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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 (ACS-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, international normalized ratio; UTI, urinary tract infection.

^aAll bolded values represent statistically significant results.^bValues expressed as mean \pm 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 \pm SD) | 0.35 \pm 7.909 | | 0.51 \pm 2.461 | | .806 |
| Total operating time (mean \pm SD; min) | 198.16 \pm 120.054 | | 250.19 \pm 150.093 | | < .001 |
| Total hospital stay length (mean \pm SD; d) | 3.91 \pm 4.856 | | 8.03 \pm 8.103 | | < .001 |
| Days from operation to death (mean \pm SD) | 7.32 \pm 7.046 | | 6.00 | | .856 |
| Days from operation to discharge (mean \pm SD) | 3.70 \pm 3.367 | | 7.52 \pm 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 ^a /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 | |
| $120 \leq x < 180$ | 2467 | 24.45 | 35 | 24.31 | |
| $180 \leq x < 240$ | 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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