

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

Waleed Ahmad, Joshua Bell, Oscar Krol, Lara Passfall, Pramod Kamalopathy, Bailey Imbo, Peter Tretiakov, Tyler Williamson, Rachel Joujon-Roche, Kevin Moattari, Nicholas Kummer, Shaleen Vira, Virginie Lafage, Carl Paulino, Andrew J. Schoenfeld, Bassel Diebo, Hamid Hassanzadeh and Peter Passias

Int J Spine Surg published online 7 February 2023
<https://www.ijssurgery.com/content/early/2023/02/03/8392>

This information is current as of May 23, 2025.

Email Alerts Receive free email-alerts when new articles cite this article. Sign up at:
<http://ijssurgery.com/alerts>

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

WALEED AHMAD, MS¹; JOSHUA BELL, MD²; OSCAR KROL, BA¹; LARA PASSFALL, BS¹;
PRAMOD KAMALAPATHY, BS²; BAILEY IMBO, BA¹; PETER TRETIKOV, BS¹; TYLER WILLIAMSON, MS¹;
RACHEL JOUJON-ROCHE, BS¹; KEVIN MOATTARI, BS¹; NICHOLAS KUMMER, BS¹; SHALEEN VIRA, MD³;
VIRGINIE LAFAGE, PhD⁴; CARL PAULINO, MD⁵; ANDREW J. SCHOENFELD, MD, MSc⁶; BASSEL DIEBO, MD⁵;
HAMID HASSANZADEH, MD²; AND PETER PASSIAS, MD¹

¹Departments of Orthopedic and Neurologic Surgery, NYU Langone Orthopedic Hospital; New York Spine Institute, New York, NY, USA; ²Department of Orthopedics, University of Virginia School of Medicine, Charlottesville, VA, USA; ³Department of Orthopedics, UT Southwestern Medical Center, Dallas, TX, USA; ⁴Department of Orthopaedics, Lenox Hill Hospital, Northwell Health, New York, NY, USA; ⁵Department of Orthopedics, SUNY Downstate Medical Center, Brooklyn, New York, NY, USA; ⁶Department 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.pearliverinc.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 χ^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 <i>n</i> = 17,087	3–4 Stents <i>n</i> = 1578	Control (No Stents) <i>n</i> = 707,396	<i>P</i> 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 (<i>n</i> = 17,087)	Control (<i>n</i> = 707,396)	<i>P</i> Value	1–2 Stents vs Control, Adjusted β (95% CI)	<i>P</i> Value
LOS, d	4.19 ± 5.01	3.63 ± 4.30	<0.001	–0.16 (–0.22 ≤ β ≤ –0.10)	<0.001
Total reimbursement	\$23,346.41 ± \$15,645.75	\$21,534.89 ± \$15,880.22	<0.001	–\$723.34 (–959.22 ≤ β ≤ –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 ≤ β ≤ 1325.88)	0.760

Abbreviations: LOS, length of stay; β , 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 β (95% CI)	P Value
LOS, d	4.41 $\pm$ 4.80	3.63 $\pm$ 4.30	<0.001	0.09 (–0.12 $\leq \beta \leq$ 0.29)	0.404
Total reimbursement	\$24,482.56 $\pm$ \$16,592.60	\$21,534.89 $\pm$ \$15,880.22	<0.001	\$449.88 (–301.56 $\leq \beta \leq$ 1201.32)	0.241
Total hospital cost	\$93,435.13 $\pm$ \$79,140.99	\$87,427.30 $\pm$ \$77,287.80	0.003	\$18.82 (–3629.25 $\leq \beta \leq$ 3666.89)	0.992

Abbreviations: LOS, length of stay; β , 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 β (95% CI)	P Value
LOS, d	4.41 $\pm$ 4.80	4.19 $\pm$ 5.01	0.081	0.27 (0.03 $\leq \beta \leq$ 0.52)	0.031
Total reimbursement	\$24,482.56 $\pm$ \$16,592.60	\$23,346.41 $\pm$ \$15,645.75	0.009	\$1182.80 (405.47 $\leq \beta \leq$ 1960.13)	0.003
Total hospital cost	\$93,435.13 $\pm$ \$79,140.99	\$93,496.48 $\pm$ \$81,354.38	0.977	–\$211.60 (–4218.99 $\leq \beta \leq$ 3795.79)	0.918

Abbreviations: LOS, length of stay; β , 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.

REFERENCES

1. Fineberg SJ, Ahmadinia K, Patel AA, Oglesby M, Singh K. Incidence and mortality of cardiac events in lumbar spine surgery. *Spine (Phila Pa 1976)*. 2013;38(16):1422–1429. doi:10.1097/BRS.0b013e3182986d71
2. Faciszewski T, Jensen R, Rokey R, Berg R. Cardiac risk stratification of patients with symptomatic spinal stenosis. *Clinical Orthopaedics and Related Research*. 2001;384:110–115. doi:10.1097/00003086-200103000-00013
3. Harwin B, Formanek B, Spoonamore M, Robertson D, Buser Z, Wang JC. The incidence of myocardial infarction after lumbar spine surgery. *Eur Spine J*. 2019;28(9):2070–2076. https://doi.org/10.1007/s00586-019-06072-4. doi:10.1007/s00586-019-06072-4
4. Lee MJ, Konodi MA, Cizik AM, Bransford RJ, Bellabarba C, Chapman JR. Risk factors for medical complication after spine surgery: a multivariate analysis of 1,591 patients. *Spine J*. 2012;22(3):197–206. https://doi.org/10.1016/j.spinee.2011.11.008. doi:10.1016/j.spinee.2011.11.008

5. Thompson JS, Baxter BT, Allison JG, Johnson FE, Lee KK, Park WY. Temporal patterns of postoperative complications. *Arch Surg*. 2003;138(6):596–602. <https://doi.org/10.1001/archsurg.138.6.596>. doi:10.1001/archsurg.138.6.596
6. Rajaei SS, Bae HW, Kanim LEA, Delamarter RB. Spinal fusion in the united states: analysis of trends from 1998 to 2008. *Spine (Phila Pa 1976)*. 2012;37(1):67–76. <https://doi.org/10.1097/BRS.0b013e31820cccfb>. doi:10.1097/BRS.0b013e31820cccfb
7. Yazdanyar A, Newman AB. The burden of cardiovascular disease in the elderly: morbidity, mortality, and costs. *Clin Geriatr Med*. 2009;25(4):563–577. <https://doi.org/10.1016/j.cger.2009.07.007>. doi:10.1016/j.cger.2009.07.007
8. Lee DY, Lee S-H, Jang J-S. Risk factors for perioperative cardiac complications after lumbar fusion surgery. *Neurol Med Chir (Tokyo)*. 2007;47(11):495–500. doi:10.2176/nmc.47.495
9. Hertzner NR, Beven EG, Young JR, et al. Coronary artery disease in peripheral vascular patients. A classification of 1000 coronary angiograms and results of surgical management. *Ann Surg*. 1984;199(2):223–233. <https://doi.org/10.1097/00000658-198402000-00016>. doi:10.1097/00000658-198402000-00016
10. Schoenfeld AJ, Ochoa LM, Bader JO, Belmont PJJ. Risk factors for immediate postoperative complications and mortality following spine surgery: a study of 3475 patients from the national surgical quality improvement program. *J Bone Joint Surg Am*. 2011;93(17):1577–1582. doi:10.2106/JBJS.J.01048
11. Lee MJ, Hacquebord J, Varshney A, et al. Risk factors for medical complication after lumbar spine surgery: a multivariate analysis of 767 patients. *Spine (Phila Pa 1976)*. 2011;36(21):1801–1806. doi:10.1097/brs.0b013e318219d28d
12. Yadla S, Malone J, Campbell PG, et al. Early complications in spine surgery and relation to preoperative diagnosis: a single-center prospective study. *J Neurosurg Spine*. 2010;13(3):360–366. <https://doi.org/10.3171/2010.3.SPINE09806>. doi:10.3171/2010.3.SPINE09806
13. Carreon LY, Puno RM, Dimar JR 2nd, Glassman SD, Johnson JR. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. *J Bone Joint Surg Am*. 2003;85(11):2089–2092. doi:10.2106/00004623-200311000-00004
14. Mack MJ, Brown PP, Kugelmass AD, et al. Current status and outcomes of coronary revascularization 1999 to 2002: 148,396 surgical and percutaneous procedures. *Ann Thorac Surg*. 2004;77(3):761–766. <https://doi.org/10.1016/j.athoracsur.2003.06.019>. doi:10.1016/j.athoracsur.2003.06.019

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The authors report no conflicts of interest in this work.

Disclosures: Virginie LaFage reports royalties/licenses for Nuvasive; consulting for Alphatec Spine and Globus Medical; paid presenter or speaker for DuPuy and Stryker, and leadership roles for Scoliosis Research Society, International Spine Study Group, and European Spine Journal. Carl B. Paulino reports consulting fees from DePuy. Andrew J. Schoenfeld reports publishing royalties from Springer and Wolters Kluwer Health and leadership positions for AAOS, *Journal of Bone and Joint Surgery*, North American Spine Society, and *Spine*. Hamid Hassanzadeh reports consulting fees from DePuy, Medtronic, and Nuvasive; a leadership role with the Scoliosis Research Society; stock/stock options from 4Web and Nuvasive; research support from Medtronic, Orthofix Inc, and Pfizer; and paid presenter/speaker for Medtronic, Nuvasive, and Orthofix Inc. Peter Passias reports consulting fees from Medtronic, Royal Biologics, SpineWave, and Terumo; paid presenter/speaker for Globus Medical; research support from the Cervical Scoliosis Research Society; leadership role with Spine; and other financial or material support from Cerapedics and Spinevision. The remaining authors have nothing to disclose.

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

This manuscript is generously published free of charge by ISASS, the International Society for the Advancement of Spine Surgery. Copyright © 2023 ISASS. To see more or order reprints or permissions, see <http://ijssurgery.com>.