

Impact of congestive heart failure on patients undergoing lumbar spine fusion for adult spine deformity

ABSTRACT

Background: With the increasing amount of elective spine fusion patients presenting with cardiac disease and congestive heart failure, it is becoming difficult to assess when it is safe to proceed with surgery. Assessing the severity of heart failure (HF) through ejection fraction may provide insight into patients' short- and long-term risks.

Purpose: The purpose of this study was to assess the severity of HF on perioperative outcomes of spine fusion surgery patients.

Study Design/Setting: This was a retrospective cohort study of the PearlDiver database.

Patient Sample: We enrolled 670,526 patients undergoing spine fusion surgery.

Outcome Measures: Thirty-day and 90-day complication rates, discharge destination, length of stay (LOS), physician reimbursement, and hospital costs.

Methods: Patients undergoing elective spine fusion surgery were isolated and stratified by preoperative HF with preserved ejection fraction (P-EF) or reduced ejection fraction (R-EF) (International Classification of Diseases-9: 428.32 [chronic diastolic HF] and 428.22 [chronic systolic HF]). Means comparison tests (Chi-squared and independent samples *t*-tests, as appropriate) compared differences in demographics, diagnoses, comorbidities, procedural characteristics, LOS, 30-day and 90-day complication outcomes, and total hospital charges between those diagnosed with P-EF and those not R-EF. Binary logistic regression assessed the odds of complication associated with HF, controlling for levels fused (odds ratio [OR] [95% confidence interval]). Statistical significance was set at $P < 0.05$.

Results: Totally 670,526 elective spine fusion patients were included. Four thousand and seventy-seven were diagnosed with P-EF and 2758 R-EF. Overall, P-EF patients presented with higher rates of morbid obesity, chronic kidney disease, chronic obstructive pulmonary disease, diabetes mellitus, and hypertension (all $P < 0.001$). In relation to No-HF, P-EF patients had higher rates of 30-day major complications including pulmonary embolism, pneumonia, cerebrovascular accident (CVA), myocardial infarctions (MI), sepsis, and death (all $P < 0.001$). Furthermore, P-EF was associated significantly with increased odds of pneumonia (OR: 2.07 [1.64–2.56], $P < 0.001$) and sepsis (OR: 2.09 [1.62–2.66], $P < 0.001$). Relative to No-HF, R-EF was associated with significantly higher odds of MI (OR: 3.66 [2.34–5.47]), CVA (OR: 2.70 [1.67–4.15]), and pneumonia (OR: 1.85 [1.40–2.40]) (all $P < 0.001$) postoperative within 30 days. Adjusting for prior history of MI, CAD, and the presence


OLUWATOBI O. ONAFOWOKAN, WALEED AHMAD, KIMBERLY MCFARLAND, TYLER K. WILLIAMSON, PETER TRETIKOV, JAMSHAD M. MIR, ANKITA DAS, JOSHUA BELL¹, SARA NAESSIG, SHALEEN VIRI², VIRGINIE LAFAGE³, CARL PAULINO⁴, BASSEL DIEBO⁵, ANDREW SCHOENFELD⁶, HAMID HASSANZADEH¹, PAWEL P. JANKOWSKI⁷, AARON HOCKLEY⁸, PETER GUST PASSIAS

Department of Orthopedic and Neurologic Surgery, New York Spine Institute, NYU Langone Orthopedic Hospital, ³Department of Orthopedics, Hospital for Special Surgery, New York, ⁴Department of Orthopedics, SUNY Downstate Medical Center, Brooklyn, New York, ¹Department of Orthopedics, University of Virginia School of Medicine, Charlottesville, VA, ²Department of Orthopedics, UT Southwestern Medical Center, Dallas, TX, ⁵Department of Orthopedics, Warren Alpert Medical School of Brown University, RI, ⁶Department of Orthopedics, Harvard Medical School, Boston, MA, ⁷Department of Neurosurgery, Hoag Neurosciences Institute, Irvine, CA, ⁸Department of Neurosurgery, University of Alberta, Calgary, Canada

Address for correspondence: Dr. Peter Gust Passias, 301 East 17th St., New York, NY 10003, USA.
E-mail: pgpassias@yahoo.com

Submitted: 29-Dec-23
Published: 13-Mar-24

Accepted: 31-Dec-23

Access this article online	
Website: www.jcvjs.com	Quick Response Code 
DOI: 10.4103/jcvjs.jcvjs_186_23	

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Onafowokan OO, Ahmad W, McFarland K, Williamson TK, Tretiakov P, Mir JM, *et al.* Impact of congestive heart failure on patients undergoing lumbar spine fusion for adult spine deformity. *J Craniovert Jun Spine* 2024;15:45-52.

of a pacemaker R-EF was a significant predictor of an MI 30 days postoperatively (OR: 2.2 [1.14–4.32], $P = 0.021$). Further adjusting for history of CABG or stent placement, R-EF was associated with higher odds of CVA (OR: 2.11 [1.09–4.19], $P = 0.028$) and MI (OR: 2.27 [1.20–4.43], $P = 0.013$).

Conclusions: When evaluating the severity of HF before spine surgery, R-EF was associated with a higher risk of major complications, especially the occurrence of a myocardial infarction 30 days postoperatively. During preoperative risk assessment, congestive HF should be considered thoroughly when thinking of postoperative outcomes with emphasis on R-EF.

Keywords: Congestive heart failure, spine deformity, spine surgery

INTRODUCTION

Heart failure (HF) describes a pathological state of the heart characterized by the impairment of ventricular filling or ejection of blood due to structural or functional etiologies.^[1] HF with preserved ejection fraction (P-EF), or diastolic HF, is characterized by signs and symptoms of HF (e.g., dyspnea and shortness of breath) and normal left ventricular ejection fraction greater than 50%.^[2,3] Conversely, HF with reduced ejection fraction (R-EF), or systolic HF, denotes HF symptoms with an ejection fraction <50%.

Surgical intervention for adult spine deformity (ASD) has demonstrated beneficial outcomes in affected patients with regard to improved alignment, health-related quality of life metrics, and reduction of disability burden.^[4,5] As the frequency of ASD-corrective surgery has increased, so has the concern for potential perioperative complications. HF has been reported to have a prevalence of up to 17.7% in hospitalized patients above 65 years of age in the United States,^[6] with a projected prevalence of 33% in the general population by 2060.^[7] Patients with cardiac comorbidities such as angina and myocardial infarction have demonstrated worse outcomes following spine surgery.^[8] The impact of HF, specifically in this cohort of patients, remains unknown however.

While previous studies analyzed the incidence of cardiac events as a complication associated with lumbar spine surgery,^[9,10] there is a paucity in the literature assessing the influence of HF in ASD patients. Within this context, this study aimed to investigate the impact of preoperative HF on perioperative outcomes in patients undergoing ASD-corrective surgery.

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 (ICD) and current procedural terminology (CPT). Queried data are de-identified and HIPAA compliant; therefore, institutional review board approval was waived for this study.

Study population

The study population included all Humana patients from the years 2006 to 2013 aged 18–85 years who underwent elective fusion for adult spinal deformity [Appendix 1]. Patients with a history of spine trauma, infection, or neoplasm were excluded from the population using ICD-9-CM diagnostic codes [Appendix 1]. Patients were stratified by preoperative HF with P-EF and R-EF (ICD-9: 428.32 [chronic diastolic HF] and 428.22 [chronic systolic HF]). The control group consisted of patients without a diagnosis of congestive HF or any previous cardiac history.

Postoperative outcomes following fusion

Study groups were evaluated for the following 30-day and 90-day outcomes: pulmonary embolism (PE), pneumonia (PNA), cerebrovascular accident (CVA), myocardial infarction (MI), sepsis, death, deep vein thrombosis, urinary tract infection, acute kidney injury, surgical wound disruption, and need for transfusion [Appendix 2]. The following data were also analyzed: emergency department (ED) visits, readmission, length of stay (LOS), total reimbursement, and total hospital cost.

Statistical analysis

Means comparison tests (Chi-squared and independent samples t-tests, as appropriate) compared differences in demographics, diagnoses, comorbidities, procedural characteristics, LOS, 30-day and 90-day complication outcomes, and total hospital charges between those diagnosed with P-EF and those with R-EF. Binary logistic regression assessed the odds of complication associated with HF, controlling for levels fused (odds ratio [95% confidence interval]). Statistical significance was set at $P < 0.05$.

RESULTS

Cohort overview

Totally 670,526 elective spine fusion patients met the inclusion criteria. Four thousand and seventy-seven were

diagnosed with P-EF and 2758 R-EF. At baseline, P-EF patients presented with higher rates of morbid obesity, chronic kidney disease, chronic obstructive pulmonary disease, diabetes mellitus, and hypertension (all $P < 0.001$) [Table 1].

Postoperative incidence of complications

In relation to No-HF (control), P-EF patients had higher rates of 30-day major complications including PE, pneumonia, CVA, MI, sepsis, and death (all $P < 0.001$). Furthermore, P-EF was associated significantly with increased adjusted odds of pneumonia, sepsis, and death (all $P < 0.05$) [Table 2]. Similar trends were seen for R-EF patients [Table 3]. With relation to P-HF, R-EF patients had higher rates of 30-day major complications including CVA and MI (both $P < 0.05$). Furthermore, R-EF was associated significantly with increased adjusted odds of CVA and MI (both $P < 0.05$) R-EF patients also had significantly higher adjusted odds of ED visits and readmissions (both $P < 0.05$) [Table 4].

For 90-day complication rates, significant trends were seen for the vast majority of the postoperative complication domains [Tables 5 and 6]. In relation to P-HF, R-EF patients had similar rates of 90-day major complications (all $P > 0.05$) [Table 7].

Assessing hospital LOS and costs in relation to No-HF, P-EF, and R-EF patients had higher LOS, total reimbursement,

and total hospital cost (all $P < 0.001$). Furthermore, P-EF was associated significantly with increased adjusted odds of LOS, total reimbursement, and total hospital cost (all $P < 0.001$) [Tables 8 and 9]. There were no differences in LOS and costs between P-EF and R-EF (all $P > 0.05$) [Table 10].

DISCUSSION

This study aimed to identify perioperative outcomes in individuals with HF undergoing elective spinal fusion. It was determined that complication rates for all HF patients were increased following the procedure. More specifically, even patients with P-EF were more likely to experience PE, pneumonia, CVA, myocardial infarctions (MI), sepsis, and death compared with patients with no HF by 30 days postoperatively. It has been stated previously that HF is a risk factor for the development of PE, and that as left ventricular function declines, the risk for PE increases.^[11,12] Similarly, pneumonia has been previously found to have an increased incidence in HF patients, especially those with P-EF.^[13]

For CVA in the setting of HF, ischemic etiology is likely due to cerebral hypoperfusion to common watershed areas, and HF concomitant with atrial fibrillation provides a thromboembolic source of stroke, specifically for patients without anticoagulation therapy.^[14-16] A study by Marquez-Lara *et al.* demonstrated that postoperative CVA in the setting of lumbar spinal fusion was

Table 1: Patient demographics

	Preserved EF ($n=4077$), n (%)	Reduced EF ($n=2758$), n (%)	Control ($n=663,691$), n (%)	P
Age (years)				
<65	949 (23.28)	630 (22.84)	187,166 (28.20)	<0.001
65–69	828 (20.31)	571 (20.70)	195,978 (29.53)	
70–74	921 (22.59)	615 (22.30)	141,086 (21.26)	
75–79	813 (19.94)	583 (21.14)	94,656 (14.26)	
80–84	566 (13.88)	359 (13.02)	44,805 (6.75)	
Male sex	1592 (39.05)	1815 (65.81)	280,922 (42.33)	<0.001
Female sex	2485 (60.95)	943 (34.19)	382,769 (57.67)	
Comorbidities				
Morbid obesity (BMI >30 kg/m ²)	1465 (35.93)	760 (27.56)	62,053 (9.35)	<0.001
PVD	1023 (25.09)	755 (27.37)	38,074 (5.74)	<0.001
Chronic kidney disease	1621 (39.76)	1076 (39.01)	31,335 (4.72)	<0.001
COPD	2745 (67.33)	1614 (58.52)	140,249 (21.13)	<0.001
Diabetes mellitus	2629 (64.48)	1645 (59.64)	160,377 (24.16)	<0.001
Hypertension	3969 (97.35)	2664 (96.59)	400,621 (60.36)	<0.001
Hyperlipidemia	3424 (83.98)	2478 (89.85)	319,225 (48.10)	<0.001
Substance use				
Alcohol	213 (5.22)	193 (7.00)	20,008 (3.01)	<0.001
Smoking	826 (20.26)	692 (25.09)	163,113 (24.58)	<0.001
Surgical characteristics				
1–2 levels fusion	3015 (73.95)	2040 (73.97)	518,854 (78.18)	<0.001
3–7 levels fusion	883 (21.66)	590 (21.39)	117,307 (17.67)	<0.001
8+ levels fusion	26 (0.64)	24 (0.87)	4819 (0.73)	<0.001

EF - Ejection fraction; BMI - Body mass index; PVD - Peripheral vascular disease; COPD - Chronic obstructive pulmonary disease

Table 2: 30-day postoperative outcomes between congestive heart failure patients with preserved ejection fraction and controls

	Preserved EF (n=4077), n (%)	Control (n=663,691), n (%)	P	Preserved EF versus control AOR (95% CI)	P
30-day major medical complications					
Pulmonary embolus	24 (0.59)	1742 (0.26)	<0.001	1.35 (0.87–1.99)	0.158
Pneumonia	91 (2.23)	2993 (0.45)	<0.001	2.07 (1.64–2.56)	<0.001
CVA	15 (0.37)	694 (0.10)	<0.001	1.36 (0.77–2.23)	0.254
MI	15 (0.37)	653 (0.10)	<0.001	1.65 (0.93–2.72)	0.064
Sepsis	73 (1.79)	2239 (0.34)	<0.001	2.09 (1.62–2.66)	<0.001
Death	16 (0.39)	440 (0.07)	<0.001	1.94 (1.10–3.18)	0.014
30-day minor medical complications					
AKI	109 (2.67)	3333 (0.50)	<0.001	1.56 (1.26–1.90)	<0.001
UTI	166 (4.07)	9678 (1.46)	<0.001	1.21 (1.03–1.42)	0.021
Wound complications	139 (3.41)	9797 (1.48)	<0.001	1.24 (1.04–1.48)	0.015
Transfusion	86 (2.11)	3109 (0.47)	<0.001	1.86 (1.47–2.32)	<0.001
DVT	37 (0.91)	2660 (0.40)	<0.001	1.32 (0.93–1.82)	0.100
30-day emergency department visit	368 (9.03)	32,094 (4.84)	<0.001	1.11 (0.99–1.24)	0.056
30-day readmission	456 (11.18)	25,826 (3.89)	<0.001	1.62 (1.46–1.79)	<0.001

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; CVA - Cerebrovascular accident; AKI - Acute kidney injury; UTI - Urinary tract infection; DVT - Deep vein thrombosis; CI - Confidence interval; AOR - Adjusted odds ratio; MI - Myocardial infarction

Table 3: 30-day postoperative outcomes between congestive heart failure patients with reduced ejection fraction and controls

	Reduced EF (n=2758), n (%)	Control (n=663,691), n (%)	P	Reduced EF versus control AOR (95% CI)	P
30-day major medical complications					
Pulmonary embolus	19 (0.69)	1742 (0.26)	<0.001	1.52 (0.92–2.34)	0.076
Pneumonia	59 (2.14)	2993 (0.45)	<0.001	1.85 (1.40–2.40)	<0.001
CVA	21 (0.76)	694 (0.10)	<0.001	2.70 (1.67–4.15)	<0.001
MI	25 (0.91)	653 (0.10)	<0.001	3.66 (2.34–5.47)	<0.001
Sepsis	39 (1.41)	2239 (0.34)	<0.001	1.62 (1.15–2.21)	0.004
Death	14 (0.51)	440 (0.07)	<0.001	2.40 (1.31–4.05)	0.002
30-day minor medical complications					
AKI	89 (3.23)	3333 (0.50)	<0.001	1.84 (1.46–2.29)	<0.001
UTI	116 (4.21)	9678 (1.46)	<0.001	1.47 (1.20–1.77)	<0.001
Wound complications	80 (2.90)	9797 (1.48)	<0.001	1.13 (0.90–1.41)	0.283
Transfusion	71 (2.57)	3109 (0.47)	<0.001	2.49 (1.93–3.17)	<0.001
DVT	21 (0.76)	2660 (0.40)	0.005	1.09 (0.68–1.64)	0.704
30-day emergency department visits	289 (10.48)	32,094 (4.84)	<0.001	1.35 (1.19–1.53)	<0.001
30-day readmission	372 (13.49)	25,826 (3.89)	<0.001	2.05 (1.82–2.29)	<0.001

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; CVA - Cerebrovascular accident; AKI - Acute kidney injury; UTI - Urinary tract infection; DVT - Deep vein thrombosis; CI - Confidence interval; AOR - Adjusted odds ratio; MI - Myocardial infarction

highly associated with patients greater than age 65 with a history of neurological disorders, paralysis, congestive heart failure, or electrolyte imbalance being at increased risk.^[17] Although not accounted for by this study, it is likely many HF patients that were analyzed likely suffered from a cardiac arrhythmia such as atrial fibrillation, increasing their odds of having a CVA when compared with patients with no HF. The correlation of HF and myocardial infarction incidence has been extensively studied,^[18,19] and sepsis has also been shown to be a major contributor of death in patients with HF.^[20]

While spinal fusion has been associated with considerable rates of complications, patients with HF introduce a

further comorbidity factor which can contribute to further deleterious outcomes.^[21-23] Both study groups, R-EF and P-EF, had a significant association with longer hospital stay, increased reimbursements, and higher total hospital costs. Relative to No-HF, R-EF was associated with significantly higher odds of MI, CVA, and pneumonia. Although classified separately, studies have shown similar survival rates among R-EF and P-EF patients.^[24-26] However, our study revealed, while adjusting for prior history of MI, CAD, and the presence of a pacemaker, that R-EF was also a significant predictor of an MI 30 days postoperatively after elective spine fusion. After further adjusting for history of CABG or stent placement, R-EF was also associated with higher odds of CVA and MI. The

Table 4: 30-day postoperative outcomes between congestive heart failure patients with preserved and reduced ejection fraction

	Reduced EF (n=2758), n (%)	Preserved EF (n=4077), n (%)	P	Reduced versus preserved EF AOR (95% CI)	P
30-day major medical complications					
Pulmonary embolus	19 (0.69)	24 (0.59)	0.720	0.98 (0.51–1.85)	0.945
Pneumonia	59 (2.14)	91 (2.23)	0.863	0.98 (0.69–1.38)	0.894
CVA	21 (0.76)	15 (0.37)	0.042	2.24 (1.12–4.55)	0.023
MI	25 (0.91)	15 (0.37)	0.007	2.24 (1.15–4.50)	0.019
Sepsis	39 (1.41)	73 (1.79)	0.269	0.84 (0.56–1.27)	0.418
Death	14 (0.51)	16 (0.39)	0.603	1.27 (0.59–2.71)	0.530
30-day minor medical complications					
AKI	89 (3.23)	109 (2.67)	0.206	1.23 (0.91–1.65)	0.181
UTI	116 (4.21)	166 (4.07)	0.832	1.14 (0.88–1.48)	0.304
Wound complications	80 (2.90)	139 (3.41)	0.271	0.87 (0.65–1.16)	0.356
Transfusion	71 (2.57)	86 (2.11)	0.239	1.23 (0.88–1.72)	0.222
DVT	21 (0.76)	37 (0.91)	0.609	0.73 (0.41–1.27)	0.276
30-day emergency department visits	289 (10.48)	368 (9.03)	0.050	1.20 (1.01–1.43)	0.036
30-day readmission	372 (13.49)	456 (11.18)	0.005	1.27 (1.08–1.48)	0.003

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; CVA - Cerebrovascular accident; AKI - Acute kidney injury; UTI - Urinary tract infection; DVT - Deep vein thrombosis; CI - Confidence interval; AOR - Adjusted odds ratio; MI - Myocardial infarction

Table 5: 90-day postoperative outcomes between congestive heart failure patients with preserved ejection fraction and controls

	Preserved EF (n=4077), n (%)	Control (n=663,691), n (%)	P	Preserved EF versus control AOR (95% CI)	P
90-day major medical complications					
Pulmonary embolus	43 (1.05)	4022 (0.61)	<0.001	1.14 (0.83–1.54)	0.395
Pneumonia	233 (5.71)	8425 (1.27)	<0.001	2.14 (1.85–2.46)	<0.001
CVA	50 (1.23)	2543 (0.38)	<0.001	1.48 (1.10–1.96)	0.008
MI	57 (1.40)	2099 (0.32)	<0.001	2.16 (1.62–2.83)	<0.001
Sepsis	151 (3.70)	5368 (0.81)	<0.001	2.08 (1.74–2.46)	<0.001
Death	46 (1.13)	1568 (0.24)	<0.001	2.18 (1.58–2.95)	<0.001
90-day minor medical complications					
AKI	252 (6.18)	7799 (1.18)	<0.001	1.74 (1.51–1.99)	<0.001
UTI	455 (11.16)	28,089 (4.23)	<0.001	1.39 (1.25–1.54)	<0.001
Wound complications	235 (5.76)	17,754 (1.35)	<0.001	1.31 (1.14–1.50)	<0.001
Transfusion	206 (5.05)	8951 (0.99)	<0.001	1.93 (1.66–2.23)	<0.001
DVT	86 (2.11)	6557 (11.81)	<0.001	1.31 (1.05–1.63)	0.016
90-day emergency department visits	931 (22.84)	78,399 (8.82)	<0.001	1.33 (1.23–1.44)	<0.001
90-day readmission	926 (22.71)	58,508 (8.82)	<0.001	1.81 (1.67–1.95)	<0.001

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; CVA - Cerebrovascular accident; AKI - Acute kidney injury; UTI - Urinary tract infection; DVT - Deep vein thrombosis; CI - Confidence interval; AOR - Adjusted odds ratio; MI - Myocardial infarction

increased susceptibility to these cardiovascular outcomes is considerable for R-EF patients when compared with patients with no HF.

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 CPT and ICD-9 coding may result in bias as the inclusion of these patients is dependent on institution-dependent coding procedures, as well as clinical presentation of the patient, which may have a subjective component. Cognizant of these limitations, the ability to

longitudinal track patients preoperative and postoperative in a temporal fashion while assessing the incidence of complications has value.

CONCLUSIONS

When evaluating the severity of HF before spine surgery, R-EF was associated with a higher risk of major complications, especially the occurrence of a myocardial infarction 30 days postoperatively. During preoperative risk assessment, congestive HF should be assessed and optimized during the planning process for elective spine fusion surgery.

Table 6: 90-day postoperative outcomes between congestive heart failure patients with reduced ejection fraction and controls

	Reduced EF (n=2758), n (%)	Control (n=663,691), n (%)	P	Reduced EF versus control AOR (95% CI)	P
90-day major medical complications					
Pulmonary embolus	40 (1.45)	4022 (0.61)	<0.001	1.55 (1.11–2.10)	0.007
Pneumonia	167 (6.06)	8425 (1.27)	<0.001	2.21 (1.87–2.59)	<0.001
CVA	44 (1.60)	2543 (0.38)	<0.001	1.86 (1.35–2.50)	<0.001
MI	53 (1.92)	2099 (0.32)	<0.001	2.70 (2.00–3.56)	<0.001
Sepsis	86 (3.12)	5368 (0.81)	<0.001	1.68 (1.34–2.09)	<0.001
Death	35 (1.27)	1568 (0.24)	<0.001	2.35 (1.62–3.28)	<0.001
90-day minor medical complications					
AKI	189 (6.85)	7799 (1.18)	<0.001	1.94 (1.65–2.26)	<0.001
UTI	262 (9.50)	28,089 (4.23)	<0.001	1.40 (1.23–1.60)	<0.001
Wound complications	130 (4.71)	17,754 (1.35)	<0.001	1.16 (0.96–1.38)	0.105
Transfusion	154 (5.58)	8951 (0.99)	<0.001	2.30 (1.93–2.72)	<0.001
DVT	49 (1.78)	6557 (11.81)	<0.001	1.10 (0.81–1.45)	0.515
90-day emergency department visits	625 (22.66)	78,399 (8.82)	<0.001	1.40 (1.27–1.53)	<0.001
90-day readmission	661 (23.97)	58,508 (8.82)	<0.001	1.96 (1.79–2.15)	<0.001

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; CVA - Cerebrovascular accident; AKI - Acute kidney injury; UTI - Urinary tract infection; DVT - Deep vein thrombosis; MI - Myocardial infarction

Table 7: 90-day postoperative outcomes between congestive heart failure patients with preserved and reduced ejection fraction

	Reduced EF (n=2758), n (%)	Preserved EF (n=4077), n (%)	P	Reduced versus preserved EF AOR (95% CI)	P
90-day major medical complications					
Pulmonary embolus	40 (1.45)	43 (1.05)	0.176	1.31 (0.83–2.07)	0.244
Pneumonia	167 (6.06)	233 (5.71)	0.593	1.10 (0.89–1.36)	0.389
CVA	44 (1.60)	50 (1.23)	0.238	1.36 (0.89–2.10)	0.151
MI	53 (1.92)	57 (1.40)	0.112	1.39 (0.93–2.07)	0.104
Sepsis	86 (3.12)	151 (3.70)	0.219	0.93 (0.70–1.23)	0.628
Death	35 (1.27)	46 (1.13)	0.679	1.27 (0.80–2.02)	0.309
90-day minor medical complications					
AKI	189 (6.85)	252 (6.18)	0.290	1.20 (0.97–1.47)	0.086
UTI	262 (9.50)	455 (11.16)	0.031	1.01 (0.85–1.19)	0.939
Wound complications	130 (4.71)	235 (5.76)	0.066	0.85 (0.68–1.07)	0.178
Transfusion	154 (5.58)	206 (5.05)	0.363	1.23 (0.98–1.54)	0.078
DVT	49 (1.78)	86 (2.11)	0.378	0.85 (0.58–1.22)	0.378
90-day emergency department visits	625 (22.66)	931 (22.84)	0.890	1.02 (0.90–1.51)	0.755
90-day readmission	661 (23.97)	926 (22.71)	0.240	1.12 (0.99–1.27)	0.066

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; CVA - Cerebrovascular accident; AKI - Acute kidney injury; UTI - Urinary tract infection; DVT - Deep vein thrombosis; MI - Myocardial infarction

Table 8: Length of stay, reimbursement, and hospital cost between congestive heart failure patients with preserved ejection fraction and controls

	Preserved EF (n=4077), n (%)	Control (n=663,691), n (%)	P	Preserved EF versus control adjusted β (95% CI)	P
Mean LOS (days)	6.28 ± 7.78	3.43 ± 3.87	<0.001	2.04 (1.93 ≤ β ≤ 2.16)	<0.001
Total reimbursement	\$28,087.91 ± 21,368.80	\$21,099.78 ± 15,293.36	<0.001	\$3826.56 (3367.71 ≤ β ≤ 4285.41)	<0.001
Total hospital cost	\$112,312.23 ± 117,715.60	\$85,842.81 ± 74,454.91	<0.001	\$18,030.90 (15,804.35 ≤ β ≤ 20,257.45)	<0.001

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; β - Standardized beta coefficient; LOS - Length of stay; CI - Confidence interval

Table 9: Length of stay, reimbursement, and hospital cost between congestive heart failure patients with reduced ejection fraction and controls

	Reduced EF (n=2758)	Control (n=663,691)	P	Reduced EF versus control adjusted β (95% CI)	P
Mean LOS (days)	5.83 ± 7.02	3.43 ± 3.87	<0.001	1.66 (1.52 ≤ β ≤ 1.81)	<0.001
Total reimbursement	\$27,432.13 ± 18,406.86	\$21,099.78 ± 15,293.36	<0.001	\$3386.13 (2832.90 ≤ β ≤ 3939.36)	<0.001
Total hospital cost	\$110,695.48 ± 100,346.10	\$85,842.81 ± 74,454.91	<0.001	\$16,789.00 (14,107.34 ≤ β ≤ 19,470.66)	<0.001

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; β - Standardized beta coefficient; LOS - Length of stay; CI - Confidence interval

Table 10: Length of stay, reimbursement, and hospital cost between congestive heart failure patients with preserved and reduced ejection fraction

	Reduced EF (n=2758)	Preserved EF (n=4077)	P	Reduced versus preserved EF Adjusted β (95% CI)	P
Mean LOS (days)	5.83±7.02	6.28±7.78	0.012	-0.31 (-0.67≤ β ≤0.05)	0.89
Total reimbursement	\$27,432.13±18,406.86	\$28,087.91±21,368.80	0.176	-\$653.89 (-1626.89≤ β ≤319.11)	0.188
Total hospital cost	\$110,695.48±100,346.10	\$112,312.23±117,715.60	0.543	-\$1544.80 (-6886.94≤ β ≤3797.34)	0.571

Values in bold denote significance determined as $P < 0.05$. EF - Ejection fraction; β - Standardized beta coefficient; LOS - Length of stay; CI - Confidence interval

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Savarese G, Becher PM, Lund LH, Seferovic P, Rosano GM, Coats AJ. Global burden of heart failure: A comprehensive and updated review of epidemiology. *Cardiovasc Res* 2023;118:3272-87.
- Grossgasteiger M, Hien MD, Graser B, Rauch H, Gondan M, Motsch J, et al. Assessment of left ventricular size and function during cardiac surgery. An intraoperative evaluation of six two-dimensional echocardiographic methods with real time three-dimensional echocardiography as a reference. *Echocardiography* 2013;30:672-81.
- Gazewood JD, Turner PL. Heart failure with preserved ejection fraction: Diagnosis and management. *Am Fam Physician* 2017;96:582-8.
- Zelenty WD, Kelly MJ, Hughes AP. Outcomes and cost-effectiveness of adult spinal deformity surgery. *Semin Spine Surg* 2022;34:100994.
- Elias E, Bess S, Line B, Lafage V, Lafage R, Klineberg E, et al. International Spine Study Group. Outcomes of operative treatment for adult spinal deformity: a prospective multicenter assessment with mean 4-year follow-up. *J Neurosurg Spine* 2022;1-10. [doi: 10.3171/2022.3.SPINE2295].
- Emmons-Bell S, Johnson C, Roth G. Prevalence, incidence and survival of heart failure: A systematic review. *Heart* 2022;108:1351-60.
- Mohebi R, Chen C, Ibrahim NE, McCarthy CP, Gaggin HK, Singer DE, et al. Cardiovascular disease projections in the United States based on the 2020 census estimates. *J Am Coll Cardiol* 2022;80:565-78.
- Guyot JP, Cizik A, Bransford R, Bellabarba C, Lee MJ. Risk factors for cardiac complications after spine surgery. *Evid Based Spine Care J* 2010;1:18-25.
- 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;38:1422-9.
- 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;28:2070-6.
- Sorensen HT, Horvath-Puho E, Lash TL, Christiansen CF, Pesavento R, Pedersen L, et al. Heart disease may be a risk factor for pulmonary embolism without peripheral deep venous thrombosis. *Circulation* 2011;124:1435-41.
- Beemath A, Stein PD, Skaf E, Al Sibae MR, Alesh I. Risk of venous thromboembolism in patients hospitalized with heart failure. *Am J Cardiol* 2006;98:793-5.
- Shen L, Jhund PS, Anand IS, Bhatt AS, Desai AS, Maggioni AP, et al. Incidence and outcomes of pneumonia in patients with heart failure. *J Am Coll Cardiol* 2021;77:1961-73.
- Prabhu S, Voskoboinik A, Kaye DM, Kistler PM. Atrial fibrillation and heart failure – Cause or effect? *Heart Lung Circ* 2017;26:967-74.
- Kotecha D, Lam CS, Van Veldhuisen DJ, Van Gelder IC, Voors AA, Rienstra M. Heart failure with preserved ejection fraction and atrial fibrillation: Vicious twins. *J Am Coll Cardiol* 2016;68:2217-28.
- Ling LH, Kistler PM, Kalman JM, Schilling RJ, Hunter RJ. Comorbidity of atrial fibrillation and heart failure. *Nat Rev Cardiol* 2016;13:131-47.
- Marquez-Lara A, Nandyala SV, Fineberg SJ, Singh K. Cerebral vascular accidents after lumbar spine fusion. *Spine (Phila Pa 1976)* 2014;39:673-7.
- Minicucci MF, Azevedo PS, Polegato BF, Paiva SA, Zornoff LA. Heart failure after myocardial infarction: Clinical implications and treatment. *Clin Cardiol* 2011;34:410-4.
- Oleynikov VE, Dushina EV, Golubeva AV, Barmenkova JA. Early predictors of heart failure progression in patients after myocardial infarction. *Kardiologiya* 2020;60:1309.
- Walker AM, Drozd M, Hall M, Patel PA, Paton M, Lowry J, et al. Prevalence and predictors of sepsis death in patients with chronic heart failure and reduced left ventricular ejection fraction. *J Am Heart Assoc* 2018;7:e009684.
- De la Garza Ramos R, Goodwin CR, Passias PG, Neuman BJ, Kebaish KM, Lafage V, et al. Timing of complications occurring within 30 days after adult spinal deformity surgery. *Spine Deform* 2017;5:145-50.
- Daniels AH, Reid DB, Tran SN, Hart RA, Klineberg EO, Bess S, et al. Evolution in surgical approach, complications, and outcomes in an adult spinal deformity surgery multicenter study group patient population. *Spine Deform* 2019;7:481-8.
- Klineberg EO, Passias PG, Poorman GW, Jalai CM, Atanda A, Worley N, et al. Classifying complications: Assessing adult spinal deformity 2-year surgical outcomes. *Global Spine J* 2020;10:896-907.
- Bhatia RS, Tu JV, Lee DS, Austin PC, Fang J, Haouzi A, et al. Outcome of heart failure with preserved ejection fraction in a population-based study. *N Engl J Med* 2006;355:260-9.
- Tsuchihashi-Makaya M, Hamaguchi S, Kinugawa S, Yokota T, Goto D, Yokoshiki H, et al. Characteristics and outcomes of hospitalized patients with heart failure and reduced versus preserved ejection fraction. Report from the Japanese cardiac registry of heart failure in cardiology (JCARE-CARD). *Circ J* 2009;73:1893-900.
- Lam CS, Gamble GD, Ling LH, Sim D, Leong KT, Yeo PS, et al. Mortality associated with heart failure with preserved versus reduced ejection fraction in a prospective international multi-ethnic cohort study. *Eur Heart J* 2018;39:1770-80.

Appendix 1: Inclusion and exclusion codes

Diagnosis	ICD codes
Primary spine fusion	ICD-9-CM: 81.00-08
Revision spine fusion	ICD-9-CM: 81.30-38
Spinal trauma	ICD-9-CM: 805.10, 805.2-5, 805.8-9, 806.00, 806.04-05, 806.4-5, 806.8-9, 905.1
Spinal neoplasm	ICD-9-CM: 192.2, 198.3, 225.3, 237.5
Spinal infection	ICD-9-CM: 324.1, 324.9

ICD - International classification of diseases

Appendix 2: Postoperative outcome codes

Diagnosis	ICD codes
Pulmonary embolus	ICD-9-CM: 415.11-415.13, 415.19
Pneumonia	ICD-9-CM: 480.0-3, 480.8-9, 481, 482.0-2, 482.30-32, 482.39-42, 482.49, 482.81-84, 482.89, 482.9, 483.0-1, 483.8, 485, 486, 997.31-32
CVA	ICD-9-CM: 434.01, 434.11, 434.91, 436, 997.02
MI	ICD-9-CM: 410.00-01, 410.10-11, 410.20-21, 410.30-31, 410.40-41 410.50-51, 410.60-61 410.70-71, 410.80-81, 410.90-91, 997.1
Sepsis	ICD-9-CM: 995.91-92
AKI	ICD-9-CM: 584.5, 584.9
UTI	ICD-9-CM: 599.0
Wound complications	ICD-9-CM: 998.12-13, 998.30-32, 998.51, 998.59, 998.83
Transfusion	ICD-9-CM: 99.00-09
DVT	ICD-9-CM: 453.40-42
Reoperation	ICD-9-CM: 81.06-08, 81.37, 84.65

DVT - Deep vein thrombosis; CVA - Cerebrovascular accident; UTI - Urinary tract infection; AKI - Acute kidney injury; MI - Myocardial infarction; ICD - International Classification of Diseases; CM - Clinical modification