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# Postoperative Morbidity and Mortality in Lumbar Spine Surgery Patients With Chronic Kidney Disease and Chronic Steroid Use

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## ABSTRACT

**Background:** Perioperative steroids have traditionally been administered during lumbar spine surgery in order to decrease local inflammation and prevent scar tissue formation, which can otherwise contribute to significant, long-lasting postoperative pain due to the formation of epidural fibrosis around lumbar nerve roots. However, the use of steroids in lumbar spine patients has raised concerns of postoperative wound complications caused by corticosteroid-induced immunomodulatory effects and changes in collagen synthesis. Patients with chronic kidney disease (CKD) undergoing spine surgery are at a particularly elevated risk of various complications due to chronic CKD-related systemic inflammation and endothelial dysfunction. It is currently uncertain whether chronic steroid use in CKD patients exerts a protective effect postoperatively due to decreased systemic inflammation or instead is correlated with increased rates of wound complications.

**Results:** Using adjusted odds ratios to control for CKD-related comorbidities, our study of lumbar spine fusion patients who were chronic steroid users vs nonusers found no significant differences in rates of postoperative wound infections in later stage CKD patients. However, we also did not observe statistically significant reductions in hospital length of stay or rates of 30-day mortality, sepsis, or cardiac, pulmonary, and renal events.

**Conclusions:** Our results indicate chronic steroid use neither contributes significantly to rates of wound infections nor exerts a protective effect against postoperative inflammatory complications in lumbar spine patients with CKD.

**Clinical Relevance:** Our findings do not support the practice of holding steroids in chronic users prior to lumbar spine surgery. Perioperative steroids do not appear to increase the risk of postoperative complications, but neither do they improve lumbar spine patient outcomes.

**Level of Evidence:** 4.

Lumbar Spine

Keywords: arthrodesis, chronic kidney disease, corticosteroids, lumbar spine, spine fusion, wound complications

## INTRODUCTION

Steroids have traditionally been administered during lumbar spine surgery to decrease local inflammation and prevent scar tissue formation,[1] which are major contributors to long-term postoperative pain due to the formation of epidural fibrosis around lumbar nerve roots.[2] However, the use of steroids in lumbar spine patients has raised concerns of postoperative wound complications caused by corticosteroid-induced immunomodulation and effects on collagen synthesis.[3] While a Cochrane meta-analysis of 37 studies found that shorter courses of perioperative dexamethasone did not have a significant effect on infection rates or wound healing,[4] chronic steroid use prior to surgery has been reported to increase the risk of surgical site infection, wound dehiscence, and venous thromboembolism.[3] However, postoperative steroid administration has also been correlated with improvements in functional recovery time, decreased hospital length of stay (LOS), and reduced postoperative morphine requirements for pain management following posterior spine fusion.[5]

Chronic kidney disease (CKD) is defined as an estimated glomerular filtration rate (eGFR) of less than 60 mL/min/1.73 $m^2$ for 3 months or more, resulting from some form of renal pathology.[6] Due to improvements in life expectancy through better access to pharmacological therapy, hemodialysis, and kidney transplantation, the

number of patients presenting for lumbar spine surgery with a history of CKD is expected to continue to rise in the future.[7] Patients with CKD are at an increased risk of postoperative complications following lumbar spine surgeries, including infection, hemorrhage requiring blood transfusion, and both 90-day and 1-year mortality, even after controlling for age, sex, and other comorbidities.[8] The risk of complications has been found to be inversely proportional to declining eGFR: patients with an eGFR <60 mL/min/1.73 $m^2$ have a 10-fold risk of developing acute renal failure in the postoperative period compared with controls.[9] Other common complications observed in CKD patients following spine surgery include deep vein thrombosis (DVT), pulmonary embolism (PE), stroke, hemorrhage, myocardial infarction, respiratory distress syndrome, and shock.[10] It is thought that the increased inflammatory response observed in patients with CKD contributes to endothelial dysfunction, which underlies the pathophysiology for many of the complications observed in CKD patients following surgery.[11]

Our study set out to examine whether chronic preoperative steroid use improves postoperative outcomes following lumbar spine surgery in patients with CKD. It is uncertain whether chronic steroid use in CKD patients exerts a protective effect postoperatively due to decreased systemic inflammation or whether it is instead correlated with increased rates of wound complications due to worsening of CKD-associated immunodeficiency. In this study, we analyzed morbidity and mortality outcomes in lumbar spine surgical patients with and without chronic preoperative corticosteroid use reported in the National Surgical Quality Improvement Program (NSQIP) database after stratifying patients by CKD staging.

## METHODS

NSQIP files from 2006 to 2019 were queried for all patients who received lumbar spinal fusion surgery and identified using the current procedural terminology codes displayed in Table 1. These current procedural terminology codes have previously been used in the literature to investigate outcomes for lumbar spinal fusion procedures recorded in the NSQIP database.[12] The eGFR status was calculated for all patients[13] and used to stratify patients into the following stages of CKD[14]:

- Stage 1, normal or high eGFR (eGFR >90 mL/min)
- Stage 2, mild CKD (eGFR 60–89 mL/min)
- Stage 3a, moderate CKD (eGFR 45–59 mL/min)
- Stage 3b, moderate CKD (eGFR 30–44 mL/min)
- Stage 4, severe CKD (eGFR 16–29 mL/min)
- Stage 5, end-stage CKD (eGFR <15 mL/min)

**Table 1.** Current Procedural Terminology Codes and Descriptions.

| Code | Description |
|---|---|
| 22533 | Arthrodesis, lateral extracavitary technique, including minimal discectomy to prepare interspace (other than for decompression), single interspace |
| 22534 | Arthrodesis, lateral extracavitary technique, including minimal discectomy to prepare interspace (other than for decompression), additional interspace |
| 22558 | Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace (other than for decompression), single interspace |
| 22585 | Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace (other than for decompression), additional interspace |
| 22612 | Arthrodesis, posterior or posterolateral technique, single level |
| 22614 | Arthrodesis, posterior or posterolateral technique, additional level |
| 22630 | Arthrodesis, posterior interbody technique, including laminectomy and/or discectomy to prepare interspace (other than for decompression), single interspace |
| 22632 | Arthrodesis, posterior interbody technique, including laminectomy and/or discectomy to prepare interspace (other than for decompression), additional interspace |
| 22633 | Arthrodesis, combined posterior or posterolateral technique with posterior interbody technique including laminectomy and/or discectomy sufficient to prepare interspace (other than for decompression), single interspace and segment |
| 22634 | Arthrodesis, combined posterior or posterolateral technique with posterior interbody technique including laminectomy and/or discectomy sufficient to prepare interspace (other than for decompression), additional interspace and segment |

*Note*: Listing of current procedural terminology codes used to select lumbar spine fusion patients for this study. All codes were referenced through standardized listings prepared by the American Academy of Professional Coders.[15]

For each CKD stage, patients with reported preoperative corticosteroid use for a chronic condition were compared with patients without reported steroid use (identified in the NSQIP database as "variable name: steroid, condition: yes" or "variable name: steroid, condition: no," respectively).

Fisher exact tests were used to find statistically significant univariate differences in preoperative comorbidities and postoperative outcomes between patients with and without corticosteroid use (Tables 2 and 3). Composite outcomes were created for the following postoperative events: renal events (postoperative dialysis and acute kidney injury), pulmonary events (prolonged intubation, repeat intubation, and pneumonia), wound events (organ space infection, wound dehiscence, surgical superficial site infection, and deep wound infection), venous thromboembolic events (VTEs) (PE and DVT), and major adverse cardiac events (MACEs) (myocardial infarction, cardiac arrest, and stroke). Rates of sepsis, urinary tract infection (UTI), return to operating room (OR), extended LOS

**Table 2.** Preoperative univariate associations by chronic kidney disease stage.

| | Stage 1 ($n$ = 76,137) | | | Stage 2 ($n$ = 92,698) | | | Stage 3a ($n$ = 20,926) | | | Stage 3b ($n$ = 7551) | | | Stage 4 ($n$ = 1552) | | | Stage 5 ($n$ = 869) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Steroid ($n$ = 3413)** | **No Steroid ($n$ = 72,724)** | ***P* Value** | **Steroid ($n$ = 4351)** | **No Steroid ($n$ = 88,347)** | ***P* Value** | **Steroid ($n$ = 1368)** | **No Steroid ($n$ = 19,558)** | ***P* Value** | **Steroid ($n$ = 593)** | **No Steroid ($n$ = 6958)** | ***P* Value** | **Steroid ($n$ = 155)** | **No Steroid ($n$ = 1397)** | ***P* Value** | **Steroid ($n$ = 45)** | **No Steroid ($n$ = 824)** | ***P* Value** |
| Sex (women) | 1931 | 35,978 | 4.65E−16 | 2786 | 46,801 | <2.2e−16 | 916 | 11,455 | 7.49E−10 | 372 | 4411 | 0.756 | 90 | 799 | 0.864 | 13 | 299 | 0.343 |
| Diabetes | 625 | 11,349 | 3.13E−05 | 810 | 16,171 | 0.602 | 335 | 5642 | 0.00052 | 236 | 2620 | 0.3104 | 65 | 709 | 0.042 | 12 | 339 | 0.0612 |
| Smoker | 768 | 21,263 | <2.2E−16 | 571 | 13,854 | 4.06E−06 | 123 | 2327 | 0.00094 | 39 | 694 | 0.0059 | 11 | 191 | 0.0227 | 12 | 149 | 0.1665 |
| Dyspnea | 318 | 3378 | <2.2E−16 | 445 | 5474 | <2.2E−16 | 203 | 1848 | 1.055E−09 | 79 | 794 | 0.1604 | 28 | 177 | 0.07879 | 4 | 84 | 1 |
| Independent functional status | 3114 | 70,062 | <2.2E−16 | 4074 | 85,548 | <2.2E−16 | 1297 | 18,725 | 0.03438 | 534 | 6528 | 0.0002586 | 135 | 1266 | 0.1427 | 37 | 687 | 1 |
| COPD | 344 | 3050 | <2.2E−16 | 483 | 4446 | <2.2E−16 | 172 | 1323 | 1.274E−13 | 40 | 569 | 0.2388 | 17 | 90 | 0.04377 | 5 | 64 | 0.3936 |
| CHF | 15 | 127 | 0.001853 | 44 | 322 | 1.48E−08 | 12 | 158 | 0.7545 | 9 | 113 | 1 | 6 | 47 | 0.6451 | 2 | 47 | 1 |
| Hypertension | 1878 | 33,571 | <2.2E−16 | 2965 | 55,310 | 9.49E−14 | 1093 | 15,806 | 0.4145 | 511 | 6060 | 0.5244 | 136 | 1268 | 0.2473 | 42 | 673 | 0.04524 |
| Dialysis | 2 | 19 | 0.2421 | 4 | 31 | 0.08007 | 0 | 21 | 0.3962 | 0 | 13 | 0.6171 | 6 | 113 | 0.07784 | 38 | 630 | 0.2763 |
| Sepsis | 154 | 1289 | <2.2E−16 | 85 | 767 | 1.06E−10 | 16 | 229 | 1 | 13 | 122 | 0.419 | 4 | 83 | 0.0968 | 4 | 88 | 1 |
| Disseminated cancer | 387 | 1485 | <2.2E−16 | 167 | 1059 | <2.2E−16 | 47 | 291 | 1.04E−06 | 21 | 116 | 0.003216 | 3 | 33 | 1 | 2 | 16 | 0.238 |
| Superficial wound infection | 1 | 12 | 0.4615 | 0 | 5 | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| Deep wound infection | 3 | 51 | 0.7396 | 3 | 23 | 0.1247 | 0 | 6 | 1 | 0 | 3 | 1 | 0 | 3 | 1 | 0 | 1 | 1 |
| Weight loss >10% | 68 | 591 | 2.79E−10 | 31 | 425 | 0.04443 | 18 | 88 | 0.000167 | 10 | 31 | 0.000994 | 6 | 19 | 0.032 | 0 | 20 | 0.6186 |
| Bleeding disorder | 121 | 992 | <2.2E−16 | 154 | 1636 | 9.80E−13 | 72 | 589 | 1.95E−05 | 34 | 248 | 0.01241 | 9 | 90 | 0.8637 | 2 | 72 | 0.4194 |
| Age ≥70 y | 369 | 5114 | 3.88E−15 | 1748 | 32,244 | 1.04E−06 | 798 | 10,904 | 0.06311 | 322 | 4644 | 1.76E−09 | 94 | 844 | 1 | 10 | 224 | 0.6047 |
| Albumin <3.4 g/dL | 421 | 3029 | <2.2E−16 | 290 | 2410 | <2.2E−16 | 81 | 761 | 0.00412 | 58 | 396 | 0.001283 | 24 | 237 | 0.631 | 19 | 233 | 0.4008 |
| WBC >11,000/$\mu$L | 578 | 5770 | <2.2E−16 | 583 | 4940 | <2.2E−16 | 198 | 1288 | <2.2E−16 | 83 | 525 | 4.15E−07 | 32 | 142 | 0.00044 | 5 | 83 | 0.8004 |
| Platelets <150,000/$\mu$L | 280 | 3028 | <2.2E−16 | 276 | 4262 | 1.29E−05 | 101 | 1242 | 0.1536 | 52 | 547 | 0.4792 | 21 | 151 | 0.3489 | 11 | 161 | 0.4451 |
| BUN >23 mg/dL | 206 | 2327 | 2.31E−16 | 658 | 9098 | <2.2E−16 | 523 | 6739 | 0.005498 | 404 | 4491 | 0.04341 | 139 | 1223 | 0.4219 | 42 | 619 | 0.003679 |
| BMI ≥30 | 1498 | 34,825 | 1.08E−05 | 2070 | 43,256 | 0.0927 | 655 | 10,475 | 2.91E−05 | 265 | 3851 | 2.29E−06 | 60 | 749 | 0.0003443 | 10 | 361 | 0.004889 |

Abbreviations: BMI, body mass index; BUN, blood urea nitrogen; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; WBC, white blood cells.
*Note*: Comparison of preoperative variables between lumbar spine fusion patient groups stratified by CKD stage. For each CKD stage, patients with reported chronic steroid use were compared with patients without chronic steroid use using Fisher exact tests. Statistical significance was defined as $P$ value ≤0.05.

**Table 3.** Postoperative univariate associations by chronic kidney disease stage.

| | Stage 1 ($n$ = 76,137) | | | Stage 2 ($n$ = 92,698) | | | Stage 3a ($n$ = 20,926) | | | Stage 3b ($n$ = 7551) | | | Stage 4 ($n$ = 1552) | | | Stage 5 ($n$ = 869) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **Steroid ($n$ = 3413)** | **No Steroid ($n$ = 72,724)** | ***P* Value** | **Steroid ($n$ = 4351)** | **No Steroid ($n$ = 88,347)** | ***P* Value** | **Steroid ($n$ = 1368)** | **No Steroid ($n$ = 19,558)** | ***P* Value** | **Steroid ($n$ = 593)** | **No Steroid ($n$ = 6958)** | ***P* Value** | **Steroid ($n$ = 155)** | **No Steroid ($n$ = 1397)** | ***P* Value** | **Steroid ($n$ = 45)** | **No Steroid ($n$ = 824)** | ***P* Value** |
| Wound infection | 101 | 1127 | **8.05E−09** | 154 | 1281 | **<2.2E−16** | 45 | 349 | **0.000273** | 16 | 146 | 0.3032 | 3 | 50 | 0.3579 | 3 | 42 | 0.5019 |
| Pulmonary event | 116 | 1060 | **4.27E−15** | 123 | 1217 | **2.68E−12** | 28 | 426 | 0.8476 | 29 | 219 | **0.02978** | 9 | 89 | 1 | 4 | 73 | 1 |
| VTE | 109 | 1117 | **1.96E−11** | 129 | 1482 | **6.18E−09** | 16 | 364 | 0.07382 | 22 | 151 | **0.02158** | 3 | 55 | 0.268 | 2 | 29 | 0.672 |
| MACE | 28 | 390 | **0.03271** | 58 | 710 | **0.00042** | 25 | 292 | 0.3036 | 5 | 150 | **0.03277** | 6 | 53 | 1 | 1 | 65 | 0.2455 |
| Renal event | 16 | 128 | **0.0007748** | 13 | 288 | 0.8913 | 16 | 99 | **0.003718** | 15 | 86 | **0.01424** | 1 | 66 | **0.0113** | 1 | 4 | 0.2339 |
| Death within 30 d | 73 | 252 | **<2.2E−16** | 49 | 403 | **7.28E−08** | 9 | 109 | 0.5748 | 4 | 81 | 0.4136 | 3 | 38 | 0.7919 | 0 | 33 | 0.4083 |
| Sepsis | 54 | 768 | **0.006418** | 92 | 766 | **4.37E−13** | 31 | 244 | **0.002941** | 20 | 110 | **0.004306** | 5 | 58 | 0.8291 | 4 | 29 | 0.08541 |
| UTI | 81 | 1104 | **0.0002175** | 152 | 1674 | **1.88E−11** | 53 | 548 | **0.02893** | 34 | 247 | **0.01225** | 7 | 69 | 1 | 2 | 12 | 0.1609 |
| Transfusion within 72 h | 782 | 10,356 | **<2.2E−16** | 941 | 13,805 | **<2.2E−16** | 330 | 3818 | **5.39E−05** | 153 | 1670 | 0.3422 | 53 | 436 | 0.4663 | 11 | 326 | 0.05818 |
| Return to OR | 197 | 2851 | **3.23E−07** | 265 | 3169 | **3.64E−15** | 102 | 872 | **2.09E−06** | 47 | 324 | **0.0009916** | 11 | 121 | 0.6483 | 13 | 89 | **0.001095** |
| LOS ≥10 d | 515 | 5763 | **<2.2E−16** | 450 | 4935 | **<2.2E−16** | 150 | 1437 | **3.95E−06** | 85 | 617 | **3.41E−05** | 34 | 322 | 0.7639 | 19 | 333 | 0.7562 |

Abbreviations: CKD, chronic kidney disease; LOS, length of stay; MACE, major adverse cardiovascular event; OR, operating room; UTI, urinary tract infection; VTE, venous thromboembolism.
*Note*: Comparison of postoperative variables between lumbar spine fusion patient groups stratified by CKD stage. For each CKD stage, patients with reported chronic steroid use were compared with patients without chronic steroid use using Fisher exact tests. Statistical significance was defined as $P$ value ≤0.05.

(defined as ≥10 days), and 30-day mortality were also analyzed. A *P* value of ≤0.05 was required for a determination of statistical significance. For each stage of CKD, all preoperative variables with a *P* value ≤0.20 were selected for multivariate logistic regression modeling. Multivariate logistic regression modeling was done for each CKD stage to identify the adjusted odds ratios (aOR) of increased or decreased odds of postoperative outcomes in patients with chronic steroid use compared with patients without chronic steroid use (Table 4). A Bonferroni-adjusted *P* value ≤0.017 was then used to determine significance in our analysis of aOR with associated confidence intervals.

## RESULTS

### Stage 1 CKD: eGFR ≥90 mL/min

Overall, 76,137 patients were identified with Stage 1 CKD who underwent lumbar spinal fusion surgery. Of these patients, 4.48% (*n* = 3413) reported preoperative chronic steroid use. On univariate analysis of perioperative comorbidities, significant differences between chronic steroid users and nonusers were found for rates of gender (*P* = 4.65E−16), diabetes (*P* = 3.13E−05), smoking status (*P* < 2.2E−16), dyspnea (*P* < 2.2E−16), functional status (*P* < 2.2E−16), chronic obstructive pulmonary disease (COPD) (*P* < 2.2E−16), congestive heart failure (*P* = 0.001853), hypertension (*P* < 2.2E−16), sepsis (*P* < 2.2E−16), cancer (*P* < 2.2E−16), weight loss (*P* = 2.79E−10), bleeding disorder (*P* < 2.2E−16), advanced age (*P* = 3.88E−15), hypoalbuminemia (*P* < 2.2E−16), leukocytosis (*P* < 2.2E−16), thrombocytopenia (*P* < 2.2E−16), uremia (*P* = 2.31E−16), and obesity (*P* = 1.08E−05).

Univariate analysis of postoperative outcomes found significant differences between patients with and without chronic steroid use for rates of wound infections (*P* = 8.05E−09), pulmonary events (*P* = 4.27E−15), VTE (*P* = 1.96E−11), MACE (*P* = 0.03271), renal events (*P* = 0.0007748), 30-day mortality (*P* < 2.2E−16), sepsis (*P* = 0.006418), UTI (*P* = 0.0002175), transfusion within 72 hours (*P* < 2.2E−16), return to OR (*P* = 3.23E-07), and extended LOS (*P* < 2.2E−16).

Multivariate analysis found that patients with chronic steroid use have significantly increased adjusted odds of the following outcomes: wound infections (aOR = 1.458, CI = 1.119–1.900, *P* = 0.00512), pulmonary events (aOR = 1.514, CI = 1.191–1.924, *P* = 0.000704), 30-day mortality (aOR = 2.134, CI 1.528–2.980, *P* = 8.48E−06), and transfusion within 72 hours (aOR = 1.270, CI 1.135–1.422, *P* = 2.98E−05).

**Table 4.** Adjusted OR for postoperative complications by CKD stage.

| Outcome and CKD Stage | Adjusted OR | 95% CI | *P* Value |
|---|---|---|---|
| Wound Infection | | | |
| Stage 1 | 1.458 | 1.119–1.900 | **0.00512** |
| Stage 2 | 2.218 | 1.780–2.765 | **1.33E−12** |
| Stage 3a | 1.577 | 1.048–2.373 | 0.0287 |
| Stage 3b | 1.114 | 0.542–2.289 | 0.768 |
| Stage 4 | 0.468 | 0.130–1.686 | 0.246 |
| Stage 5 | 1.689 | 0.487–5.856 | 0.408 |
| Pulmonary Event | | | |
| Stage 1 | 1.514 | 1.191–1.924 | **0.000704** |
| Stage 2 | 1.010 | 0.752–1.356 | 0.944 |
| Stage 3a | 1.063 | 0.681–1.661 | 0.786 |
| Stage 3b | 1.654 | 0.989–2.766 | 0.0550 |
| Stage 4 | 0.843 | 0.398–1.784 | 0.656 |
| Stage 5 | 0.811 | 0.276–2.377 | 0.703 |
| Venous thromboembolism | | | |
| Stage 1 | 1.293 | 0.993–1.684 | 0.0561 |
| Stage 2 | 1.423 | 1.110–1.825 | **0.00540** |
| Stage 3a | 0.624 | 0.336–1.158 | 0.135 |
| Stage 3b | 2.209 | 1.306–3.735 | **0.0031** |
| Stage 4 | 0.550 | 0.161–1.869 | 0.338 |
| Stage 5 | 1.703 | 0.366–7.928 | 0.497 |
| MACE | | | |
| Stage 1 | 1.248 | 0.7977–1.952 | 0.332 |
| Stage 2 | 1.148 | 0.775–1.700 | 0.489 |
| Stage 3a | 0.929 | 0.507–1.702 | 0.814 |
| Stage 3b | 0.127 | 0.017–0.925 | 0.0417 |
| Stage 4 | 0.665 | 0.257–1.719 | 0.401 |
| Stage 5 | 0.236 | 0.031–1.768 | 0.160 |
| Renal event | | | |
| Stage 1 | 0.773 | 0.320–1.865 | 0.567 |
| Stage 2 | 0.561 | 0.228–1.381 | 0.209 |
| Stage 3a | 3.873 | 1.993–7.526 | **6.44E−05** |
| Stage 3b | 1.922 | 0.944–3.914 | 0.0715 |
| Stage 4 | 0.098 | 0.013–0.732 | 0.0235 |
| Stage 5 | 6.34E−08 | 0–inf | 0.998 |
| Death within 30 d | | | |
| Stage 1 | 2.134 | 1.528–2.980 | **8.48E−06** |
| Stage 2 | 1.252 | 0.814–1.924 | 0.305 |
| Stage 3a | 1.650 | 0.772–3.530 | 0.196 |
| Stage 3b | 0.973 | 0.331–2.853 | 0.960 |
| Stage 4 | 0.612 | 0.170–2.194 | 0.451 |
| Stage 5 | 1.78E−07 | 0–inf | 0.986 |
| Sepsis | | | |
| Stage 1 | 0.940 | 0.662–1.335 | 0.731 |
| Stage 2 | 2.202 | 1.634–2.967 | **2.09E−07** |
| Stage 3a | 0.975 | 0.585–1.626 | 0.925 |
| Stage 3b | 1.869 | 1.004–3.479 | 0.0483 |
| Stage 4 | 0.940 | 0.360–2.457 | 0.901 |
| Stage 5 | 2.296 | 0.750–7.022 | 0.145 |
| Urinary tract infection | | | |
| Stage 1 | 1.050 | 0.775–1.422 | 0.750 |
| Stage 2 | 1.535 | 1.208–1.950 | **0.000446** |
| Stage 3a | 0.946 | 0.635–1.409 | 0.788 |
| Stage 3b | 1.826 | 1.130–2.951 | **0.0138** |
| Stage 4 | 1.171 | 0.508–2.699 | 0.711 |
| Stage 5 | 2.506 | 0.525–11.946 | 0.249 |
| Transfusion within 72 h | | | |
| Stage 1 | 1.270 | 1.135–1.422 | **2.98E−05** |
| Stage 2 | 1.358 | 1.225–1.504 | **5.09E−09** |
| Stage 3a | 1.046 | 0.878–1.245 | 0.611 |
| Stage 3b | 0.961 | 0.746–1.238 | 0.761 |
| Stage 4 | 1.203 | 0.833–1.737 | 0.324 |
| Stage 5 | 0.368 | 0.177–0.765 | **0.00738** |
| Return to operating room | | | |
| Stage 1 | 1.186 | 0.973–1.445 | 0.0905 |
| Stage 2 | 1.687 | 1.421–2.002 | **2.07E−09** |
| Stage 3a | 1.276 | 0.948–1.719 | 0.107 |
| Stage 3b | 1.103 | 0.684–1.777 | 0.687 |
| Stage 4 | 0.940 | 0.476–1.856 | 0.860 |
| Stage 5 | 3.744 | 1.844–7.602 | **0.000258** |
| Length of stay ≥10 d | | | |
| Stage 1 | 0.988 | 0.854–1.145 | 0.882 |
| Stage 2 | 1.144 | 0.981–1.334 | 0.0853 |
| Stage 3a | 0.970 | 0.750–1.254 | 0.820 |
| Stage 3b | 1.031 | 0.728–1.461 | 0.859 |
| Stage 4 | 1.024 | 0.659–1.590 | 0.916 |
| Stage 5 | 0.876 | 0.464–1.656 | 0.686 |

Abbreviations: CKD, chronic kidney disease; MACE, major adverse cardiovascular event.
*Note*: Adjusted OR for each postoperative outcome variable stratified by CKD staging. For each CKD stage, multivariate logistic regression modeling used patients without chronic steroid use as the reference group to determine adjusted ORs. Statistical significance was defined as a Bonferroni-adjusted *P* value ≤0.017.

### Stage 2 CKD: eGFR 60 to 89 mL/min

A total of 92,698 patients were identified with Stage 2 CKD who underwent lumbar spinal fusion surgery. Of these patients, 4.69% ($n$ = 4351) reported preoperative chronic steroid use. Univariate analysis of perioperative comorbidities found significant differences between chronic steroid users and nonusers for rates of gender ($P \leq$ 2.2E−16), smoking status ($P$ = 4.06E−06), dyspnea ($P <$ 2.2E−16), functional status ($P <$ 2.2E−16), COPD ($P <$ 2.2E−16), congestive heart failure ($P$ = 1.48E−08), hypertension ($P$ = 9.49E−14), sepsis ($P$ = 1.06E−10), cancer ($P <$ 2.2E−16), weight loss ($P$ = 0.0443), bleeding disorder ($P$ = 9.80E−13), advanced age ($P$ = 1.04E−06), hypoalbuminemia ($P <$ 2.2E−16), leukocytosis ($P <$ 2.2E−16), thrombocytopenia ($P$ = 1.29E−05), and uremia ($P <$ 2.2E−16).

Univariate analysis of postoperative outcomes found significant differences between patients with and without chronic steroid use for rates of wound infections ($P <$ 2.2E−16), pulmonary events ($P$ = 2.68E−12), VTE ($P$ = 6.18E−09), MACE ($P$ = 0.00042), 30-day mortality ($P$ = 7.28E−08), sepsis ($P$ = 4.37E−13), UTI ($P$ = 1.88E−11), transfusion within 72 hours ($P <$ 2.2E−16), return to OR ($P$ = 3.64E−15), and extended LOS ($P <$ 2.2E−16).

Multivariate analysis found that patients with chronic steroid use had significantly increased adjusted odds of the following perioperative outcomes: wound infections (aOR = 2.218, CI = 1.780–2.765, $P$ = 1.33E−12), VTE (aOR = 1.423, CI = 1.110–1.825, $P$ = 0.00540), sepsis (aOR = 2.202, CI = 1.634–2.967, $P$ = 2.09E−07), UTI (aOR = 1.535, CI = 1.208–1.950, $P$ = 0.000446), transfusion within 72 hours (aOR = 1.358, CI = 1.225–1.504, $P$ = 5.09E−09), and return to OR (aOR = 1.687, CI = 1.421–2.002, $P$ = 2.07E−09).

### Stage 3a CKD: eGFR 45 to 59 mL/min

A total of 20,926 patients were identified with Stage 3a CKD who underwent lumbar spinal fusion surgery. Of these patients, 6.54% ($n$ = 1368) reported preoperative chronic steroid use. Univariate analysis of perioperative comorbidities found significant differences between chronic steroid users and nonusers for rates of gender ($P$ = 7.49E−10), diabetes ($P$ = 0.00052), smoking status ($P$ = 0.00094), dyspnea ($P$ = 1.055E−09), functional status ($P$ = 0.03438), COPD ($P$ = 1.274E−13), cancer ($P$ = 1.04E−06), weight loss ($P$ = 0.000167), bleeding disorder ($P$ = 1.95E−05), hypoalbuminemia ($P$ = 0.00412), leukocytosis ($P <$ 2.2E−16), uremia ($P$ = 0.005498), and obesity ($P$ = 2.91E−05).

Univariate analysis of postoperative outcomes found significant differences between patients with and without chronic steroid use for rates of wound infections ($P$ = 0.000273), renal events ($P$ = 0.003718), sepsis ($P$ = 0.002041), UTI ($P$ = 0.02893), transfusion within 72 hours ($P$ = 5.39E−05), return to OR ($P$ = 2.09E−06), and extended LOS ($P$ = 3.95E−06). Multivariate analysis found that patients with chronic steroid use had significantly increased adjusted odds of renal events (aOR = 3.873, CI 1.993–7.526, $P$ = 6.44E−05).

### Stage 3b CKD: eGFR 30 to 44 mL/min

A total of 7551 patients were identified with Stage 3b CKD who underwent lumbar spinal fusion surgery. Of these patients, 7.85% ($n$ = 593) reported preoperative chronic steroid use. Univariate analysis of perioperative comorbidities found significant differences between chronic steroid users and nonusers for rates of smoking status ($P$ = 0.0059), functional status ($P$ = 0.0002586), cancer ($P$ = 0.003216), weight loss ($P$ = 0.000994), bleeding disorder ($P$ = 0.01241), advanced age ($P$ = 1.76E−09), hypoalbuminemia ($P$ = 0.001283), leukocytosis ($P$ = 4.15E−07), uremia ($P$ = 0.04341), and obesity ($P$ = 2.29E−06).

Univariate analysis of postoperative outcomes found significant differences between patients with and without chronic steroid use for rates of pulmonary events ($P$ = 0.02978), VTE ($P$ = 0.02158), MACE ($P$ = 0.03277), renal events ($P$ = 0.01424), sepsis ($P$ = 0.004306), UTI ($P$ = 0.01225), return to OR ($P$ = 0.0009916), and extended LOS ($P$ = 3.41E−05). Multivariate analysis found that patients with chronic steroid use had significantly increased adjusted odds of VTE (aOR = 2.209, CI 1.306–3.735, $P$ = 0.0031) and UTI (aOR = 1.826, CI 1.130–2.951, $P$ = 0.0138).

### Stage 4 CKD: eGFR 16 to 29 mL/min

A total of 1552 patients were identified with Stage 4 CKD who underwent lumbar spinal fusion surgery. Of these patients, 9.99% ($n$ = 155) reported preoperative chronic steroid use. Univariate analysis of perioperative comorbidities found significant differences between chronic steroid users and nonusers for rates of diabetes ($P$ = 0.042), smoking status ($P$ = 0.0227), COPD ($P$ = 0.04377), weight loss ($P$ = 0.032), leukocytosis ($P$ = 0.00044), and obesity ($P$ = 0.0003443).

Univariate analysis of postoperative outcomes found a significant difference between patients with and without chronic steroid use for rates of renal events ($P$ = 0.0113). Multivariate analysis found that patients with

chronic steroid use did not have significantly increased adjusted odds of any postoperative outcomes.

### Stage 5 CKD: eGFR <15 mL/min

A total of 869 patients were identified with Stage 5 CKD who underwent lumbar spinal fusion surgery. Of these patients, 5.18% ($n$ = 45) reported preoperative chronic steroid use. Univariate analysis of perioperative comorbidities found significant differences between chronic steroid users and nonusers for rates of hypertension ($P$ = 0.04524), uremia ($P$ = 0.003679), and obesity ($P$ = 0.004889).

Univariate analysis of postoperative outcomes found a significant difference between patients with and without chronic steroid use for rates of return to OR ($P$ = 0.001095). Multivariate analysis found that patients with chronic steroid use had decreased adjusted odds of transfusion within 72 hours (aOR = 0.368, CI 0.177–0.765, $P$ = 0.00738) and increased adjusted odds of return to OR (aOR = 3.744, CI 1.844–7.602, $P$ = 0.000258).

## DISCUSSION

While perioperative steroid use in patients undergoing lumbar spine surgery has been associated with reduced postoperative pain, hospital LOS, and time to return to work,[5,16] the effect of chronic preoperative steroid use in CKD patients undergoing lumbar spine surgery has not previously been studied in the literature. Several studies have shown that lumbar spine patients with CKD are at increased risk of blood transfusion requirements, postoperative intensive care unit transfer, DVT/PE, sepsis, and longer hospital stays compared with controls.[8,10,17] A study by Bains et al of 12,276 spine fusion patients also found that CKD patients are at significantly higher risk of postoperative mortality compared with controls; however, their study did not examine rates of wound complications and noted that CKD patients in their analysis had multiple comorbidities, which were not controlled for and likely contributed to their observed increase in postoperative mortality.[18]

The etiology of postoperative thromboembolic events in CKD patients is unclear and proposed to be either related to chronic inflammation[11] or secondary to derangements in procoagulant and fibrinolytic pathways due to uremia and excess loss of serum proteins in the urine.[19] Impaired wound healing in CKD patients is also thought to be caused by chronic inflammation and endothelial dysfunction,[20] as well as disruption of normal platelet function and hemostasis.[21] Increased rates of wound infection occur due to impairment of lymphocyte, macrophage, and neutrophil function[18] resulting from the interruption of immune signaling processes by uremic toxins.[22] Thus, it has been uncertain whether steroid use in postoperative CKD patients may improve rates of VTE, MACE, renal and pulmonary events, and wound healing due to reduction of systemic inflammation or, conversely, exacerbate risks of wound complications and sepsis by disrupting collagen deposition and immune function.

Steroid use in patients to treat autoimmune-mediated causes of proteinuric kidney disease is not uncommon. However, the risk of steroid-associated adverse effects has been reported to be much higher in these patients compared with controls, with hypertension, diabetes, obesity, and infection found to be the most common side effects.[23] Short-term dexamethasone use in surgical patients has not been found to result in significant differences in rates of postoperative wound infection or healing between treated patients and controls.[4] Perioperative intravenous methylprednisolone has similarly been shown to decrease inflammatory cytokine production and reduce time to normal locomotive status following spine surgery in animal models, without producing significant effects on granulocyte and monocyte numbers or activity.[24] However, chronic preoperative steroid use has previously been associated with increased risk of postoperative surgical site infection, UTI, PE, and readmission in lumbar spine fusion patients.[3]

In contrast to the findings of Ranson et al,[3] our study of lumbar spine fusion patients with CKD receiving chronic steroids found no significant differences in rates of postoperative wound infections between patients with and without preoperative chronic steroid use for moderate or severe CKD subgroups (Stages 3a, 3b, 4, and 5). However, chronic steroid use was also not found to have a significant effect on reducing hospital LOS or rates of MACE, pulmonary and renal events, 30-day mortality, or sepsis in patients with later stages of CKD (Stages 3b, 4, and 5). While rates of MACE, renal events, sepsis, and return to OR were initially found to be elevated in CKD patients using chronic steroids compared with CKD patients not using chronic steroids, when adjusted for age, sex, functional status, and other comorbidities, these differences were not observed in our calculation of aOR. This result suggests that increased rates of CKD-related comorbidities play a significant role in rates of postoperative outcomes observed in prior studies that did not adjust for differences in age, sex, functional status, and comorbidities between steroid users and nonusers. We would also

hypothesize that increased rates of dialysis and more stringent medication management of advanced CKD patients (Stages 3a, 3b, 4, and 5) may contribute to the improved postoperative outcomes compared with mild to moderate CKD patients (Stages 1 and 2).

While chronic perioperative steroid use was not found to result in increased wound complications in later stage CKD patients undergoing lumbar spine fusion surgery, we also did not observe statistically significant reductions in hospital LOS or rates of 30-day mortality, sepsis, or cardiac, pulmonary, and renal events. However, our analysis was limited by heterogeneity of CKD subgroup sizes and uncertainty about steroid dosage and length of use in the chronic steroid CKD group. Studies stratifying patient groups by steroid dosages or length of use are warranted to further evaluate for dose-related steroid treatment-related benefits in postoperative CKD patients.

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