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# Failure to Normalize Risk Profile of Spine Fusion Patients With Coronary Artery Disease Previously Treated With Percutaneous Stent Revascularization

WALEED AHMAD, MS[1]; JOSHUA BELL, MD[2]; OSCAR KROL, BA[1]; LARA PASSFALL, BS[1]; PRAMOD KAMALAPATHY, BS[2]; BAILEY IMBO, BA[1]; PETER TRETIAKOV, BS[1]; TYLER WILLIAMSON, MS[1]; RACHEL JOUJON-ROCHE, BS[1]; KEVIN MOATTARI, BS[1]; NICHOLAS KUMMER, BS[1]; SHALEEN VIRA, MD[3]; VIRGINIE LAFAGE, PhD[4]; CARL PAULINO, MD[5]; ANDREW J. SCHOENFELD, MD, MSc[6]; BASSEL DIEBO, MD[5]; HAMID HASSANZADEH, MD[2]; AND PETER PASSIAS, MD[1]

*[1]Departments of Orthopedic and Neurologic Surgery, NYU Langone Orthopedic Hospital; New York Spine Institute, New York, NY, USA; [2]Department of Orthopedics,, University of Virginia School of Medicine, Charlottesville, VA, USA; [3]Department of Orthopedics, UT Southwestern Medical Center, Dallas, TX, USA; [4]Department of Orthopaedics, Lenox Hill Hospital, Northwell Health, New York, NY, USA; [5]Department of Orthopedics, SUNY Downstate Medical Center, Brooklyn, New York, NY, USA; [6]Department of Orthopedics, Harvard Medical School, Boston, MA, USA*

## ABSTRACT

**Background:** The impact of an initially less invasive cardiac intervention on outcomes of future surgical spine procedures has been understudied; therefore, we sought to investigate the effect of coronary stents on postoperative outcomes in an elective spine fusion cohort.

**Methods:** Elective spine fusion patients were isolated with International Classification of Diseases-Ninth Edition and current procedural terminology procedure codes in the PearlDiver database. Patients were stratified by number of coronary stents: (1) 1 to 2 stents (ST12); (2) 3 to 4 stents (ST34); (3) no stents. Mean comparison tests compared differences in demographics, diagnoses, comorbidities, and 30-day and 90-day complication outcomes. Logistic regression assessed the odds of complications associated with coronary stents, controlling for levels fused, age, sex, and comorbidities (odds ratio [95% confidence interval]). Statistical significance was $P < 0.05$.

**Results:** A total of 726,061 elective spine fusion patients were isolated. Of those patients, 707,396 patients had no stent, 17,087 ST12, and 1578 ST34. At baseline (BL), ST12 patients had higher rates of morbid obesity, chronic kidney disease, congestive heart failure, chronic obstructive pulmonary disease, and diabetes mellitus compared with no stent and ST34 patients (all $P < 0.001$). Relative to no stent patients, ST12 patients had a longer length of stay and, at 30 days, significantly higher complication rates, including pneumonia, myocardial infarction (MI), sepsis, acute kidney injury, urinary tract infection (UTI), wound complications, transfusions, and 30-day readmissions ($P < 0.05$). Controlling for age, sex, comorbidities, and levels fused, ST12 was a significant predictor of MI within 30 days (OR 2.15 [95% CI 1.7–2.7], $P < 0.001$) and 90 days postoperatively (OR 1.87 [95% CI 1.6–2.2], $P < 0.001$). ST34 patients compared with no stent patients at 30 days presented with increased rates of complication, including pneumonia, MI, sepsis, UTI, wound complications, and 30-day readmissions. Regression analysis showed no significant differences in complications between ST12 vs ST34 at 30 days, but at 90 days, ST34 was associated with significantly increased rate and odds of death (1.1% vs 0.3%, $P = 0.021$; OR 1.94 [95% CI 1.13–3.13], $P = 0.01$).

**Conclusion:** Cardiac stents failed to normalize risk profile of patients with coronary artery disease. Postoperatively at 90 days, elective spine fusion patients with 3 or more stents were significantly at risk of mortality compared with patients with fewer or no stents.

**Level of Evidence:** 3.

Lumbar Spine

Keywords: stent, cardiac, risk, spine surgery, spine deformity

## INTRODUCTION

Elective spine surgery has been increasing in volume as new techniques and innovations allow for dramatic improvement in patient disability and pain.[1] Despite the rising prevalence, spine surgery remains an invasive intervention that is often associated with high rates of peri- and postoperative complications. With an aging population in the United States and a projected continued increase in spine surgery, there has been an increased focus in the literature investigating modalities to optimize patients for surgery and limit the high incidence complications.

One of the most common comorbidities affecting postoperative outcomes of spine surgery patients is coronary artery disease (CAD).[2] Often, patients will have a coronary stent placed to treat their heart condition and proceed with spine surgery. However, the impact of an initially less invasive cardiac intervention on outcomes of future surgical spine procedures is not fully understood. Previous literature has demonstrated that despite the success of lumbar spine surgery, there is an associated risk of cardiac complications, specifically myocardial infarctions (MIs).[3–5]

The aim of this study was to determine whether placement of a coronary stent normalizes the risk profile of patients undergoing elective spine fusion surgery. Additionally, we set out to determine whether increasing the level of intervention with multiple stent placements changed the risk of postoperative complications.

## MATERIALS AND METHODS

### Data Source

A retrospective database review was conducted utilizing the commercially available PearlDiver patient records database (www.pearldiverinc.com; PearlDiver Inc., Colorado Springs, CO, USA), which contains all Humana Private/Commercial and Medicare patients from 2006 to 2013, searchable by International Classification of Diseases, current procedural terminology, and national drug codes, among others(online supplementary file 1). Queried data are deidentified and Health Insurance Portability and Accountability Act of 1996 compliant; therefore, Institutional Review Board approval was waived for this study.

### Postoperative Outcomes Following Elective Spine Fusion Surgery

Patients were stratified by number of coronary stents placed preoperatively: (1) 1 to 2 stents (ST12); (2) 3 to 4 stents (ST34); and (3) no stents. The cohorts were evaluated for following 30-day and 90-day outcomes: pulmonary embolism, pneumonia, deep vein thrombosis, urinary tract infection (UTI), acute kidney injury, surgical wound disruption, hematoma, and need for transfusion. The following complications within 1 and 2 years of surgery were also analyzed: revision, hardware infection, and mechanical complications.

### Statistical Analysis

Pearson's $\chi^2$ analysis was used to compare all outcomes of interest in addition to baseline demographics and comorbidities. Multivariate logistic regression was used to determine the independent effect of increasing number of coronary stents had on postoperative outcomes after adjusting for age, gender, number of levels fused, and the following pre-existing comorbidities: obesity, chronic kidney disease (CKD), peripheral vascular disease, chronic obstructive pulmonary disease, diabetes mellitus (DM), hyperlipidemia, hypertension, CAD, congestive heart failure, depression, alcohol abuse, and tobacco use. All statistical analysis was performed using R Project for statistical computing, which is embedded in the PearlDiver software. Statistical significance was determined by a $P$ value <0.05.

## RESULTS

### Cohort Overview

A total of 726,061 elective spine fusion patients met inclusion criteria. Overall, 707,396 patients had no stent placed, 17,087 had 1 or 2 stents, and 1578 patients had 3 or 4 stents. Average age was between 70 and 74 years for ST12 and ST34 patients and between 65 to 69 years for control patients. Gender breakdown was 40% women for ST12, 35% women for ST34, and 58% women for the control groups. At baseline, the patients with 1 or 2 stents had significantly higher rates of morbid obesity (22.7% vs 20.4% vs 17.9%, $P$ < 0.001), CKD (21.1% vs 20.0% vs 13.6%, $P$ < 0.001), congestive heart failure (29.2% vs 26.2% vs 21.2%, $P$ < 0.001), chronic obstructive pulmonary disease (43.8% vs 37.8% vs 39.2%, $P$ < 0.001), and DM (50.6% vs 49.6% vs 45.3%, $P$ < 0.001) compared with patients with 3 to 4 stents and patients with no stent (Table 1).

### Surgical Overview

The control cohort had 550,669 (78%) of patients with 1- to 2-level fusions, 126,737 (18%) with 3- to 7-level fusions, and 5262 (0.7%) with >8-level fusions. The ST12 group had 13,143 (76.9%) with 1 to 2 levels fused, 3312 (19.4%) with 3 to 7 levels fused, and 84 (0.5%) with 8+ levels fused. ST34 group had 1195 (75.7%) of patients with 1 to 2 levels fused, 316 (20.0%) with 3 to 7 levels fused, and 10 (0.6%) with 8+ levels fused. Breakdown for the region of spine treated is as follows: for the ST12 group, 38% were cervical, 3% thoracolumbar, and 57% lumbosacral. For the ST34 group, 36.8% were cervical, 3.7% were thoracolumbar, and 59.7% were lumbosacral. For the control group, 37.5% were cervical, 3.6% were thoracolumbar, and 60.2% were lumbosacral. The rate of decompressions was 12.3% for the control group, 12.2% for the ST12 group, and 13.9% for the ST34 group. The rate of osteotomy usage was 0% for the control group, 0.1% for ST12, and 0% for ST34 (Table 1).

**Table 1.** Patient demographics.

| Demographic | 1–2 Stents *n* = 17,087 | 3–4 Stents *n* = 1578 | Control (No Stents) *n* = 707,396 | *P* Value |
|---|---|---|---|---|
| Age, y | | | | |
| <65 | 3087 (18.1%) | 263 (16.7%) | 198,451 (28.1%) | <0.001 |
| 65–69 | 3464 (20.3%) | 322 (20.4%) | 204,913 (29.0%) | |
| 70–74 | 4809 (28.1%) | 452 (28.6%) | 149,913 (21.2%) | |
| 75–79 | 3796 (22.2%) | 360 (22.8%) | 103,084 (14.6%) | |
| 80–84 | 1931 (11.3%) | 181 (11.5%) | 51,035 (7.2%) | |
| Sex | | | | |
| Male | 10,365 (60.7%) | 1031 (65.3%) | 297,591 (42.1%) | <0.001 |
| Female | 6722 (39.3%) | 547 (34.7%) | 409,805 (57.9%) | |
| Home discharge | 4524 (26.5%) | 408 (25.9%) | 172,938 (24.4%) | <0.001 |
| Comorbidities | | | | |
| Morbid obesity (BMI >30) | 3876 (22.7%) | 322 (20.4%) | 72,924 (10.3%) | <0.001 |
| PVD | 4877 (28.5%) | 459 (29.1%) | 44,211 (6.2%) | <0.001 |
| Chronic kidney disease | 3604 (21.1%) | 315 (20.0%) | 42,801 (6.1%) | <0.001 |
| CHF | 4989 (29.2%) | 413 (26.2%) | 50,449 (7.1%) | <0.001 |
| COPD | 7476 (43.8%) | 597 (37.8%) | 164,959 (23.3%) | <0.001 |
| Diabetes mellitus | 8641 (50.6%) | 783 (49.6%) | 184,501 (26.1%) | <0.001 |
| Hypertension | 16,381 (95.9%) | 1512 (95.8%) | 439,450 (62.1%) | <0.001 |
| Hyperlipidemia | 16,019 (93.7%) | 1483 (94.0%) | 359,138 (50.8%) | <0.001 |
| Substance Use | | | | |
| Alcohol | 755 (4.4%) | 65 (4.1%) | 22,456 (3.2%) | <0.001 |
| Smoking | 8718 (51.0%) | 790 (50.1%) | 171,370 (24.2%) | <0.001 |
| Surgical variables | | | | |
| 1–2 Levels fusion | 13,143 (76.9%) | 1195 (75.7%) | 550,669 (77.8%) | 0.002 |
| 3–7 Levels fusion | 3312 (19.4%) | 316 (20.0%) | 126,737 (17.9%) | <0.001 |
| 8+ Levels fusion | 84 (0.5%) | 10 (0.6%) | 5262 (0.7%) | 0.001 |
| Decompression | 2078 (12.2%) | 220 (13.9%) | 87,318 (12.3%) | 0.120 |
| Osteotomy | 10 (0.1%) | 0 (0.0%) | 320 (0.0%) | 0.505 |
| Anterior cervical | 5069 (29.7%) | 459 (29.1%) | 213,455 (30.2%) | 0.233 |
| Posterior cervical | 1134 (6.6%) | 107 (6.8%) | 41,787 (5.9%) | <0.001 |
| Combined cervical | 236 (1.4%) | 27 (1.7%) | 9031 (1.3%) | 0.152 |
| Anterior thoracolumbar | 30 (0.2%) | 3 (0.2%) | 2196 (0.3%) | 0.005 |
| Posterior thoracolumbar | 458 (2.7%) | 52 (3.3%) | 22,169 (3.1%) | 0.003 |
| Combined thoracolumbar | 18 (0.1%) | 3 (0.2%) | 1588 (0.2%) | 0.005 |
| Anterior lumbosacral | 512 (3.0%) | 42 (2.7%) | 24,080 (3.4%) | 0.004 |
| Posterior lumbosacral | 9208 (53.9%) | 845 (53.5%) | 374,636 (53.0%) | 0.050 |
| Combined lumbosacral | 537 (3.1%) | 56 (3.5%) | 27,110 (3.8%) | <0.001 |

Abbreviations: BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular disease.

**Table 2.** Length of stay, reimbursement, and hospital cost between patients with 1 to 2 stents and controls.

| Variable | 1–2 Stents (*n* = 17,087) | Control (*n* = 707,396) | *P* Value | 1–2 Stents vs Control, Adjusted $\beta$ (95% CI) | *P* Value |
|---|---|---|---|---|---|
| **LOS, d** | **4.19 ± 5.01** | **3.63 ± 4.30** | **<0.001** | **−0.16 (−0.22 ≤ $\beta$ ≤ −0.10)** | **<0.001** |
| **Total reimbursement** | **$23,346.41 ± $15,645.75** | **$21,534.89 ± $15,880.22** | **<0.001** | **−$723.34 (−959.22 ≤ $\beta$ ≤ −487.46)** | **<0.001** |
| Total hospital cost | $93,496.48 ± $81,354.38 | $87,427.30 ± $77,287.80 | <0.001 | $178.9 (−968.08 ≤ $\beta$ ≤ 1325.88) | 0.760 |

Abbreviations: LOS, length of stay; $\beta$, standardized beta coefficient.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

## Incidence of Complications Between Patients With 1 to 2 Stents and No Stents

Relative to patients with no stents, 1 or 2 stent patients experienced a greater length of stay (4.19 vs 3.63 days, $P < 0.001$), and at 30 days had significantly increased incidence of complication rates including pneumonia (1.1% vs 0.5%, $P < 0.001$), MI (0.5% vs 0.1%, $P < 0.001$), sepsis (0.7% vs 0.4%, $P < 0.001$), acute kidney injury (1.4% vs 0.6%, $P < 0.001$), UTI (2.6% vs 1.6%, $P < 0.001$), wound complications (2.2% vs 1.6%, $P < 0.001$), blood transfusions (1.3% vs 0.5%, $P < 0.001$), and 30-day readmissions (7.5% vs 4.2%, $P < 0.001$) (Table 2). Adjusting for age, sex, comorbidities, and levels fused, 1 or more coronary stents was a significant predictor of a MI within 30 days (OR 2.15 [95% CI 1.7–2.7] $P < 0.001$), with a rate of 0.5% in ST12 and 0.1% in the control group, as well as within 90 days postoperatively (OR 1.87 [95% CI 1.6–2.2], $P < 0.001$), with a rate of 1.4% for ST12 and 0.4% for the control group (Tables 3 and 4).

## Incidence of Complications Among Patients With 3 to 4 Stents

Patients with 3 or 4 stents compared with those with no coronary stent had increased rates of pneumonia, MI, sepsis, UTI, wound complication, and 30-day readmission (Table 5). The 90-d postoperative comparisons are provided in Table 6, and length of stay, reimbursement, and hospital cost comparisons are provided in Table 7.

**Table 3.** The 30-d postoperative outcomes between patients with 1 to 2 stents and controls.

| 30-d Medical Complications | 1–2 Stents (*n* = 17,087) | Control (*n* = 707,396) | *P* Value | 1–2 Stents vs Control, Adjusted OR (95% CI) | *P* Value |
|---|---|---|---|---|---|
| Major | | | | | |
| Pulmonary embolus | 64 (0.4%) | 1968 (0.3%) | 0.023 | 0.84 (0.65–1.08) | 0.189 |
| Pneumonia | 190 (1.1%) | 3775 (0.5%) | <0.001 | 0.97 (0.83–1.12) | 0.671 |
| CVA | 38 (0.2%) | 874 (0.1%) | <0.001 | 0.76 (0.54–1.04) | 0.105 |
| **MI** | **93 (0.5%)** | **776 (0.1%)** | **<0.001** | **2.15 (1.70–2.69)** | **<0.001** |
| Sepsis | 128 (0.7%) | 2760 (0.4%) | <0.001 | 0.91 (0.75–1.09) | 0.299 |
| Death | 33 (0.2%) | 601 (0.1%) | <0.001 | 0.94 (0.64–1.33) | 0.752 |
| Minor | | | | | |
| AKI | 235 (1.4%) | 4192 (0.6%) | <0.001 | 0.95 (0.83–1.09) | 0.495 |
| UTI | 446 (2.6%) | 11,275 (1.6%) | <0.001 | 0.94 (0.85–1.03) | 0.194 |
| Wound complications | 383 (2.2%) | 11,031 (1.6%) | <0.001 | 0.95 (0.86–1.06) | 0.381 |
| **Transfusion** | **221 (1.3%)** | **3776 (0.5%)** | **<0.001** | **1.25 (1.08–1.44)** | **0.002** |
| **DVT** | **83 (0.5%)** | **2962 (0.4%)** | **0.201** | **0.74 (0.58–0.91)** | **0.007** |
| 30-d Readmission | **1279 (7.5%)** | **29,761 (4.2%)** | **<0.001** | **1.09 (1.02–1.16)** | **0.006** |

Abbreviations: AKI, acute kidney injury; CVA, cerebrovascular accident; DVT, deep vein thrombosis; MI, myocardial infarction; UTI, urinary tract infection.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

**Table 4.** The 90-d postoperative outcomes between patients with 1 to 2 stents and controls.

| 90-d Medical Complications | 1–2 Stents (*n* = 17,087) | Control (*n* = 707,396) | *P* Value | 1–2 Stents vs Control, Adjusted OR (95% CI) | *P* Value |
|---|---|---|---|---|---|
| Major | | | | | |
| **Pulmonary embolus** | **124 (0.7%)** | **4599 (0.7%)** | **0.244** | **0.77 (0.63–0.91)** | **0.004** |
| Pneumonia | 469 (2.7%) | 10,617 (1.5%) | <0.001 | 0.95 (0.86–1.04) | 0.267 |
| CVA | 136 (0.8%) | 3160 (0.4%) | <0.001 | 0.87 (0.73–1.04) | 0.125 |
| **MI** | **232 (1.4%)** | **2518 (0.4%)** | **<0.001** | **1.87 (1.62–2.15)** | **<0.001** |
| Sepsis | 297 (1.7%) | 6664 (0.9%) | <0.001 | 0.96 (0.85–1.09) | 0.564 |
| Death | 105 (0.6%) | 2112 (0.3%) | <0.001 | 1.00 (0.81–1.22) | 0.984 |
| Minor | | | | | |
| AKI | 528 (3.1%) | 10,036 (1.4%) | <0.001 | 0.97 (0.88–1.06) | 0.533 |
| **UTI** | **1095 (6.4%)** | **32,952 (4.7%)** | **<0.001** | **0.90 (0.84–0.96)** | **0.001** |
| Wound complications | 667 (3.9%) | 20,181 (2.9%) | <0.001 | 0.99 (0.91–1.07) | 0.826 |
| Transfusion | 482 (2.8%) | 10,904 (1.5%) | <0.001 | 1.08 (0.98–1.19) | 0.098 |
| **DVT** | **210 (1.2%)** | **7484 (1.1%)** | **0.034** | **0.76 (0.66–0.88)** | **<0.001** |
| **90-d Readmission** | **2605 (15.2%)** | **67,366 (9.5%)** | **<0.001** | **1.11 (1.06–1.16)** | **<0.001** |

Abbreviations: AKI, acute kidney injury; CVA, cerebrovascular accident; DVT, deep vein thrombosis; MI, myocardial infarction; UTI, urinary tract infection.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

**Table 5.** The 30-d postoperative outcomes between patients with 3 to 4 stents and controls.

| 30-d Medical Complications | 3–4 Stents (*n* = 1578) | Control (*n* = 707,396) | *P* Value | 3-4 Stents vs Control, Adjusted OR (95% CI) | *P* Value |
|---|---|---|---|---|---|
| Major | | | | | |
| Pulmonary embolus | 5 (0.3%) | 1968 (0.3%) | 0.959 | 0.71 (0.25–1.53) | 0.439 |
| Pneumonia | 16 (1.0%) | 3775 (0.5%) | 0.015 | 0.90 (0.52–1.43) | 0.680 |
| CVA | 3 (0.2%) | 874 (0.1%) | 0.694 | 0.66 (0.16–1.72) | 0.472 |
| **MI** | **9 (0.6%)** | **776 (0.1%)** | **<0.001** | **2.26 (1.08–4.14)** | **0.016** |
| Sepsis | 17 (1.1%) | 2760 (0.4%) | <0.001 | 1.33 (0.79–2.09) | 0.242 |
| Death | 2 (0.1%) | 601 (0.1%) | 0.891 | 0.62 (0.10–1.93) | 0.497 |
| Minor | | | | | |
| AKI | 15 (1.0%) | 4192 (0.6%) | 0.092 | 0.67 (0.38–1.07) | 0.123 |
| UTI | 42 (2.7%) | 11,275 (1.6%) | 0.001 | 1.00 (0.72–1.34) | 0.979 |
| Wound complications | 36 (2.3%) | 11,031 (1.6%) | 0.027 | 0.99 (0.70–1.37) | 0.975 |
| Transfusion | 23 (1.5%) | 3776 (0.5%) | <0.001 | 1.46 (0.94–2.16) | 0.075 |
| DVT | 7 (0.4%) | 2962 (0.4%) | 1 | 0.67 (0.29–1.31) | 0.300 |
| 30-d Readmission | 108 (6.8%) | 29,761 (4.2%) | <0.001 | 1.00 (0.82–1.22) | 0.985 |

Abbreviations: AKI, acute kidney injury; CVA, cerebrovascular accident; DVT, deep vein thrombosis; MI, myocardial infarction; UTI, urinary tract infection.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

### 1 to 2 Coronary Stents vs 3 to 4 Coronary Stents

Adjusting age, sex, comorbidities, and levels fused, there were no significant differences at 30 days postoperative between 1 to 2 stent and 3 to 4 stent cohorts (Table 8). However, at 90 days, 3 to 4 stents were associated with significantly increased odds of death (OR: 1.94 [1.13–3.13], $P = 0.01$) (Table 9). Length of stay, reimbursement, and hospital cost comparisons are provided in Table 10.

## DISCUSSION

Elective spine surgery has increased in prevalence recently as advances in the field have allowed patients to improve significantly clinically and show marked reduction in pain and disability.[6] Despite the increased surgical volume and achievement of successful patient outcomes, spine surgery remains an invasive procedure with high risk of complications. Focusing on optimizing

**Table 6.** The 90-d postoperative outcomes between patients with 3 to 4 stents and controls.

| 90-d Medical Complications | 3–4 Stents (*n* = 1578) | Control (*n* = 707,396) | *P* Value | 3–4 Stents vs Control, Adjusted OR (95% CI) | *P* Value |
|---|---|---|---|---|---|
| Major | | | | | |
| Pulmonary embolus | 12 (0.8%) | 4599 (0.7%) | 0.698 | 0.81 (0.43–1.36) | 0.460 |
| Pneumonia | 44 (2.8%) | 10,617 (1.5%) | <0.001 | 0.99 (0.72–1.33) | 0.953 |
| CVA | 11 (0.7%) | 3160 (0.4%) | 0.194 | 0.77 (0.40–1.33) | 0.392 |
| **MI** | **26 (1.6%)** | **2518 (0.4%)** | **<0.001** | **2.26 (1.49–3.28)** | **<0.001** |
| Sepsis | 35 (2.2%) | 6664 (0.9%) | <0.001 | 1.25 (0.87–1.73) | 0.195 |
| **Death** | **18 (1.1%)** | **2112 (0.3%)** | **<0.001** | **1.88 (1.13–2.93)** | **0.009** |
| Minor | | | | | |
| AKI | 50 (3.2%) | 10,036 (1.4%) | <0.001 | 1.02 (0.76–1.35) | 0.868 |
| UTI | 107 (6.8%) | 32,952 (4.7%) | <0.001 | 1.00 (0.81–1.22) | 0.997 |
| Wound complications | 55 (3.5%) | 20,181 (2.9%) | 0.152 | 0.90 (0.68–1.17) | 0.456 |
| Transfusion | 48 (3.0%) | 10,904 (1.5%) | <0.001 | 1.20 (0.89–1.59) | 0.215 |
| DVT | 18 (1.1%) | 7484 (1.1%) | 0.843 | 0.71 (0.43–1.10) | 0.151 |
| 90-d Readmission | 220 (13.9%) | 67,366 (9.5%) | <0.001 | 1.01 (0.87–1.17) | 0.889 |

Abbreviations: AKI, acute kidney injury; CVA, cerebrovascular accident; DVT, deep vein thrombosis; MI, myocardial infarction; UTI, urinary tract infection.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

**Table 7.** Length of stay, reimbursement, and hospital cost between patients with 3 to 4 stents and controls.

| Variable | 3–4 Stents (*n* = 1578) | Control (*n* = 707,396) | *P* Value | 3–4 Stents vs Control, Adjusted $\beta$ (95% CI) | *P* Value |
|---|---|---|---|---|---|
| LOS, d | 4.41 ± 4.80 | 3.63 ± 4.30 | <0.001 | 0.09 ($-0.12 \leq \beta \leq 0.29$) | 0.404 |
| Total reimbursement | $24,482.56 ± $16,592.60 | $21,534.89 ± $15,880.22 | <0.001 | $449.88 ($-301.56 \leq \beta \leq 1201.32$) | 0.241 |
| Total hospital cost | $93,435.13 ± $79,140.99 | $87,427.30 ± $77,287.80 | 0.003 | $18.82 ($-3629.25 \leq \beta \leq 3666.89$) | 0.992 |

Abbreviations: LOS, length of stay; $\beta$, standardized beta coefficient.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

**Table 8.** The 30-d postoperative outcomes between patients with 3 to 4 stents and 1 to 2 stents.

| 30-d Medical Complications | 3–4 Stent (*n* = 1578) | 1–2 Stent (*n* = 17,087) | *P* Value | 3–4 Stents vs 1–2 Stents, Adjusted OR (95% CI) | *P* Value |
|---|---|---|---|---|---|
| Major | | | | | |
| Pulmonary embolus | 5 (0.3%) | 64 (0.4%) | 0.885 | 0.81 (0.28–1.84) | 0.662 |
| Pneumonia | 16 (1.0%) | 190 (1.1%) | 0.818 | 0.93 (0.53–1.51) | 0.787 |
| CVA | 3 (0.2%) | 38 (0.2%) | 1 | 0.86 (0.21–2.39) | 0.803 |
| MI | 9 (0.6%) | 93 (0.5%) | 1 | 1.06 (0.50–2.00) | 0.863 |
| Sepsis | 17 (1.1%) | 128 (0.7%) | 0.204 | 1.48 (0.86–2.40) | 0.131 |
| Death | 2 (0.1%) | 33 (0.2%) | 0.780 | 0.68 (0.11–2.23) | 0.592 |
| Minor | | | | | |
| AKI | 15 (1.0%) | 235 (1.4%) | 0.197 | 0.71 (0.40–1.15) | 0.194 |
| UTI | 42 (2.7%) | 446 (2.6%) | 0.968 | 1.07 (0.77–1.46) | 0.672 |
| Wound complications | 36 (2.3%) | 383 (2.2%) | 0.989 | 1.05 (0.72–1.45) | 0.816 |
| Transfusion | 23 (1.5%) | 221 (1.3%) | 0.665 | 1.16 (0.73–1.76) | 0.500 |
| DVT | 7 (0.4%) | 83 (0.5%) | 0.967 | 0.90 (0.38–1.81) | 0.784 |
| 30-d Readmission | 108 (6.8%) | 1279 (7.5%) | 0.379 | 0.93 (0.75–1.14) | 0.496 |

Abbreviations: AKI, acute kidney injury; CVA, cerebrovascular accident; DVT, deep vein thrombosis; MI, myocardial infarction; UTI, urinary tract infection.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

**Table 9.** The 90-d postoperative outcomes between patients with 3 to 4 stents and 1 to 2 stents.

| 90-d Medical Complications | 3–4 Stents (*n* = 1578) | 1–2 Stents (*n* = 17,087) | *P* Value | 3–4 Stents vs 1–2 Stents, Adjusted OR (95% CI) | *P* Value |
|---|---|---|---|---|---|
| Major | | | | | |
| Pulmonary embolus | 12 (0.8%) | 4599 (0.7%) | 1 | 1.06 (0.55–1.85) | 0.843 |
| Pneumonia | 44 (2.8%) | 10,617 (1.5%) | 0.983 | 1.05 (0.76–1.43) | 0.752 |
| CVA | 11 (0.7%) | 3160 (0.4%) | 0.782 | 0.89 (0.45–1.58) | 0.717 |
| MI | 26 (1.6%) | 2518 (0.4%) | 0.406 | 1.23 (0.80–1.82) | 0.324 |
| Sepsis | 35 (2.2%) | 6664 (0.9%) | 0.201 | 1.31 (0.90–1.85) | 0.137 |
| **Death** | **18 (1.1%)** | **2112 (0.3%)** | **0.021** | **1.94 (1.13–3.13)** | **0.010** |
| Minor | | | | | |
| AKI | 50 (3.2%) | 10,036 (1.4%) | 0.923 | 1.07 (0.79–1.43) | 0.650 |
| UTI | 107 (6.8%) | 32,952 (4.7%) | 0.601 | 1.13 (0.91–1.38) | 0.266 |
| Wound complications | 55 (3.5%) | 20,181 (2.9%) | 0.450 | 0.91 (0.68–1.20) | 0.518 |
| Transfusion | 48 (3.0%) | 10,904 (1.5%) | 0.670 | 1.12 (0.82–1.50) | 0.467 |
| DVT | 18 (1.1%) | 7484 (1.1%) | 0.853 | 0.93 (0.55–1.47) | 0.768 |
| 90-d Readmission | 220 (13.9%) | 67,366 (9.5%) | 0.178 | 0.92 (0.79–1.07) | 0.289 |

Abbreviations: AKI, acute kidney injury; CVA, cerebrovascular accident; DVT, deep vein thrombosis; MI, myocardial infarction; UTI, urinary tract infection.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

**Table 10.** Length of stay, reimbursement, and hospital cost between patients with 3 to 4 stents and 1 to 2 stents.

| Variable | 3–4 Stents $n$ = 1578 | 1–2 Stents $n$ = 17,087 | $P$ Value | 3–4 Stents vs 1–2 Stents, Adjusted $\beta$ (95% CI) | $P$ Value |
|---|---|---|---|---|---|
| **LOS, d** | **4.41 ± 4.80** | **4.19 ± 5.01** | **0.081** | **0.27 (0.03 ≤ $\beta$ ≤ 0.52)** | **0.031** |
| **Total reimbursement** | **$24,482.56 ± $16,592.60** | **$23,346.41 ± $15,645.75** | **0.009** | **$1182.80 (405.47 ≤ $\beta$ ≤ 1960.13)** | **0.003** |
| Total hospital cost | $93,435.13 ± $79,140.99 | $93,496.48 ± $81,354.38 | 0.977 | −$211.60 (−4218.99 ≤ $\beta$ ≤ 3795.79) | 0.918 |

Abbreviations: LOS, length of stay; $\beta$, standardized beta coefficient.
*Note*: Values in bold denote statistical significance determined by $P < 0.05$.

patients for surgery and minimizing risk, a thorough understanding of a patient's previous medical history may be advantageous to the continued improvement of postoperative outcomes.

With cardiac disease being one of the most predominant comorbidities in the United States, spine surgery on these patients may present additional postoperative challenges.[7] After noncardiac surgery, a perioperative cardiac event is the most prominent cause of mortality.[2,8,9] In a recent study by Harwin et al, the authors demonstrated MIs after lumbar fusion surgeries were significantly greater compared with nonfusion lumbar procedures.[3] The authors speculated that due to the complexity and invasiveness of spine fusion surgery as well as the increased incidence of baseline risk factors, a spine fusion cohort may be at higher risk of MIs. Previous literature has also suggested that cardiac complications among patients undergoing lumbar procedures can range from 0.2% to 13%.[4,8,10–13]

To optimize patients for surgery and possibly prevent future cardiac complications, coronary revascularization is a common intervention for patients with CAD.[14] Specifically, percutaneous coronary interventions have become the predominant method of revascularization for patients with CAD.[14] However, there is a paucity of evidence on the impact of a previous history coronary stenting on patients undergoing invasive procedures in the future, such as spine surgery. With spine surgery patients often being older and presenting with a higher comorbidity burden, our study focused on the impact of coronary stents on postoperative outcomes in an elective spine fusion cohort.

Our study determined that patients with previous history of coronary stent also presented with higher rates of other comorbidities such as obesity, DM, and CKD. Additionally, coronary intervention was significantly associated with a postoperative MI and increased incidence of complications such as pneumonia, sepsis, UTIs, wound complications, and hospital readmissions within 30 days. Furthermore, relative to patients with CAD and no intervention, coronary stents continued to be significantly associated MIs postoperatively. As spine surgeons continue to take on more challenging cases and the field of spine surgery advances, our study is one of the first assessing how prior treatment of CAD can impact future surgical outcomes.

This study had several limitations that are characteristic of large database analysis. Utilizing a national database, the conclusions and accuracy of results are dependent on correct inputting and recording of data. Furthermore, the reliance on current procedural terminology and International Classification of Diseases-Ninth Edition coding may result in bias as the inclusion of these patients is dependent on institution-dependent coding procedures. Cognizant of these limitations, the ability to longitudinally track patients preoperative and postoperative in a temporal fashion while assessing incidence of complications has value. As one of the first studies to longitudinally follow spine surgery patients with previous history of coronary artery intervention, we believe our findings will be beneficial to the discussion of minimizing complications in the field of spine and patient optimization.

## CONCLUSION

Cardiac stents failed to normalize risk profile of patients with CAD. Postoperatively at 90 days, elective spine fusion patients with 3 or more stents were significantly at risk of mortality compared to patients with fewer or no stents.

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**Corresponding Author:** Peter Passias, Division of Spinal Surgery, Departments of Orthopedic and Neurological Surgery, New York Spine Institute, NYU Langone Medical Center, Orthopedic Hospital – NYU School of Medicine, 301 E 17th St, New York, NY 10003, USA; Peter.Passias@nyumc.org

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