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Risk Factors for Postoperative Urinary Tract Infections Following Anterior Lumbar Interbody Fusion

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ABSTRACT

Background: Although risk factors contributing to UTI have been studied in posterior approaches to lumbar fusion, there is a lack of literature on factors contributing to UTI in anterior lumbar interbody fusion (ALIF). Our purpose was to identify preoperative independent risk factors for postoperative urinary tract infection (UTI) following anterior lumbar interbody fusion (ALIF) so that surgeons may be able to initiate preventative measures and minimize the risk of UTI-related morbidity following ALIF.

Methods: The American College of Surgeons–National Surgical Quality Improvement Program database was queried to identify 10 232 patients who had undergone ALIF from 2005 to 2016; 144 patients (1.41%) developed a postoperative UTI while 10 088 patients (98.59%) did not. Univariate analyses were conducted to compare the 2 cohorts' demographics and preoperative comorbidities. Multivariate logistic regression models were then utilized to identify significant predictors of postoperative UTI following ALIF while controlling for differences seen in univariate analyses.

Results: Age ≥ 60 years ($P = .022$), female sex ($P < .001$), alcohol use ($P = .014$), open wound or wound infections ($P = .019$), and steroid use ($P = .046$) were independent risk factors for postoperative UTI. Longer operative times were also independent predictors for developing UTI: 120 minutes $\leq x < 180$ minutes ($P = .050$), 180 minutes $\leq x < 240$ minutes ($P = .025$), and ≥ 240 minutes ($P = .001$). Postoperative UTI independently increased the risk for pneumonia, blood transfusions, sepsis, thromboembolic events, and extended length of stay as well.

Conclusions: Age ≥ 60 years, female sex, alcohol use, steroid use, and open wound or wound infections independently increased the risk for UTI following ALIF. Future work analyzing the efficacy of tapering alcohol and steroid use preoperatively and reducing procedural time with the aim of lowering UTI risk is warranted. Preoperative wound care is strongly encouraged to decrease UTI risk.

Level of Evidence: III.

Lumbar Spine

Keywords: anterior lumbar interbody fusion, urinary tract infection, anterior approach, operative time

INTRODUCTION

Urinary tract infections (UTIs) are a common example of nosocomial infections in the postoperative period. Indwelling catheter use increases the risk for UTIs as the artificial plastic surface serves as a nidus for multiple species of bacterial growth that can lead to cystitis, and in some cases, pyelonephritis.^{1,2} Accounting for almost 40% of all nosocomial infections, UTIs contribute significantly to increased length of stay, mortality risk, sepsis, superficial infection, and the economic burden following hospitalizations.^{3–6} In the United States, many insurers have deemed nosocomial UTIs as preventable adverse events for which reimbursement will

adversely affected, so there is an increasing financial pressure for surgeons and institutions alike to decrease the incidence of UTIs as well.⁷

Anterior lumbar interbody fusion (ALIF) has been a mainstay treatment modality for a variety of conditions affecting the lumbar spine, including degenerative disc disease, pseudarthrosis, and spondylolisthesis.^{8–10} ALIF has been proposed to have several biomechanical advantages when compared to posterior approaches including preservation of posterior spinal musculature, more direct visualization of the disc space, and decreased development of adjacent segment disease.^{11–13} Although risk factors contributing to UTI have been studied in posterior approaches to lumbar fusion, there is a lack of

literature on factors contributing to UTI in ALIF.¹⁴ This current study seeks to establish risk factors that predispose patients undergoing ALIF to developing UTIs by utilizing The American College of Surgeons–National Surgical Quality Improvement Program (ASC-NSQIP) database so that surgeons can better stratify patients and take appropriate prophylactic measures to prevent certain postoperative complications that are associated with UTIs.

METHODS

The ACS maintains a multi-institutional clinical registry of over 5,000,000 surgical patients who have undergone procedures from 2005 to 2016 in its NSQIP database. The ACS-NSQIP database contains 274 variables for each surgical patient detailing demographics, operative parameters, and postoperative complications.

Patient Cohort Selection

The ACS-NSQIP was queried to identify patients who had undergone ALIF from 2005 to 2016. Patients with Current Procedure Terminology (CPT) codes 22558 and 22585 were isolated for further analysis. 10 232 patients who had undergone ALIF were included in this retrospective study. It is important to note that 22558 also refers to lateral approaches to the spine (extreme lateral interbody fusion, lateral lumbar interbody fusion, and oblique lateral lumbar interbody) at the time of writing of this paper. All included patients were ≥ 18 years old and had complete information regarding the incidence of postoperative UTIs following their ALIF procedures. Patients were then stratified into 2 separate cohorts—those who had experienced postoperative UTIs and those who did not. These 2 patient cohorts were then analyzed for differences in demographics, preoperative comorbidities, and additional complications.

Variables

The demographic factors included in this retrospective study were age, sex, race, and body mass index. Only preoperative comorbidities that had more than an 85% response rate were included for analysis in this study. The list of complete comorbidities and administrative or operative variables included in this study can be found in Tables 1 and 2, respectively.^{15,16} Demographic factors and operation-specific parameters were analyzed for differ-

ences between the 2 patient cohorts to identify risk factors for UTIs following ALIF. Incidence of additional postoperative complications were also analyzed for differences between the 2 cohorts in the 30-day period following their procedures. The complete list of postoperative complications included in this study can be found in Table 3.

Statistical Analysis

Univariate analyses were used to assess differences in the incidence of patient demographic factors, preoperative comorbidities, operation-specific variables, and postoperative complications between the 2 cohorts. Pearson χ^2 tests and Fischer exact tests (expected cell sizes < 5) were utilized to evaluate differences in prevalence rates of categorical variables expressed as number and rate of incidence. One-way analyses of variance were utilized for continuous variables, such as age, laboratory values, and time variables. These variables were expressed as mean values with respective standard deviations. All statistical findings for univariate analyses with P values less than or equal to .05 were considered significant for this retrospective study.

Variables that were found to be significantly different in prevalence upon univariate analyses were included in the multivariate logistic regression models in order to identify significant risk factors for postoperative UTIs in patients undergoing ALIF.

Multivariate logistic regression models were developed to identify complications that may be associated with UTIs following ALIF by controlling for significant demographic factors and preoperative comorbidities. All statistical findings with P values less than or equal to .05 in the multivariate analyses were considered significant for this retrospective study. All statistical analyses were completed using the IBM SPSS Statistics Version 25 software (IBM Corporation, Armonk, New York).

RESULTS

By querying the ACS-NSQIP database, we identified 10 232 patients who had undergone anterior approaches to the spine from 2005 to 2016, of whom 144 (1.41%) had developed postoperative UTI and 10 088 whom (98.59%) had not. These 2 cohorts of patients were analyzed for differences in various characteristics; those who had developed postoperative UTIs were significantly older (61.67 years, SD 13.283 versus 55.27 years,

Table 1. Demographics and comorbidities stratified by postoperative UTI.

	Control		UTI		P value ^a
	No.	%	No.	%	
Demographics					
Total	10 088		144		
Age (mean ± SD) ^b	55.27 ± 13.627		61.67 ± 13.283		< .001
Sex					< .001
Female	5384	53.37	112	77.78	
Male	4702	46.61	32	22.22	
Race					.875
American Indian or Alaska Native	44	44	0	0.00	
Asian or Pacific Islander	137	1.36	1	0.69	
Black or African American	735	7.29	10	6.94	
Hispanic	5	0.05	0	0.00	
White	8618	85.43	125	86.81	
Body mass index (kg/m ²)					.055
Normal (< 25.0)	2101	20.83	30	20.83	
Overweight (25.0-29.9)	3390	33.60	46	31.94	
Class I (30.0-34.9)	2668	26.45	31	21.53	
Class II (35.0-39.9)	1289	12.78	20	13.89	
Class III (> 40.0)	609	6.04	17	11.81	
Preoperative comorbidities^c					
Obesity (Class I, II, and III)	4566	45.26	68	47.22	.663
Diabetes mellitus					.013
No diabetes mellitus	423	4.19	12	8.33	
Non-insulin dependent	906	8.98	18	12.50	
Insulin dependent	8759	86.83	114	79.17	
Smoke	2359	23.38	20	13.89	.007
Alcohol	36	0.36	2	1.39	.043
Dyspnea					.012
No dyspnea	9609	95.25	131	90.97	
Moderate exertion	449	4.45	11	7.64	
At rest	30	0.30	2	1.39	
Ventilator dependence	7	0.07	1	0.69	.008
COPD	381	3.78	8	5.56	.268
Congestive heart failure	22	0.22	1	0.69	.231
Hypertension	4587	45.47	86	59.72	< .001
Ascites	3	0.03	0	0.00	.836
Acute renal failure	2	0.02	0	0.00	.866
Dialysis dependence	21	0.21	0	0.00	.584
Disseminated cancer	31	0.31	0	0.00	.505
Wound infection	46	0.46	4	2.78	< .001
Steroid use	306	3.03	10	6.94	.007
Weight loss	28	0.28	2	1.39	.014
Bleeding disorders	111	1.10	2	1.39	.742
Blood transfusions within 48 h preoperatively	38	0.38	2	1.39	.053
Systemic sepsis	69	0.68	2	1.39	.312
Functional status					.013
Independent	9864	97.78	136	94.44	
Partially dependent	170	1.69	7	4.86	
Totally dependent	12	0.12	0	0.00	
Laboratory values^b					
Sodium (mEq/L)	139.35 ± 2.864		138.97 ± 3.069		.122
Blood urea nitrogen (mg/dL)	15.60 ± 6.593		17.08 ± 8.046		.011
Creatinine (mg/dL)	0.90 ± 0.466		0.88 ± 0.285		.639
Albumin (g/dL)	4.14 ± 0.475		3.93 ± 0.478		< .001
White blood cells (10 ³ c/mL)	7.27 ± 2.376		7.27 ± 2.541		.996
Hematocrit (%)	41.12 ± 4.458		38.85 ± 4.516		< .001
Platelets (per mL)	218.23 ± 118.158		226.93 ± 104.456		.380
INR ratio	1.00 ± 0.167		1.05 ± 0.326		.003

Abbreviations: COPD, chronic obstructive pulmonary disease; INR, XXX; UTI, urinary tract infection.

^aAll bolded values represent statistically significant results.^bValues expressed as mean ± SD. All other values expressed as N and percent.^cPneumonia and angina were excluded due to < 85% of patients containing data on preoperative pneumonia or angina status.

Table 2. Operative variables.

Operative Variables	Control		UTI		P value ^a
	No.	%	No.	%	
Total	10 088		144		
Days to operation from admission (mean ± SD)	0.35 ± 7.909		0.51 ± 2.461		.806
Total operating time (mean ± SD; min)	198.16 ± 120.054		250.19 ± 150.093		< .001
Total hospital stay length (mean ± SD; d)	3.91 ± 4.856		8.03 ± 8.103		< .001
Days from operation to death (mean ± SD)	7.32 ± 7.046		6.00		.856
Days from operation to discharge (mean ± SD)	3.70 ± 3.367		7.52 ± 7.290		< .001
Discharge destination					< .001
Home	6830	67.70	66	45.83	
Other than home	1111	11.01	43	29.86	
Not reported	2147	21.28	35	24.31	
Care type					.243
Inpatient	9877	97.91	143	99.31	
Outpatient	211	2.09	1	0.69	
Anesthesia administered					< .001
Epidural	3	0.03	0	0.00	
General	10007	99.20	140	97.22	
Local/regional	2	0.02	1	0.69	
MAC ^d /IV sedation	3	0.03	0	0.00	
Spinal	11	0.11	3	2.08	
Other	54	0.54	0	0.00	
Wound class					.840
1. Clean	9925	98.38	141	97.92	
2. Clean/contaminated	84	0.83	2	1.39	
3. Contaminated	20	0.20	0	0.00	
4. Dirty/infected	59	0.58	1	0.69	
Total operating time (min)					.002
≤ 119	2925	28.99	23	15.97	
120 ≤ x < 180	2467	24.45	35	24.31	
180 ≤ x < 240	1807	17.91	29	20.14	
≥ 240	2886	28.61	57	39.58	

Abbreviations: MAC, monitored anesthesia care; UTI, urinary tract infection.

^aAll bolded values represent statistically significant values.

SD 13.627; $P < .001$) and more likely to be female (77.78% versus 53.37%; $P < .001$). These patients also had significantly higher levels of blood urea nitrogen ($P = .011$) and greater international normalised ratio ($P = .003$) but lower levels of serum albumin ($P < .001$) and hematocrit ($P < .001$) (Table 1).

There were significant differences in the prevalence of numerous preoperative comorbidities between the 2 cohorts. Patients who experienced UTIs had significantly higher rates of alcohol use ($P = .043$), dyspnea ($P = .012$), ventilator dependence ($P = .008$), hypertension requiring medications ($P < .001$), open wound/wound infections ($P < .001$), steroid use for chronic conditions ($P = .007$), significant weight loss ($P = .014$), and functional dependence ($P = .013$). UTI patients also had significantly higher rates of non-insulin-dependent diabetes mellitus but lower rates of insulin-dependent diabetes mellitus ($P < .001$), as well as smoking history ($P = .007$) (Table 1).

Patients who developed UTIs following ALIF had significantly longer operative times (250.19 minutes, SD 150.093 versus 198.16 min, SD

120.054; $P < .001$), total length of hospital stay (8.03 days, SD 8.103 versus 3.91 days, SD 4.856; $P < .001$), and inpatient stay following the operation (7.52 days, SD 7.290 versus 3.70 days, SD 3.367; $P < .001$). These patients also experienced increased discharge to destinations other than their own homes ($P < .001$), including separate acute care, skilled facilities, etc. (Table 2).

Upon multivariate analyses, several patient characteristics and comorbidities were found to be significant independent risk factors for postoperative UTIs in patients undergoing ALIF. Female patients were 3.1 times more likely to develop UTIs (95% confidence interval [CI] 2.08-4.64; $P < .001$) compared to men, and patients who were at least 60 years of age were 1.5 times more likely to experience postoperative UTIs (95% CI 1.07-2.20; $P = .022$) than younger patients. Several preoperative comorbidities were found to increase the risk for patients developing UTIs, including significant alcohol use (odds ratio [OR] 6.504, 95% CI 1.47-28.85; $P = .014$), open wounds or wound infections (OR 3.955, 95% CI 1.25-12.51; $P = .019$), and steroid use for chronic conditions (OR 1.965, 95% CI 1.01-3.82; P

Table 3. Risk factors for postoperative urinary tract infections.

Risk Factors	Odds Ratio	95% Confidence Interval		P Value ^a
Age (y)				
< 60	Reference	NA	NA	NA
≥ 60	1.543	1.066	2.233	.022
Sex				
Male	Reference	NA	NA	NA
Female	3.104	2.079	4.635	< .001
Diabetes mellitus				
Nondiabetic	Reference	NA	NA	NA
NIDDM	1.685	0.902	3.148	.102
IDDM	1.142	0.669	1.949	.626
Smoke	0.648	0.396	1.061	.085
Alcohol use	6.504	1.466	28.847	.014
Dyspnea				
No dyspnea	Reference	NA	NA	NA
Moderate exertion	1.322	0.683	2.561	.408
At rest	3.694	0.837	16.305	.084
Ventilator dependence	3.494	0.273	44.798	.336
Functional status				
Independent	Reference	NA	NA	NA
Dependent	1.850	0.805	4.252	.147
Hypertension	1.353	0.932	1.966	.112
Open wound/wound infection	3.955	1.251	12.506	.019
Steroid use	1.965	1.011	3.82	.046
Significant weight loss	3.299	0.631	17.248	.157
Operation duration (min)				
≤ 119	Reference	NA	NA	NA
120 ≤ x < 180	1.703	0.999	2.904	.050
180 ≤ x < 240	1.895	1.085	3.311	.025
≥ 240	2.337	1.431	3.818	.001

Abbreviations: IDDM, insulin-dependent diabetes mellitus; NA, not applicable; NIDDM, non-insulin-dependent diabetes mellitus.

^aAll bolded values represent statistically significant results.

= .046). Longer operative times were also found to independently increase the risk for developing UTIs when compared to operations under 120 minutes, with ORs increasing for each subsequent time stratification: 120 min ≤ x < 180 min (OR 1.703, 95% CI 1.00-2.90; *P* = .050), 180 min ≤ x < 240 min (OR 1.895, 95% CI 1.09-3.31; *P* = .025), ≥ 240 min (OR 2.337, 95% CI 1.431-3.82; *P* = .001) (Table 3).

Patients who developed UTIs following their procedure also had significantly greater rates of other numerous postoperative complications. A complete list of postoperative complications and *P* values can be seen in Table 4. In addition, multivariate logistic regression models demonstrating increased risk for several complications in association with the UTI following ALIF can be found in Table 5.

DISCUSSION

The current retrospective study sought to identify risk factors that independently increased the risk for postoperative UTIs following ALIF. By identifying independent risk factors for UTI in patients undergoing ALIF, proper prophylactic measures can be taken to decrease the risk of UTI in these

patients and prevent associated postoperative adverse events as UTIs have been associated with increased rates of postoperative complications, mortality, and increased length of stay.^{3,4,6,17,18} Indeed, the results of this retrospective study contribute to this growing body of evidence as UTIs were associated with increased postoperative complications following ALIF (Table 5).

Risk factors identified in this study include age ≥ 60 years, female sex, alcohol use, chronic steroid use, preoperative open wound or wound infections, and longer operative times as independent risk factors for the development of UTIs following ALIF. To the authors' knowledge, there has been no previously reported association of chronic steroid use with UTI in ALIF. The results of this study support the current literature as the association between chronic steroid use and UTI occurrence has been previously reported in various urological procedures and total joint arthroplasty.^{19,20} Steroids have been known to predispose patients to infectious complications as they are immunosuppressive via anti-inflammatory gene expression and alterations in immune cell trafficking.^{21,22}

In addition to chronic steroid use, this current study identifies significant alcohol intake as increas-

Table 4. Univariate analyses for postoperative complications in patients that developed UTIs.

Postoperative Complications	Control		UTI		P Value ^a
	N	%	N	%	
Total	10 088		144		
Superficial incisional SSI ^a	103	1.02	8	5.56	< .001
Deep incisional SSI	49	0.49	3	2.08	.007
Organ/space SSI	31	0.31	2	1.39	.023
Wound disruption	21	0.21	1	0.69	.211
Pneumonia	85	0.84	7	4.86	< .001
Unplanned intubation	31	0.31	4	2.78	< .001
Pulmonary embolism	56	0.56	1	0.69	.823
Ventilator dependence (> 48 h)	44	0.44	7	4.86	< .001
Progressive renal insufficiency	12	0.12	0	0.00	.679
Acute renal failure	10	0.10	1	0.69	.030
CVA/stroke	8	0.08	1	0.69	.013
Cardiac arrest	22	0.22	1	0.69	.231
Myocardial infarction	30	0.30	0	0.00	.512
Blood transfusions	941	9.33	36	25.00	< .001
Deep venous thromboembolism	80	0.79	4	2.78	.009
Systemic sepsis	56	0.56	12	8.33	< .001
Septic shock	12	0.12	0	0.00	.679
Death	21	0.21	1	0.69	.211
Return to operating room	321	3.18	14	9.72	< .001
Extended length of stay (≥ 5 d)	2351	23.30	85	59.03	< .001
Readmission	518	5.13	24	16.67	< .001

Abbreviations: CVA, cerebrovascular accident; SSI, surgical site infection.
^aAll bolded values represent statistically significant values.

ing the rate of UTI in ALIF patients. Alcohol has long been known to have deleterious effects via various cellular mechanisms when consumed in excess due to subclinical immunosuppressive properties that may only become apparent during physiological stress such as surgery.^{23,24} Future research examining the efficacy of steroid tapering and alcohol cessation in decreasing UTI rates post-ALIF is warranted.

Female sex and age ≥ 60 years were also identified as risk factors for precipitating UTI in

ALIF patients. Outside the setting of surgery, females have higher rates of UTIs compared to males when matched for age and other demographic variables due to (1) the shorter female urethra and (2) the proximity of the urethral opening to the end of the gastrointestinal tract.^{1,25,26} Early genotypic studies of *Escherichia coli* in female UTIs have demonstrated identical genomic profiles to that of enteric *E. coli*.²⁷

Older age is another risk factor that increases the likelihood of developing a UTI following ALIF.

Table 5. Multivariate analyses assessing urinary tract infections as an independent risk factor for experiencing other postoperative complications.

Postoperative Complications	Odds Ratio	95% Confidence Interval		P Value ^a
Superficial incisional SSI	5.835	2.732	12.466	< .001
Deep incisional SSI	2.846	0.825	9.822	.098
Organ/space SSI	3.763	0.804	17.603	.092
Wound disruption	2.670	0.349	20.422	.344
Pneumonia	5.087	2.173	11.911	< .001
Unplanned intubation	6.531	2.115	20.172	.001
Pulmonary embolism	1.219	0.166	8.969	.846
Ventilator dependence (> 48 h)	6.248	2.409	16.203	< .001
Acute renal failure	5.041	0.562	45.235	.148
CVA/stroke	2.334	0.168	32.503	.528
Cardiac arrest	2.649	0.342	20.491	.351
Blood transfusions	2.144	1.433	3.208	< .001
Deep venous thromboembolism	2.873	0.999	8.262	.050
Systemic sepsis	14.328	7.096	28.929	< .001
Death	2.373	0.275	20.479	.432
Return to operating room	2.548	1.424	4.558	.002
Extended length of stay (≥ 5 d)	3.631	2.557	5.156	< .001
Readmission	3.044	1.920	4.828	< .001

Abbreviations: CVA, cerebrovascular accident; SSI, surgical site infection.
^aAll bolded values represent statistically significant values.

Benign prostatic hypertrophy in older men leads to increased urinary stasis that promotes the growth of bacterium in the urinary tract.²⁸ Menopausal changes have also been known to predispose older women to UTI development due to decreases in estrogen in the vaginal epithelium.²⁹ Additionally, immune function declines as patients age, potentially preventing older individuals from mounting adequate immune responses to prevent UTI.³⁰ Bohl et al previously reported that female sex increased the risk for UTI in posterior approaches to lumbar fusion. In addition, patients ≥ 60 years old had an increased risk of UTI that correlated positively with increasing age, whereas patients ages 50 to 59 years old had no difference in UTI rates compared to a younger population cohort.¹⁴ As age and sex are nonmodifiable risk factors for UTI, a lower threshold of suspicion for UTI should be held for patients undergoing ALIF who are female and ≥ 60 years of age. Although appropriate removal of catheters is a standard of care,²⁵ stringent adherence to guidelines for these high-risk patients is warranted to prevent further morbidity.

The current retrospective study lends further supporting evidence to a growing body of literature that reports longer operative times lead to increased UTI development. We report operative times greater than 119 minutes demonstrate a direct positive correlation with increased postoperative UTI development—each additional stratification of operative time demonstrated increased statistical significance. Previous reports have shown that longer operative times increase the risk of UTI across all surgical fields, including posterior lumbar fusion and single-level lumbar fusion of different approaches.^{14,31–33} To the authors' knowledge, this relationship has not been previously demonstrated in anterior approaches to the lumbar spine. The ACS-NSQIP database does not report why certain operations are of longer duration or the specific length of operative times, likely representing limitations to this study. Longer operative times can be due to a number of factors including additional levels, excessive bleeding requiring operative control, high soft-tissue body habitus, and surgeon experience or case volume. Longer operative times have been reported to increase the risk of pathogen exposure and increased iatrogenic tissue trauma that may increase the risk of UTI.³² Increased operative time can also lead to UTI via hypothermia induced lymphocytic dysfunction.³⁴ In addition, an in-

creased operative time could also indicate a more complex operation that could require extended postoperative catheterization, allowing bacteria more time to ascend the urinary tract and cause infection.¹ Further quality improvement focused work investigating methods to reduce operative time in ALIF may prove beneficial in reducing UTI rates.

Our study identified preoperative open wounds or wound infections to be an independent risk factor for the development of UTI in ALIF patients. UTIs have been reported to increase the risk of various infectious complications in the postoperative period following many surgical procedures. Asymptomatic and symptomatic preoperative UTIs and postoperative UTIs have been linked to increased rates of infectious complications, sepsis, morbidity, and mortality.^{35,36} Multivariate analyses in this study provides supporting evidence as UTIs were found to increase the risk for postoperative surgical site infection and pneumonia as well. These complications likely arise from more severe UTIs that can lead to urosepsis, widespread migration of bacteria throughout the body, and subsequent infectious complications. However, to the authors' knowledge, there appears to be no other reports of the inverse relationship.

There is a lack of literature investigating preoperative wounds and their association with UTI in the postoperative period. The exact link between preoperative wounds that lead to UTI in the postoperative period is as of yet unclear. It is plausible that those with preoperative wound infections may already be immunocompromised, leading to an increased likelihood of developing UTIs following ALIF. As the ACS-NSQIP database does not provide specific parameters of immune functioning in these patient files, this represents a limitation of the database for this study. *Staphylococcus aureus* has been implicated in primary *S. aureus* UTI as the bacterium can seed the urinary tract hematogenously as opposed to fecal-perineal-urethral contamination by enteric organisms.³⁷ Hematogenous spread of staphylococcal species may very well lead to UTI in ALIF patients. Future work analyzing the correlation of nonenteric bacterium in UTI and the presence of preoperative open wounds or wound infections is warranted. In light of these results, surgeons should postpone elective ALIF operation until all open wounds and wound infections have been resolved to reduce the risk of UTI and subsequent increased morbidity.

This current retrospective study presents with several limitations. This study only analyzed demographic variables, comorbidities, and complications in which $\geq 85\%$ of the patient files were recorded. By excluding other variables that did not meet these inclusion criteria, several other demographic factors, postoperative complications, and comorbidities that may in reality be associated with UTIs may have not been reported. In addition, the inability to verify the information being entered into the database is a limitation inherent to all nationwide database studies. Furthermore, CPT codes are not designed for research purposes—the use of CPT codes can introduce coding bias based on financial reimbursement.³⁸ This current study included all ALIF procedure files that met inclusion criteria. However, as ALIF is indicated for a variety of spinal conditions, distinct pathologies may represent systematic confounding variables that this retrospective study could not account for. An additional confounding variable not accounted for in this study is that all ALIF procedures, including multilevel operations, were included. Future studies examining the effect of multilevel operations on postoperative UTI rates may prove to demonstrate increasing risk of UTI with increasing levels of operation. Finally, the ACS-NSQIP database does not provide details on catheter use. Specific information regarding duration of catheterization in ALIF patients could provide data on whether there is a particular period of time that UTI risk becomes unacceptable in the postoperative period. Elucidating a specific catheterization duration after which the risk of UTI becomes unacceptable may prove useful in formulating quantitative guidelines in the future.

CONCLUSIONS

The present study demonstrated that age ≥ 60 years, female sex, alcohol use, chronic steroid use, preoperative open wound/wound infections, and longer operative times increase the risk for postoperative UTI following ALIF. Identification of risk factors for UTI after ALIF may allow surgical care teams to better risk stratify patients in order to initiate more aggressive prophylactic measures to mitigate the effects of UTIs and their associated complications. The earliest possible removal of catheters must be stringently adhered to in these patients. Providers should have lower thresholds of suspicion for high-risk patients in the postoperative

period following ALIF to avoid UTI and its associated complications. Quality improvement initiatives focusing on ensuring earliest postoperative catheter removal may help mitigate risk in these high-risk patients.

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