several comorbidities were associated with POUR in patients experiencing pTKA and were identified as potential predictors of POUR. According to Gacci et al., [32] alcohol abuse might increase the incidence of irritative urinary symptoms, which were correlated with many urinary complications. On the other hand, DM presented as an independent predictor for developing POUR in the pTKA population. However, previous studies had elucidated that patients with DM might also experience impaired bladder

Table 4 Complications and inpatient outcomes of patients either developing postoperative urinary retention or not after primary total knee arthroplasty

Complications and inpatient outcomes	POUR[a]	No POUR	*P* value
Major complication			
Acute myocardial infarction	99(0.42%)	2,358(0.2%)	< 0.0001
Cardiac arrest	14(0.06%)	643(0.05%)	0.7906
Septicemia	< 10(0%)	17(0%)	0.2937
Shock	< 10(0.02%)	196(0.02%)	0.442
Stroke	9(0.04%)	455(0.04%)	1
Pulmonary embolism and infarction	187(0.8%)	5,063(0.42%)	< 0.0001
Overall	303(1.29%)	8,336(0.69%)	< 0.0001
Minor complication			
Deep venous thrombosis	166(0.71%)	5,417(0.45%)	< 0.0001
Acute renal failure	1,425(6.06%)	17,961(1.49%)	< 0.0001
Pneumonia	72(0.31%)	2,989(0.25%)	0.0872
Acute post-hemorrhagic anemia	6,790(28.89%)	234,337(19.45%)	< 0.0001
Complications of procedure	20(0.09%)	837(0.07%)	0.4384
Complications of devices	< 10(0.01%)	215(0.02%)	0.4515
Central nervous system complications	< 10(0.01%)	102(0.01%)	0.4572
Cardiac complications	283(1.2%)	7,799(0.65%)	< 0.0001
Peripheral vascular complications	49(0.21%)	1,805(0.15%)	0.027
Respiratory complications	154(0.66%)	3,078(0.26%)	< 0.0001
Digestive system complications	174(0.74%)	3,412(0.28%)	< 0.0001
Urinary complications	4,589(19.53%)	1,720(0.14%)	< 0.0001
Infection	68(0.29%)	1,841(0.15%)	< 0.0001
Overall	11,228(47.77%)	262,070(21.75%)	< 0.0001
Inpatient outcomes			
LOS[b]	3(3–4)	3(3–4)	< 0.0001
Total charge	44,338(32,492.5–61,797.25)	41,228(30,538 – 57,272)	< 0.0001
Mortality	24(0.1%)	875(0.07%)	0.1242

a: postoperative urinary retention; b: Length of hospital stay

sensation and decreased detrusor contractility, emphasizing that baseline glycemic control and other DM-related complications should be taken into consideration when evaluating DM's impact on developing POUR [33, 34]. Our findings suggest that diabetic patients may benefit from closer perioperative bladder monitoring and tailored management strategies to reduce the incidence of POUR. In addition, multiple investigators have suggested that intravenous fluid volume might serve as an independent predictor for POUR [18, 35, 36]. Consisted with Kang et al. [37] and Scholten et al. [17], perioperative fluid and electrolyte balance was suggested as a nonnegligible predictor for POUR, although the underlying mechanisms remain unclear. Recent reviews and meta-analyses suggest that excessive intravenous fluid administration may lead to bladder overdistension, which can inhibit detrusor muscle function and contribute to POUR. [37a] Moreover, perioperative administration of at least 1,000 mL of intravenous fluids was associated with a significant increase in the incidence of POUR. [37b] While these observations offer a plausible explanation, the mechanistic evidence remains preliminary and warrants further investigation. Interestingly, we found that obesity (usually defined as BMI > 35 kg/m^2) might serve as a negative predictor for POUR, whereas weight loss might present as a predictor, in contrast to the findings of some previous studies [18, 38, 39]. One possible explanation is that obese patients may be more likely to undergo prophylactic urinary catheterization before joint arthroplasty procedures, which could facilitate bladder emptying and thereby reduce the incidence of POUR. Although this hypothesis is supported in some clinical practice, it remains speculative and warrants validation through prospective research examining perioperative catheterization strategies across BMI categories. In our study, patients with POUR appeared to experience higher risks of developing minor postoperative complications as well as some major complications, including acute myocardial infarction and pulmonary embolism and infarction (PEI). Ichiba [40] reported an older male diagnosed with acute urinary retention who developed ST-segment elevation myocardial infarction soon after urinary catheterization, which was considered to be common management of POUR. In this case, acute pain and fluctuation of blood pressure might have contributed to the appearance of cardiovascular comorbidities. On the other hand,

Kawada et al. [41] reported another older male with urinary retention who developed deep venous thrombosis and pulmonary embolism due to venous compression by an extremely distended bladder. The association between POUR and adverse outcomes may be explained by mechanisms such as autonomic dysregulation, electrolyte and fluid imbalances, and elevated intra-abdominal pressure leading to hemodynamic instability. Nevertheless, such postoperative complications in those who had POUR were seldomly reported and investigated, and because the relationship between POUR and other postoperative complications lacked evidence in our study, more detailed research is needed to estimate whether the relationship is related rather than casual. Larger hospital bed size and teaching hospital status may be associated with higher POUR incidence due to multiple factors. For example, teaching hospitals often handle more complex cases, and their emphasis on training may lead to variations in catheterization practices or anesthesia management. Additionally, larger hospitals may have different pain management protocols, potentially influencing POUR risk. Due to the limitations of the NIS database, we cannot directly assess these mechanisms, but we acknowledge this as an area for further investigation. It should be noticed that some observed differences in comorbidity prevalence between the POUR and non-POUR groups may be partially explained by other factors, such as age differences. Older patients tend to have a higher burden of comorbidities, which could contribute to the associations observed in unadjusted comparisons. However, our multivariable logistic regression analysis adjusted for key confounders, including age, sex, and major comorbidities, to better isolate independent predictors of POUR. Despite these adjustments, residual confounding due to unmeasured factors cannot be entirely ruled out, and further prospective studies are needed to explore these interrelationships in more detail.

Based on our findings, clinicians should consider implementing targeted perioperative strategies for high-risk patients. Male patients with elder age, individuals with diabetes, and those with related higher comorbidity burdens may benefit from closer postoperative bladder monitoring, early use of bladder scanners, and individualized catheterization protocols to reduce POUR risk [18]. Given the increasing incidence of POUR, future studies should evaluate the efficacy of these strategies and their impact on postoperative outcomes. Prospective cohort studies could be conducted to assess the temporal relationship between POUR and complications, as well as randomized trials to evaluate targeted prevention strategies, such as bladder monitoring and perioperative fluid management. In the era of value-based care and bundled payment models for joint arthroplasty, even modest increases in resource utilization can have substantial implications for cost-efficiency. While the NIS database did not include patient-reported outcomes, POUR may negatively influence satisfaction and perceived recovery due to associated discomfort, delays in mobilization, and increased care needs. As quality-of-life measures become increasingly emphasized in orthopedic outcome assessment, future studies should investigate the impact of POUR on these patient-centered metrics. Identifying and managing patients at higher risk for POUR may help reduce avoidable complications and associated expenditures, ultimately supporting both clinical outcomes and financial sustainability. The significant predictors identified in this study may serve as the foundation for developing a preoperative risk stratification tool. These variables could inform future efforts to create a clinically applicable calculator to guide individualized monitoring or prophylactic strategies.

Our study has several limitations. First, like the findings of many other retrospective studies using the NIS database, coding and data-entry errors might have existed. This may have resulted in exposure or outcome misclassification bias, leading to misestimation of the incidence and outcomes of POUR. We focused on the ICD-9 era to ensure a consistent coding framework across all study years, which might need future research using more recent datasets. On the other hand, stepwise selection process was used to build the logistic regression model, which may have the advantage of capturing many predictors while decreasing the precision of the ORs. While we prioritized clinically distinct comorbidities, residual multicollinearity may exist. Second, the interpretation of results in the NIS database might require the use of ICD-9 codes, which are considered to have limited sensitivity and specificity. Patients with missing data were excluded, potentially leading to selection bias. And although no studies have specifically evaluated the accuracy of ICD-9 codes for POUR or total knee arthroplasty, previous research has highlighted limitations in coding accuracy for other complications, such as acute myocardial infarction and deep vein thrombosis, where diagnoses were sometimes recorded without corresponding confirmatory tests [42, 43]. However, studies have also concluded that the NIS remains a valuable resource for large-scale analyses, particularly for evaluating length of stay and providing broad geographic representation. Our findings are based on unweighted analyses, which may not fully account for national representativeness. Nonetheless, the large sample size and rigorous statistical approach strengthen the validity of our results. Finally, the limited elements in the NIS database prevented a more in-depth analysis. For instance, several studies have indicated an association between the development of POUR and type of anesthesia [21, 44, 45], and the dose of opioids might play an important role in patients

developing POUR. However, we could not detect this association because of the lack of corresponding variables in the database. Nonetheless, using the NIS database, a relatively large sample size could be applied to estimate the rare outcomes of POUR in patients undergoing pTKA, which might be worthy of further investigation.

Conclusions

The incidence of POUR in patients undergoing pTKA continues to increase (1.91% overall, increasing from 1.51 to 2.29% during 2005 to 2014). Patients with key predictors, including male gender (OR = 3.40) and fluid and electrolyte disorders (OR = 2.02), should be considered for targeted prevention management. Although it has a nonsignificant influence on inpatient mortality, POUR might be associated with poor postoperative outcomes and higher likelihood of developing other troublesome complications (28.89% acute post-hemorrhagic anemia, 19.53% other urinary complications, 6.06% acute renal failure), aggravating both the health and financial burden of patients. To further improve patient outcomes, orthopedic workers should prioritize enhanced monitoring and early intervention for patients with the potential predictors of POUR. Preventive strategies, such as optimized perioperative fluid management and bladder monitoring, may help reduce the risk of POUR. With the increasing trend toward outpatient TKA procedures, future research should focus on developing preventive strategies, and examining regional variations in perioperative care such as catheterization practices and multimodal pain management strategies, to mitigate its impact.

Abbreviations

BMI	Body mass index
CCI	Charlson Comorbidity Index
CI	Confidence intervals
DVT	Deep vein thrombosis
ECI	Elixhauser Comorbidity Index
ICD-9 CM	International Classification of Diseases, Ninth Revision, Clinical Modification
LOS	Length of stay
NIS	National Inpatient Sample
OR	Odds ratios
pTKA	Primary total knee arthroplasty
PE	Pulmonary embolism
POUR	Postoperative urinary retention
TJA	Total joint arthroplasty
TKA	Total knee arthroplasty

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Not applicable.

Author contributions

XH.C, Y.Z. and YH.C. wrote the main manuscript text. J.L, QH.L. and JP.Z. prepared figure and tables. J.L, JP.Z, L.Y. and XH.C. collected the data. QH.L, Y,Z. and YH.C. analyzed the data. YH.C. and L.Y. revised the manuscript. All authors reviewed the manuscript.

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Data availability

This study is based on data provided by Nationwide Inpatient Sample (NIS) database, part of the Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality. The NIS database is a large publicly available full-payer inpatient care database in the United States and the direct web link to the database is https://www.ahrq.gov/data/hcup/index.html. Therefore, individual or grouped data cannot be shared by the authors.

Declarations

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors. Administrative permissions were required to access the raw data employed in this study, and the affiliation of co-author has already granted permission from the Agency for Healthcare Research and Quality (AHRQ) to access Healthcare Cost and Utilization Project (HUCP) Nationwide Databases. However, our observational study was deemed exempt by the Ethics Committee of Nanfang Hospital of Southern Medical University for using deidentified publicly available data. Besides, the data collected in our study were unnecessary to be anonymized before its use. All methods were carried out following relevant guidelines and regulations.

Consent for publication

Not applicable.

Study registration

Not applicable.

Competing interests

The authors declare no competing interests.

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