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Research Article

Impact of Comorbid Disease on Length of Hospitalization in Spine Fusion Patients: An HCUP-US-NIS Study

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Abstract

Introduction: The following is a study of the impact of comorbid conditions on hospital length of stay following spinal fusion.

Methods: Surgeries were identified from the 2016 Healthcare Cost and Utilization Project National Inpatient Sample (HCUP-US-NIS) by Medicare Severity Diagnosis Related Group (MS-DRG) codes and subdivided for analysis by fusion location and procedure approach. Length of stay was evaluated in relation to comorbid disease status, fusion location, and surgical technique. Comorbidities of interest included hypothyroidism, diabetes mellitus, hypertension, hyperlipidemia, anxiety, obesity, chronic obstructive pulmonary disease, osteoarthritis, rheumatoid arthritis, major depression, coronary atherosclerosis, arrhythmia, congestive heart failure, osteoporosis, stroke, and transient ischemic attack. Patients hospitalized longer than two months were excluded from this analysis.

Results: 185,216 patients undergoing an inpatient spinal fusion were identified (Cervical 32,753, Cervicothoracic 2,633, Thoracic 2,817, Thoracolumbar 4,761, Lumbar 32,316, Lumbosacral 17,326). Each comorbid disease was found to significantly increase the length of hospital stay for at least one procedure location ($p<.05$), with transient ischemic attack (8.5 days in cervicothoracic cases), arrhythmia (5.4 days in thoracic cases), and chronic heart failure (4.8 days in cervicothoracic cases) associated with substantially increased duration of hospitalization. Chronic heart failure (β 2.85, SE 0.11, $p <.001$), stroke (β 3.05, SE 0.08, $p <.001$), and osteoarthritis (β 2.12, SE 0.41, $p <.001$) demonstrated strong positive association with increases in length of peroperative hospitalization.

Conclusion: Preoperative comorbidities contribute variably to the length of post-spinal fusion hospital stay. With increasing trends towards predictive modeling in healthcare outcomes these conditions represent important factors for consideration in surgical planning.

Keywords: Spinal Fusion; Hospitalization; Comorbidity

1. Introduction

Spinal surgery represents a growing proportion of total surgical cases performed globally, the majority of which occur within the United States [1]. As the prevalence of spine-related pathologies continue to increase, addressing the burdens placed on the healthcare system as a result of this expanding surgical case volume will require better understanding of the modifiable cost drivers of spine care. Among spinal surgeries, fusion procedures are the most frequently performed and have more than doubled in number since the late 1990s [2-5]. Mean length of hospital stay (LOS) following fusion procedures is reported between 3-7 days, with an average hospitalization of approximately 3-4 days [6-8]. Still, spinal fusion represents the procedure with greatest aggregate hospital costs incurred across all inpatient surgeries, according to previous reports by the Healthcare Cost and Utilization Project (HCUP) [5]. LOS reduction initiatives for spinal fusion may yield substantial benefits to healthcare delivery networks. A multitude of comorbidities have been shown to impact LOS to varying degrees for patients undergoing spinal fusion [6, 9, 10]. Understanding which of these factors contributes most to prolonged hospitalization is important for optimizing patient care and determining appropriate hospital resource allocation. The following presents retrospective review of the 2016 Healthcare Cost and Utilization Project National Inpatient Sample (HCUP-US-NIS) database examines the relationship between various comorbid conditions and duration of postoperative hospital LOS in spine fusion patients.

2. Materials and Methods

2.1 Healthcare cost and utilization project national inpatient sample (HCUP-US-NIS)

This study is a retrospective cohort analysis of secondary data (level 3 evidence). Patients were identified from the 2016 HCUP-US-NIS, the largest publicly available all-payer inpatient health care database in the United States [11]. The NIS provides national estimates of hospital inpatient stays including 46 states and the District of Colombia across 4,575 hospitals and 7,135,090 patients approximating more than 35 million hospitalizations nationally. Data encompasses a full calendar year of hospitalizations representing more than 97 percent of the United States' population and serves as an estimate of a 20% stratified sample of discharges from community hospitals excluding rehabilitation and long-term acute care facilities. Billing data are compiled from patients with coverage provided by Medicare, Medicaid, private insurance, and the uninsured. Patient information is encoded as International Classification of Diseases, Tenth Revision, Clinical Modification/Procedure Coding System (ICD-10-CM/PCS) diagnosis, procedures, and external cause of morbidity codes beginning October 1, 2015. Confidentiality is ensured with safeguards to protect the privacy of individual patients, physicians, and hospitals. Data include patient demographic characteristics, hospital characteristics, expected payment source, total charges, discharge status, length of hospital stay, and severity as well as comorbidity measures.

2.2 Inclusion criteria

Patients undergoing spinal procedures were identified by Medicare Severity Diagnosis Related Group (MS-DRG) codes 028, 029, 030, 453, 454, 455, 459, 460, 471, 472, and 473 (Table 1). A subsequent filter was applied using ICD-10-PCS codes, from which patients were included if the ICD-10-PCS code description contained the string search term "fusion." Patients who remained in the hospital longer than two months were excluded from this study in an attempt to minimize outlier effects. The subsequent cohort was stratified by ICD-10-PCS codes and spinal fusion region including cervical (C), cervicothoracic (CT), thoracic (T), thoracolumbar (TL), lumbar (L), and lumbosacral (LS) in addition to the directionality of procedure approach either as anterior (A), combined anterior / posterior (A/P), or posterior (P).

MS-DRG #	MS-DRG Description
028	Spinal procedures with major complications or comorbidities
029	Spinal procedures with complications or comorbidities or spinal neurostimulators
030	Spinal procedures without complications or comorbidities / major complications or comorbidities
453	Combined anterior/posterior spinal fusion with major complications or comorbidities
454	Combined anterior/posterior spinal fusion with complications or comorbidities
455	Combined anterior/posterior spinal fusion without complications or comorbidities / major complications or comorbidities
459	Spinal fusion except cervical with major complications or comorbidities
460	Spinal fusion except cervical without major complications or comorbidities
471	Cervical spinal fusion with major complications or comorbidities
472	Cervical spinal fusion with complications or comorbidities
473	Cervical spinal fusion without complications or comorbidities / major complications or comorbidities

Table 1: Medicare Severity Diagnosis Related Group (MS-DRG) codes relating to spinal fusions that were used for inclusion criteria in this study.

2.3 Comorbidity

Presence of preoperative comorbid disease was queried by ICD-10-CM codes for hypothyroidism, diabetes mellitus, hypertension, hyperlipidemia, anxiety, obesity, chronic obstructive pulmonary disease, major depression, coronary atherosclerosis, arrhythmia, chronic heart failure, osteoporosis, and nicotine dependence (Table 2). Length of hospitalization was calculated and compared based on the presence or absence of these comorbidities.

Hypertension	**53,397**	**Major depression**	**15,937**
I10 – Essential (primary) hypertension	48,464	F32 – Major depressive disorder, single episode	15,374
I11 – Hypertensive heart disease	542	F33 – Major depressive disorder, recurrent	563
I12 – Hypertensive chronic kidney disease	4,047	**Nicotine dependence**	**14,879**
I13 – Hypertensive heart and chronic kidney disease	251	F17 – Nicotine dependence	14,879
I15 – Secondary hypertension	55	**Hypothyroidism**	**11,777**
I16 – Hypertensive crisis	38	E01 – Iodine-deficiency related thyroid disorders and allied conditions	6
Hyperlipidemia	**34,870**	E02 – Subclinical iodine-deficiency hypothyroidism	5
E78 – Disorders of lipoprotein metabolism and other lipidemias	34,870	E03 – Other hypothyroidism	11,766
Diabetes mellitus	**22,034**	**Coronary atherosclerosis,**	**9,589**
E08 – Diabetes mellitus due to underlying condition	7	I251 – Atherosclerotic heart disease of native coronary artery	9,589
E09 – Drug or chemical induced diabetes mellitus	74	**Chronic Obstructive Pulmonary Disease**	**8,076**
E10 – Type 1 diabetes mellitus	557	J44 – Other chronic obstructive pulmonary disease	8,076
E11 – Type 2 diabetes mellitus	21,355	**Osteoporosis**	**3,805**
E13 – Other specified diabetes mellitus	41	M80 – Osteoporosis with current pathological fracture	216
Obesity	**17,686**	M81 – Osteoporosis without current pathological fracture	3,589
E66 – Overweight and obesity	17,686	**Chronic heart failure**	**2,448**
Anxiety	**16,215**	I50 – Heart failure	2,448
F41 – Other anxiety disorders	16,215	**Arrhythmia**	**831**
		I49 – Other cardiac arrhythmias	831

Table 2: ICD-10-CM codes used for identification of preoperative comorbid disease and associated frequencies observed among the study dataset.

2.4 Statistical analysis

Statistical analysis was performed using MATLAB version 9.3.0.713579 (R2017b), The Mathworks, Inc. (Natick, Massachusetts). Statistical significance was defined as $p < .05$ with a confidence interval (CI) of 95%. Two sample two-tailed Student's T-Tests were used to compare observed increases in length of hospitalization by the presence of each comorbidity. Comparison groups were separated from fusion location (C, CT, T, TL, L, LS) and procedure approach (A, A/P, P). A multiple linear regression was performed to determine the predictive relationship between comorbidities and LOS.

3. Results

Significant increases in LOS by comorbidity were observed for hypothyroidism (C,TL,L,LS), diabetes mellitus (C,T,TL,L,LS), hypertension (C,CT,T,TL,L,LS), hyperlipidemia (C,T,TL,L,LS), anxiety (TL,L,LS), obesity (C,TL,L,LS), chronic obstructive pulmonary disease (C,CT,T,TL,LS), osteoarthritis (C,L,LS), rheumatoid arthritis (CT), major depression (C,TL,L,LS), coronary atherosclerosis (C,CT,T,TL,L,LS), arrhythmia (C,CT,T,TL,L,LS), congestive heart failure (C,CT,T,TL,L,LS), osteoporosis (C,TL,L,LS), stroke (C,CT,T,TL,L,LS), and transient ischemic attack (C,CT). A more granular analysis of the two most common procedures, cervical and lumbar fusion, follows.

3.1 Cervical spinal fusion

32,753 patients were identified who underwent cervical spinal fusion procedures. Fusion patients with concomitant chronic heart failure experienced an average additional 3-6 days of hospitalization depending on the surgical approach (82 – 150 hours, $p < .001$) compared to patients without a diagnosis of CHF. Other significant predictors of increased length of stay included arrhythmia (+2 days, 38 – 46 hours, $p < .001 – .029$), diabetes (+1 day, 16 – 26 hours, $p < .001$), coronary atherosclerosis (+1 day, 20 – 27 hours, $p < .001 – .004$), and hypertension (+1 day, 12 – 24 hours, $p < .001$). These increases were observed for all surgical approaches. A 0.75 day increase in LOS was observed for COPD excluding combined A/P approach (14 – 21 hours, $p < .001 – .005$). Minimal differences were observed by the surgical approach with the presence of osteoporosis (9 – 17 hours, $p < .001 – .002$), hyperlipidemia (6 – 7 hours, $p < .001$), hypothyroidism (4 hours, $p = .013$), obesity (4 hours, $p < .001 – .019$), depression (3 hours, $p = .026 – .033$), and nicotine dependence (3 – 4 hours, $p < .001 – .005$). No statistically significant differences were observed for anxiety across any surgical approach.

3.2 Lumbar spinal fusion

32,316 patients were identified who underwent lumbar spinal fusion procedures. Fusion patients with concomitant chronic heart failure experienced an average additional 2-3 days of hospitalization across all approaches (54 – 69 hours, p <. 001) compared to patients without a diagnosis of CHF. Other significant predictors of increased length of stay across all approaches included arrhythmia (+0.5 – 2.5 days, 13 – 62 hours, $p < .001 – .018$) and osteoporosis (+0.5 – 1 days, 17 – 25 hours, $p < .001 – .006$). Minimal differences were observed by surgical approach with the presence of COPD (11 – 17 hours, $p < .001$), coronary atherosclerosis (10 – 14 hours, $p < .001$), depression (6 – 18 hours, p < .001), diabetes (9 – 11 hours, p < .001 – .045), obesity (6 – 10 hours, p < .001), anxiety (4 – 15 hours, p < .001 – .015); hypertension (6 – 8 hours, p < .001); hypothyroidism (4 – 7 hours, p <.001 – .028), and hyperlipidemia (2 – 3 hours, p <.001 – .009). No statistically significant differences were observed for nicotine dependence.

3.3 Regression

Multiple linear regression across the entire sample highlighted 11 comorbidities associated with significantly increased LOS following spinal fusion (Table 3). Chronic heart failure (β 2.85, SE 0.11, p < .001) demonstrated a strong positive association with increases in length of perioperative hospitalization while weak positive associations were also observed between arrhythmia (β 1.39, SE 0.14, p < .001) and osteoporosis (β 1.00, SE 0.06, p < .001).

Risk Factor	**ß**	**SE**	***p***
Chronic heart failure	3.05	0.08	<.001†
Arrhythmia	1.39	0.14	<.001†
Osteoporosis	1.00	0.06	<.001†
Chronic Obstructive Pulmonary Disease	0.44	0.05	<.001†
Coronary Atherosclerosis	0.34	0.04	<.001†
Hypertension	0.33	0.03	<.001†
Diabetes Mellitus	0.32	0.03	<.001†
Anxiety	0.18	0.04	<.001†
Obesity	0.14	0.03	<.001†
Major Depression	0.13	0.04	<.001†
Hypothyroidism	0.09	0.04	.023†
Nicotine Dependence	-0.10	0.04	.004†
Hyperlipidemia	-0.21	0.03	<.001†

Table 3: Linear regression demonstrating impact of comorbid disease on length of hospital stay for spinal fusion surgery. † Indicates statistical significance (p< .05).

4. Discussion

Previous studies have examined the relationship between comorbidity and length of postoperative hospital stay among spinal fusion patients. Of the thirteen comorbid diseases included in this analysis, chronic heart failure and arrhythmia were found to be both positively associated with increased LOS by regression and responsible for substantial increases in observed duration of additional hospitalization post-surgery. Chronic heart failure demonstrated anywhere between 3-9 additional days of hospital stay in comorbid fusion patients compared to disease-free counterparts, while arrhythmia accounted for 1-15 additional days of hospitalization. These findings are consistent with reports that suggest chronic heart failure is a significant risk factor for postoperative complications, increasing risks for morbidity and mortality in spine surgery by 1.6 and 5.6 fold, respectively [12-14]. Chronic heart failure has also been identified as an independent risk factor of post-spinal fusion admissions to the intensive care unit, possibly explaining the prolonged course of hospital stay observed across the NIS database [15]. Similarly, the potential impact of cardiac arrhythmia on prolonged LOS following spine surgery has been anecdotally discussed, but a direct linkage has not been formally established [16, 17]. Additional findings that lacked positive association in regression but were still associated with increased hospital LOS included diabetes, coronary atherosclerosis, hypertension, and COPD, all accounting for approximately 1-2 additional days of hospitalization. The impact of diabetes has been repeatedly reported to adversely impact spine surgical outcomes [18, 19]. Diabetics undergoing spinal fusion are at increased risk of discharge to non-home facilities such as skilled nursing or rehabilitation units which sometimes present delays in discharge and could explain observed increases in LOS [20]. Atherosclerosis and hypertension have also been linked to poor surgical outcomes following fusion, and similarly have been reported to increase likelihood of patient discharge to non-home facilities as in diabetes [21-25]. Additionally, COPD has been shown to prolong hospitalization of spine surgery patients, however this is often linked to the risk of developing postoperative pneumonia [26, 27]. Judicious efforts by the surgeon should be taken to minimize this risk when possible. Of note, anxiety, depression, and nicotine dependence accounted for little to no additional length of stay following fusion observed in this study. Nicotine has been well-studied in rabbit models, showing negative effects on fusion outcomes with increased rates of nonunion, poor revascularization, and postoperative stiffness [28-30]. Analysis of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database across 2005 – 2014 was unable to identify increased odds of single or major postoperative complication in current smokers independent of pack-years consumed, although ever-smoker status did increase the risk of incurring single major postoperative adverse events [31]. More detailed analyses of post-fusion bone revascularization mirror the animal model data, with inferior outcomes and delayed rates of revascularization observed in smokers [32]. Meaningful interpretations of these data in the contexts of patient satisfaction domains have proven challenging, with literature reporting conflicting findings. One study from Denmark identified smoking as associated with increased risk of nonunion but was unable to identify functional deficits among patients by the Dallas Pain Questionnaire [33]. This is in contrast to analyses of the Swedish Spine Register which show that while patients report postoperative satisfaction independent of smoking status, the degree to which smokers were satisfied was less so than nonsmokers two years following lumbar spinal surgery [34]. Consensus appears to suggest that while patients are satisfied following spinal surgery regardless of smoking status, smoking serves as an independent risk factor for diminished subjective gains among spine surgery patients [35, 36].

Depression and anxiety are less well-understood in the context of spine surgery as studies primarily focus on the risks for postoperative delirium and short-term quality of life improvements [37-39]. Although the prevalence of psychiatric disorders is widely understood to be increased among patients with complaints of chronic neck and back pain, these analyses group depression alongside other psychiatric diagnoses such as schizophrenia and dementia and are difficult to interpret in the contexts of anxiety or depression alone [40]. By some estimates depression has been found to positively associate with shortened postoperative LOS in spine fusion patients however this was not observed in our analysis [41]. It is possible surgeons are underestimating the role of these comorbidities in postoperative recovery and should be subject to further investigation. Management of medical comorbidities may benefit from cooperative partnership between primary care physicians and operating surgeons. Programs such as the Perioperative Enhancement Team (POET) formed at Duke University School of Medicine have successfully enhanced perioperative care coordination [42]. The POET program has performed preoperative risk stratification while reducing risk and optimizing care for the patient. Targeted clinics have been implemented for preoperative management of anemia, diabetes, nutrition optimization, pain, and elderly patients. Similar constructs could be undertaken by spine surgeons working in conjunction with primary care providers and pre-anesthesia testing centers. The recent efforts by the Global Spine Care Initiative, for example, have taken early steps towards implementing international interprofessional attempts at delivering spine care to developing and underserved populations around the globe [43]. The opportunity exists for orthopaedic spine and neurosurgeons to take substantive leadership roles in such organizations and help deliver valuable evidence-based care.

Limitations

The findings presented rely on data from information available through the HCUP-US-NIS database and necessarily rely on the integrity of their database. As this is a broadly available collection of inpatient hospitalizations, not specifically indicative of spine patient populations, cases may be underreported that are more prevalent in specialty spine surgery centers. Although cervical, lumbar, and lumbosacral spine fusion cohorts demonstrate the robust sample size, cervicothoracic, thoracic, and thoracolumbar regions are comparatively few in number. The result may be artificially distorted differences between data for patients with and without comorbidity of interest. However, as this database presents a large sample for study, we are confident that any inherent biases have been mitigated to the greatest extent possible.

5. Conclusion

Comorbid diseases play a significant role in prolonging postoperative hospitalization among spine fusion patients. This analysis presents a study of specific interplay between comorbidity, directionality of surgical approach, and region of the spine undergoing surgical fusion. Thorough understanding of the extent to which these factors interrelate may assist surgeons in preparing patients more effectively during the preoperative phase through enhanced medical optimization prior to surgery. Continued study as to additional factors that could impact patient length of stay following spinal fusion including additional comorbidities, patient demographic variables, and socioeconomic data may provide additional insights to further enhance these findings.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Author Contribution

All authors satisfy the criteria set forth by the ICMJE in the Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly work in Medical Journals.

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