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Predictors of Outcomes and Hospital Charges Following Atlantoaxial Fusion

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Abstract

Background Context—Atlantoaxial fusion is used to correct atlantoaxial instability that is often secondary to traumatic fractures, Down syndrome, or rheumatoid arthritis. The effect of age and comorbidities on outcomes following atlantoaxial fusion is unknown.

Purpose—To better understand trends and predictors of outcomes and charges following atlantoaxial fusion and to identify confounding variables that should be included in future prospective studies.

Study Design—Retrospective analysis of data from the Nationwide Inpatient Sample (NIS), a nationally representative, all-payer database of inpatient diagnoses and procedures in the United States.

Patient Sample—We included all patients that underwent atlantoaxial fusion (International Classification of Disease, Ninth Revision, Clinical Modification code 81.01) between 1998–2011 that were 18 years or older at the time of admission.

Outcome Measures—Outcome measures included in-hospital charges, length of hospital stay (LOS), in-hospital mortality, and discharge disposition.

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Methods—Predictors of outcome following atlantoaxial fusion were assessed using a series of univariable analyses. Those predictors with a p-value of less than 0.2 were included in the final multivariable models. Independent predictors of outcome were those that were significant at an alpha level of 0.05 following inclusion in the final multivariable models. Logistic regression was used to determine predictors of in-hospital mortality and discharge disposition whereas linear regression was used to determine predictors of hospital charges and LOS. Discharge weights were used to produce generalizable results.

Results—From 1998-2011, there were 8,914 hospitalizations recorded wherein atlantoaxial fusion was performed during the inpatient hospital stay. Of these hospitalizations, 8,189 (91.9%) met inclusion criteria. 62% of the study sample was white, while the majority of patients were either insured by Medicare (47.2%) or had private health insurance (35.6%). The most common comorbidity as defined by the NIS and the Elixhauser comorbidity index was hypertension (43.2%). The in-hospital mortality rate for the study population was 2.7% and the median LOS was 6.0 days. The median total charge (inflation adjusted) per hospitalization was \$73,561. 48.9% of patients were discharged to home. Significant predictors of in-hospital mortality included increased age, emergent or urgent admissions, weekend admissions, congestive heart failure, coagulopathy, depression, electrolyte disorder, metastatic cancer, neurological disorder, paralysis, and non-bleeding peptic ulcer. Many of these variables were also found to be predictors of LOS, hospital charges, and discharge disposition.

Conclusion—This study found that older patients and those with greater comorbidity burden had greater odds of postoperative mortality and being discharged to another care facility, longer hospital length of stay, and incurred greater hospital charges following atlantoaxial fusion.

Keywords

atlantoaxial fusion; mortality; hospital charges; Nationwide Inpatient Sample; cervical fusion

Introduction

Atlantoaxial fusion is used to correct atlantoaxial instability (AAI) that is often secondary to traumatic fractures (17%),[1] Down syndrome (10-30%),[2, 3] degenerative disease or rheumatoid arthritis (RA) (20%-86% have AAI).[4] Among patients that undergo atlantoaxial fusion, 4.1% develop vertebral artery injury,[5] 11.2% develop an area of sensory loss in the distribution of the C2 nerve,[1] and 16.7% develop a complication.[6] Prior studies on atlantoaxial fusion relied on single-institution data to quantify outcomes in the context of specific pathologies.[7-11] Limitations due to sample size and sampling bias render prior studies unable to accurately determine predictors of outcome following atlantoaxial fusion because they cannot control for confounders such as socioeconomic status, race, and patient clustering. Insufficient sample size is also likely a problem for studies that would use disease-specific registries. Identifying the preoperative factors that predict postoperative outcomes for relatively rare procedures such as atlantoaxial fusion depends on having significant sample sizes such as those available in administrative databases. Additionally, administrative databases are uniquely positioned to study regional differences in practice patterns and hospital charges because they can draw from multiple institutions across the country.

Prior studies that utilized larger national patient databases have focused on the predictors of outcomes following surgery at any vertebral level in the subaxial spine rather than atlantoaxial fusion specifically.[12-14] Such studies have found that age and comorbidity burden of patients undergoing spinal fusion has increased over the last decade.[12] However, the effects of age, specific comorbidities, and hospital characteristics on outcomes immediately following atlantoaxial fusion have not yet been quantified. Identifying and quantifying predictors of postoperative outcome can improve patient risk counseling for atlantoaxial fusion. As the U.S. healthcare system continues to transition toward value-based care, understanding the predictors of outcomes and hospital charges following spinal procedures such as atlantoaxial fusion will benefit patients, surgeons, and hospital systems.

There is a dearth of large-scale studies that identify predictors of outcomes following atlantoaxial fusion. The present study uses a large, multi-institutional, retrospectively collected, all-payer database of inpatient diagnoses and procedures to determine significant predictors of outcomes following atlantoaxial fusion. We hypothesized that older patients and those with greater comorbidity burden would have greater odds of postoperative in-hospital mortality, longer hospital length of stay, and incur greater hospital charges.[12, 15]

Methods

Data Collection

This study used Nationwide Inpatient Sample (NIS) data from 1998-2011. Data points were included if any diagnosis listed the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) procedure code for atlantoaxial fusion (81.01).

The NIS is the largest all-payer healthcare database in the United States.[16] Established by the Agency for Healthcare Research and Quality (AHRQ), the database is comprised of a 20% stratified sample of all hospital discharges from 1988-2011. Within the NIS, each entry represents a single hospital admission. Data recorded in the NIS includes patient demographics, comorbidities, diagnoses, procedures performed, outcomes (e.g., length of hospital stay, hospital charges, in-hospital mortality), and hospital features.[16] Lastly, the NIS records admission diagnoses, procedures, and in-hospital complications using ICD-9-CM codes.

We used data starting in 1998 to mitigate bias, as the sampling strategy of the NIS changed that year.[17] Additionally, Elixhauser comorbidity data[18, 19] were collected beginning in 1998. The Elixhauser index is made up of thirty comorbidities representing significant pre-existing conditions (including both acute and chronic comorbidities) that are associated with in-hospital mortality. Using the Elixhauser index enables standardized risk adjustment in administrative databases. The NIS includes 29 of the AHRQ comorbidities originally discussed by Elixhauser et al.[18]

We also used data on patient age, gender, race (black, Hispanic, Native American, Asian, and other, relative to white), median income based on patient's zip code, primary payment type (Medicaid, private insurance, self payment, no charge, relative to Medicare), academic hospital setting, hospital admission source (emergent and urgent relative to elective),

weekend admission, hospital bed size (large or medium sized hospitals relative to small hospitals), and hospital region (all relative to northeastern hospitals). Age was stratified into five groups (<50, 50-59, 60-69, 70-79, and >79 years), and only patients aged eighteen years and older were included.

Statistical Analysis

Statistical tests were performed using in-hospital mortality, length of hospital stay (LOS), hospital charges (adjusted for inflation to 2011 dollars, the last year used in the analysis), and discharge disposition (discharge to home or to another care facility) as dependent variables. Both LOS and total hospital charges were log-transformed prior to analysis and reverse transformed when interpreting our results. Initially, we considered age, race, gender, median income in a patient's zip code, primary payment type, academic hospital setting, hospital admission source, weekend admission, hospital bed size, hospital region, and comorbid conditions as predictor variables. Hospital charges were adjusted for inflation using the Bureau of Labor Statistics CPI Inflation Calculator.[20] Discharge weights were used to generate national estimates.

We used linear or logistic regression to assess predictors of outcome in a unique univariable model for each outcome variable. We designated each hospital as a repeated factor to account for clustering by hospital. All predictors with a p-value of less than 0.2 were included in the final multivariable model. We identified independent predictors of outcome as those variables that were statistically significant at an alpha level of 0.05 after inclusion in the final multivariable model. Age groups were included in all final models because of its clinical significance. All model assumptions were tested and met. All analyses were performed using Stata software version 13.0 (Stata Corporation, College Station, TX, USA).

Results

Between 1998-2011, there were 8,914 hospitalizations recorded wherein atlantoaxial fusion was performed during the inpatient hospital stay. Of these hospitalizations, 8,189 (91.9%) met inclusion criteria of age greater than 18. As shown in Table 1, mean patient age was 60.2 years (18.8 years) and 52.3% were men. The study sample was 62% white, and the majority of patients were either insured by Medicare (47.2%) or had private health insurance (35.6%). The most common comorbidities were hypertension (43.2%), electrolyte disorder (17.3%), and diabetes mellitus (11.1%). Elective admissions accounted for 50.3% of all admissions, with 75.2% of admissions occurring in academic hospitals. The most common primary diagnoses were closed C2 vertebral fracture (18.9%), fracture non-union (9.4%), cervical spondylosis with myelopathy (8.1%), and closed C1 vertebral fracture (7.0%).

The in-hospital mortality rate for the study population was 2.7% and the median LOS was 6.0 days (interquartile range 8 days). Adjusted for inflation, the median total charge per hospitalization was \$73, 561 (interquartile range \$100,836). Lastly, 48.9% of patients were discharged home.

Significant predictors of in-hospital mortality included increased age (greater than 60 years relative to <50 years), female gender, elective admission source, weekend admissions,

congestive heart failure, coagulopathy, depression, electrolyte disorder, metastatic cancer, neurological disorder, and paralysis (Table 2). The predictor with greatest odds of mortality was among patients aged 80 and older (OR 4.5, 95% confidence interval (CI) 2.2-9.2), patients aged 70-79 (OR 3.8, 95% CI 1.8-7.9), and coagulopathy (OR 2.9, 95% CI 1.8-4.6). The largest protective effect was seen for depressed patients (OR 0.38 95% CI 0.19-0.76) and elective admissions (OR 0.53, 95% CI 0.38-0.73).

Significant predictors of LOS included older age (>70 years relative to <50 years), elective admission source, weekend admissions, larger and medium sized hospitals (relative to small sized hospitals), Midwestern hospitals, academic hospitals, Medicaid, private, and other payment as primary payment source, non-White race, median income in a patient's zip code, alcohol abuse, deficiency anemia, chronic blood loss anemia, congestive heart failure, coagulopathy, depression, diabetes with chronic complications, drug abuse, electrolyte disorder, hypertension, neurological disorder, electrolyte disorder, metastatic cancer, paralysis, psychiatric disorders, pulmonary circulation disorders, pathologic weight loss, and presence of a tumor (Table 3). The predictors that led to the greatest increase in mean LOS were paralysis, where the mean LOS was 74% longer (95% CI 58%-91% longer), and pathological weight loss, where the mean LOS was 77% longer (95% CI 61%-96% longer). The predictor that shortened the mean LOS the most was elective admission source, with a mean LOS that was 47% shorter (95% CI 44%-49% shorter).

The significant predictors of hospital charges were female gender, elective admissions, weekend admissions, large hospitals (relative to small hospitals), academic hospitals, western hospitals (relative to northeastern hospitals), other as primary payment source, non-White race, median income in a patient's zip code, alcohol abuse, deficiency anemia, chronic blood loss anemia, coagulopathy, congestive heart failure, diabetes mellitus, electrolyte disorder, metastatic cancer, neurological disorder, obesity, paralysis, psychiatric disorder, pulmonary circulation disorders, renal failure, presence of a tumor, and pathological weight loss (Table 4). The predictors that led to the greatest increases in charges were pathological weight loss, which increased mean hospital charges by 84% (95% CI 64%-105% increase), and electrolyte disorder, which increased mean hospital charges by 59% (95% CI 50%-70% increase). Elective hospital admissions were associated with mean hospital charges that were lowered by 19% (95% CI 15%-23% less).

Finally, the significant predictors of discharge to the patient's home were older age (all age groups relative to <50 years), elective admissions, weekend admissions, southern hospitals, private, self, and other as primary payment sources, Black race (relative to white), deficiency anemia, chronic blood loss anemia, congestive heart failure, coagulopathy, electrolyte disorder, metastatic cancer, neurological disorder, paralysis, psychiatric disorder, pulmonary circulation disorders, and pathological weight loss (Table 5). The patients with the greatest odds of being discharged to home rather than another care facility were those from elective admissions (OR 2.39 95% CI 2.06-2.78). Those patients age 80 and older faced the lowest odds of being discharged home (OR 0.12, 95% CI 0.09-0.17).

Discussion

In the present study, we identified significant predictors of in-hospital mortality, LOS, discharge disposition, and hospital charges following atlantoaxial fusion. The number of cervical spine surgeries performed annually has increased over the past few decades.[21-25] Stein et al. used the NIS to analyze trends in utilization of atlantoaxial fusion and found that the incidence nearly doubled from 0.53 per 100,000 people in 1992 to 1.02 per 100,000 people in 2008.[26] This is likely related, in part, to both improved diagnostic methods and improved surgical techniques and devices.[27-31] Variation in outcomes and hospital charges have been documented in other surgical cohorts, and it remains unknown if these variations exist among atlantoaxial fusion patients after controlling for patient demographics, hospital characteristics, and geographic location.[32-39] In conjunction with the relative rarity of atlantoaxial fusion compared to other cervical fusion procedures, the heterogeneity of pathologies that atlantoaxial fusion is used to treat renders atlantoaxial fusion patients an interesting subgroup of all cervical fusion patients to analyze for unique predictors of outcomes and hospital charges.

Accurate determination of predictors of outcomes and hospital charges requires a significant sample size to adequately control for patient and hospital level confounders. Few large-scale studies have investigated predictors of outcomes following cervical spine fusion and atlantoaxial fusion in particular. The present study included 8,189 patients that underwent atlantoaxial fusion, more than seven times the next largest study on outcomes following atlantoaxial fusion.[40] Identifying and quantifying these predictors can help improve patient selection and preoperative risk counseling for atlantoaxial fusion. For example, uncertainty exists regarding the optimal treatment approach for type II odontoid fractures, a pathology requiring atlantoaxial fusion. Various studies have compared clinical and quality of life outcomes following surgery versus conservative management for type II odontoid fracture.[41, 42] Determining the predictors of outcomes following atlantoaxial fusion can further resolve this debate. Furthermore, while hospital charges should not be used to determine treatment approach and strategy, disparities in hospital charges such as those described in the present study may indicate differences in care quality among subgroups of atlantoaxial fusion patients. As surgeons and hospital systems are increasingly measured according to care quality, identifying drivers of variation in hospital charges following atlantoaxial fusion highlights some of the incentives facing those surgeons and hospital systems that can improve care quality. Prior to initiating this study, we hypothesized that older patients with greater comorbidity burden would have greater odds of in-hospital mortality, longer LOS, and greater hospital charges after undergoing atlantoaxial fusion.

In-hospital mortality

We found eleven significant predictors of in-hospital mortality following atlantoaxial fusion. Among these predictors, seven were comorbidities (e.g., coagulopathy, metastatic cancer, congestive heart failure, and neurological disease). Our findings are similar to those of Goz et al. regarding predictors following spinal fusion at any level.[12] Using NIS data from 2001-2010, Goz et al. analyzed significant predictors of in-hospital mortality among 3.5 million patients that underwent spinal fusion at any level. The authors found that co-

characteristics or comorbidities. Elective admission, Midwestern hospitals, private payment, and hypertension were significant patient demographics, comorbidities, and hospital characteristics associated with a shortened mean LOS. The underlying causes of the observed disparities in LOS according to primary payer status are likely multifactorial. Using single-institution data on 24,105 patients with diagnosed lumbar radiculopathy and/or myelopathy, Derakhshan et al. found that robust insurance coverage and higher income were significantly associated with imaging utilization.[47] The authors hypothesized that physician awareness of a patient's payer status can alter practice patterns either away or toward imaging utilization. Although data on imaging use are not present in the NIS, Medicaid patients may have had less adequate perioperative imaging, which may have contributed to significantly longer LOS. Further study is needed to understand the driving forces behind the disparities we observed.

Only the study by Ohya et al. previously investigated predictors of prolonged LOS after atlantoaxial fusion. Ohya et al. studied the effect of rheumatoid arthritis (RA) on mortality, LOS, and complication rates following atlantoaxial fusion for treatment of spondylosis. They found that RA was a significant predictor of longer LOS relative to patients without RA.[40] In contrast, when we included RA in an analysis of a similar population (i.e. only non-emergent patients), we did not find that RA was a significant predictor of LOS. One possible explanation for this difference is that we included many more patient level variables and comorbidities in our model than did Ohya et al. As a result, the predictive power of their model, which relied on a disease-specific cohort, may be less than that of the model presented in this paper. The sample size and data limitations of the study by Ohya et al. illustrate the value of using a large, all-payer administrative database such as the one used in this study to determine predictors of outcome following atlantoaxial fusion.

Charges

There were 30 variables that independently predicted greater hospital charges following atlantoaxial fusion. Among these predictors, larger hospitals, hospitals in the Western United States, non-White race, alcohol abuse, deficiency anemia, chronic blood loss anemia, congestive heart failure, coagulopathy, diabetes, electrolyte disorder, metastatic cancer, neurological disease, obesity, paralysis, psychiatric disorder, pulmonary circulatory disease, renal failure, and pathological weight loss disorder were all associated with increased hospital charges. Several comorbidities (such as paralysis, pathological weight loss, and electrolyte disorder) and weekend admissions were associated with an increase in hospital charges of greater than 35%. In contrast, elective admissions were associated with a 20% reduction in charges. The patients with a greater number of co-morbidities incurred greater hospital charges as they had significantly longer LOS, and likely required more interventions and treatment during their stay. Larger hospitals may have incurred greater charges related to a sicker patient population and differences in charge and reimbursement agreements with insurance companies. Finally, disparities in type and cost of care for non-White racial minorities have been studied extensively, and our findings are consistent with these results. [48, 49]

Regional variations in rates of spinal fusion surgery are well documented.[32, 33, 50, 51] Western hospitals had the highest mean charges relative to northeastern hospitals despite having a mean LOS that was almost a full day shorter (9.6 days for western hospitals compared to 10.4 days in northeastern hospitals) and no statistically significant difference in odds of in-hospital mortality. These regional differences in hospital charges may result from variations in practice patterns and differences between reimbursement models across the country. This geographic heterogeneity in outcomes following an identical treatment is concerning from several perspectives, and previous studies have documented similar regional differences in delivered spine care for other pathologies.[33] For example, James et al. used NIS data on 443,194 patients that underwent spine procedures from 2007-2011 and found that the use of intraoperative neurophysiological monitoring varied widely by geographic location, from 8% of surgeries in the Northeast to over 21% of surgeries in the West.[52] Additionally, Mroz et al. surveyed 2,560 orthopaedic and neurosurgical spine surgeons in the United States to assess surgical treatment patterns for recurrent lumbar disc herniation and found significant differences in treatment plans across several demographic variables.[33] If these differences extend to the pathologies that necessitate atlantoaxial fusion and to the techniques used to perform atlantoaxial fusion, then this inter-surgeon variability might explain the observed geographical differences in hospital charges. While the underlying reasons for the disparity are unclear and theoretical at this time, the subject certainly deserves further investigation as we move closer to a value-based health care economy.

Discharge disposition

Using NIS data from 2002-2011, Marquez-Lara et al. analyzed predictors of discharge disposition following anterior cervical fusion. In their unpublished data, the authors found that older age, non-Caucasian ethnicity, psycho-neurological conditions, and large teaching hospitals were associated with increased likelihood of being discharged to an outside care facility rather than to home following anterior cervical fusion.[53] In the present study, we found twenty-five independent predictors of discharge disposition following atlantoaxial fusion, many of which were shown by Marquez-Lara et al. pertaining to anterior cervical fusion. Older age, weekend admission, Black race (relative to white race), and comorbid conditions (including deficiency anemia, chronic blood loss anemia, congestive heart failure, coagulopathy, electrolyte disorder, paralysis, pulmonary circulation disorders, psychiatric disorder, and pathological weight loss) were independently associated with significantly worse odds of being discharged home after atlantoaxial fusion. In contrast, elective admission, hospitalization in southern hospitals, and private, self, and other primary payment sources were associated with greater odds of being discharged to home following surgery. These findings suggest that emergent cases, particularly among older and minority patients and those with numerous co-morbidities, have greater odds of being discharged to care facilities rather than home. While these findings are intuitive, quantifying the relationship between specific patient characteristics and discharge disposition can significantly improve pre-operative patient counseling and enable patients to make a more informed decision regarding their potential treatment options based on the likelihood of returning home following surgery.

Clinical Impact and Future Directions

This study identified significant baseline predictors of adverse outcomes following atlantoaxial fusion. The literature currently lacks evidence drawn from an all-pathology, all-admission type study population that quantifies these variables. Using baseline demographic/operative variables to understand and quantify outcomes is imperative for patients to make informed decisions. Although many of our findings are not novel, quantifying *a priori* beliefs about predictors of outcome following atlantoaxial fusion will enable surgeons to make more precise, evidence based decisions. In the absence of this study, surgeons rely on general principles regarding the effects of age and specific comorbidities on patient outcomes following atlantoaxial fusion. This study provides the foundation for future work that will build clinical decision tools to enable patients to better anticipate postoperative outcomes, likely leading to higher satisfaction and quality of life. These decision tools will empower physicians to more accurately assess patient risk prior to recommending atlantoaxial fusion while also helping to provide a more informative risk explanation to patients.

Limitations and Strengths

There are several limitations that should be considered. Importantly, procedures and diagnoses are recorded in the NIS using ICD-9-CM codes and are subject to misclassification.[54] Coders assign ICD-9-CM codes based on a clinician's note and data omitted from the note are therefore not included in the database. Second, the set of predictor variables included in the NIS is not exhaustive of all potential predictors of outcomes following atlantoaxial fusion. Specifically, neurologic status, response to conservative management, and the degree of instability on imaging are important clinical factors in surgical decision-making that are not present in administrative databases such as the NIS. Additionally, trends uncovered in population-based studies should not be attributed to individual patients in order to avoid the ecological fallacy.[55] Lastly, the NIS gathers administrative data from the inpatient episode of care and, therefore, conditions and outcomes that may only become apparent with extended follow-up remain outside the scope of investigation. Despite these limitations, this is the first study identifying predictors of atlantoaxial fusion outcomes for all patient populations. The analysis included a wide array of comorbidities, hospital characteristics, patient demographics, and outcomes in both our univariable and multivariable models that may be unavailable in the absence of a large administrative database. Using the NIS database, we were able to provide the results of a large cohort composed of patients from numerous institutions around the country, thereby allowing for generalizable results.

Conclusion

This study identified significant, independent risk factors for in-hospital mortality, LOS, hospital charges, and discharge disposition following atlantoaxial fusion. Generally, older patients with a greater comorbidity burden experienced increased odds of in-hospital mortality, longer mean LOS, increased mean hospital charges, and were less likely to be discharged to home. Additionally, we identified significant regional variations across our outcome variables. Hospital size, time and type of admission, race, gender, insurance status,

and other socioeconomic factors were also significant predictors of in-hospital mortality, LOS, hospital charges, and likelihood of being discharged home following an inpatient episode of care. Our findings can improve patient selection and preoperative counseling by serving as the starting point in the construction of clinical decision tools that can calculate and visually depict risk of in-hospital mortality or non-routine discharge following atlantoaxial fusion. Better patient selection will lead to improved outcomes while controlling charges associated with atlantoaxial fusion. Further prospective studies, building on our results, will allow for cost-effectiveness analyses and determination of optimal treatment methods for specific patient cohorts that undergo atlantoaxial fusion. Ultimately, use of these types of predictive tools will enable optimal individualized care based on a specific patient's demographic, medical, and operative characteristics.

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Table 1
Baseline Demographics, Diagnoses, and Hospital Characteristics

Characteristic	N (%)
Age (years)	
<50 years	2372 (29.0)
50-59 years	1351 (16.5)
60-69 Years	1375 (16.8)
70-79 Years	1670 (20.4)
80-89 Years	1416 (17.3)
Female	4282 (52.2)
Race	
Asian	122 (1.5)
Black	581 (7.1)
Hispanic	474 (5.8)
Native American	32 (0.4)
White	5085 (62.1)
Other	180 (2.2)
Number of Elixhauser Comorbidities	
0	2014 (24.6)
1	1981 (24.2)
2	1785 (21.8)
3+	2358 (28.8)
Elixhauser Comorbidity	
Deficiency Anemia	835 (10.2)
Arthritis	851 (10.4)
CHF	483 (5.9)
Chronic Lung Disease	1146 (14)
Depression	696 (8.5)
Diabetes Mellitus	908 (11.1)
Hypertension	3537 (43.2)
Hypothyroidism	761 (9.3)
Electrolyte Disorder	1416 (17.3)
Neurological Disorder	458 (5.6)
Paralysis	458 (5.6)
Valvular Disease	409 (5.0)
Pathological Weight Loss	343 (4.2)
Primary Diagnosis	
C2 vertebral fracture	1549 (18.9)
Fracture non-union	766 (9.4)
Primary Payment Source	
Medicare	3865 (47.2)
Medicaid	614 (7.5)

Characteristic	N (%)
Private	2915 (35.6)
Self	286 (3.5)
No Charge	24 (0.3)
Other	458 (5.6)
Median Income Quartile	
1	1506 (18.4)
2	2088 (25.5)
3	2071 (25.3)
4	2309 (28.2)
Admission Source	
Elective	4119 (50.3)
Emergent	1883 (23.0)
Urgent	892 (10.9)
Weekend	917 (11.2)
Hospital Bedsize	
Small	466 (5.7)
Medium	1465 (17.9)
Large	6215 (75.9)
Hospital Region	
Northeast	1514 (18.5)
Midwest	1785 (21.8)
South	2939 (35.9)
East	1948 (23.8)
Teaching Hospital	6158 (75.2)
Outcomes	
In-Hospital Mortality	221 (2.7)
Median LOS (Days)	6 (IQR: 8 days)
Median Charges (USD)	\$73,561 (IQR: \$100,836)
Discharge To Home	4004 (48.9)
CSM	663 (8.1)
C1 vertebral fracture	571 (7.0)

All data come from the NIS. All patients that underwent atlantoaxial fusion between 1998-2011 and that were 18 years or older at the time of admission were included. All values are listed as number of patients with percent of total population in parenthesis unless otherwise indicated. CHF is congestive heart failure. LOS is length of hospital stay. IQR is interquartile range. CSM is cervical spondylosis with myelopathy. All calculations were performed using Stata 13.0.

Table 2
Predictors of In-Hospital Mortality Following Atlantoaxial Fusion

Predictor	In-hospital Mortality (OR)	95% CI
Age		
60-69 Years	2.2 *	(1.05 - 4.4)
70-79 Years	3.8 *	(1.8 - 7.9)
80+ Years	4.5 *	(2.2 - 9.2)
Female	0.75 *	(0.56 - 0.99)
Comorbidity		
CHF	2.4 *	(1.6 - 3.6)
Coagulopathy	2.9 *	(1.8 - 4.6)
Depression	0.38 *	(0.19 - 0.76)
Electrolyte Disorder	1.6 *	(1.1 - 2.2)
Metastatic Cancer	2.5 *	(1.2 - 5.1)
Neurological Disorder	1.8 *	(1.2 - 2.9)
Paralysis	1.7 *	(1.1 - 2.7)
Elective Admission	0.53 *	(0.38 - 0.73)
Weekend Admission	1.7 *	(1.21 - 2.5)

All data come from the NIS. All patients that underwent atlantoaxial fusion between 1998-2011 and that were 18 years or older at the time of admission were included. Statistical tests were performed using logistic regression and in-hospital mortality as the outcome variable. All variables listed in the table were included in the final model along with age, hospital characteristics, primary payer status, and median income in patient's zip code. OR is odds ratio.

* Denotes statistical significance at $p < 0.05$. Reference variables were age <50 years, White race, Medicare as a primary payment source, emergent or urgent admission, Northeastern hospitals, and median incomes in the fourth (highest) quartile.

Table 3
Predictors of LOS following atlantoaxial fusion

Predictor	Change in LOS	95% CI
Age		
70–79 y	13% *	(4%–21%)
80+ y	16% *	(7%–26%)
Race		
Black	20% *	(11%–30%)
Hispanic	22% *	(14%–32%)
Other	19% *	(9%–30%)
Comorbidity		
Alcohol abuse	22% *	(12%–32%)
Deficiency anemia	22% *	(16%–28%)
Blood Loss Anemia	44% *	(22% to –71%)
CHF	30% *	(20%–40%)
Coagulopathy	26% *	(13%–41%)
Depression	–7% *	(–1% to –12%)
Diabetes with chronic complications	26% *	(11%–44%)
Drug abuse	17% *	(1%–36%)
Hypertension	–12% *	(–9% to –16%)
Electrolyte disorder	61% *	(52%–70%)
Metastatic cancer	47% *	(32%–64%)
Neurologic disorder	19% *	(11%–28%)
Paralysis	74% *	(58%–91%)
Psychiatric disorder	20% *	(8%–34%)
Pulmonary circulation disorder	28% *	(12%–47%)
Tumor	19% *	(7%–33%)
Pathologic weight loss	77% *	(61%–96%)
Primary payment source		
Medicaid	20% *	(9%–31%)
Private	–12% *	(–8% to –16%)
Other	–16% *	(–8% to –23%)
Median income in patient's zip code (quartile)		
Second	–9% *	(–4% to –13%)
Elective admission	–47% *	(–44% to –49%)
Weekend admission	39% *	(32%–46%)
Hospital size		

Predictor	Change in LOS	95% CI
Medium	12% *	(3%–23%)
Large	24% *	(14%–34%)
Hospital region		
Midwest	–14% *	(–1% to –24%)
Teaching hospital	–22% *	(–17% to –26%)

LOS, length of stay; CHF, congestive heart failure; CI, confidence interval.

All data come from the Nationwide Inpatient Sample. All patients who underwent atlantoaxial fusion between 1998 and 2011 and who were 18 years or older at the time of admission were included. Hospital LOS is the outcome variable. LOS was log-transformed before analysis and reverse-transformed for interpretation. These results are listed as percent change. Linear regression was used with all variables in the table included in the final model in addition to gender.

* Denotes significance at $p < .05$. Reference variables were age <50 years, White race, Medicare as a primary payment source, emergent or urgent admission, Northeastern hospitals, and median incomes in the fourth (highest) quartile.

Table 4
Predictors of Hospital Charges Following Atlantoaxial Fusion

Predictor	Changes in Hospital Charges	95% CI
Female	-5.9% *	(-1% - -11%)
Race		
Black	21.0% *	(10% - 32%)
Hispanic	30.0% *	(20% - 40%)
Other	20.0% *	(7% - 35%)
Comorbidity		
Alcohol Abuse	15.0% *	(5.3% - 27%)
Deficiency Anemia	24.0% *	(17% - 32%)
Blood Loss Anemia	39.0% *	(15% - 68%)
CHF	17.0% *	(8.2% - 27%)
Coagulopathy	48.0% *	(33% - 64%)
Diabetes Mellitus	6.0% *	(0.2% - 12%)
Electrolyte Disorder	59.0% *	(50% - 70%)
Metastatic Cancer	38.0% *	(19% - 59%)
Neurological Disorder	20.0% *	(12% - 30%)
Obese	12.0% *	(2.2% - 22%)
Paralysis	59.0% *	(47% - 73%)
Psychiatric Disorder	18.0% *	(6.3% - 32%)
Pulmonary Circulation Disorder	27.0% *	(8.1% - 50%)
Renal Failure	16.0% *	(4.8% - 30%)
Tumor	-12.0% *	(-1.9% - -21.4%)
Pathological weight Loss	84.0% *	(64% - 105%)
Primary Payment Source		
Other	-11.0% *	(-3.0% - -19%)
Median Income in Patient Zipcode (quartile)		
1 st	15.0% *	(6.5% - 24%)
Elective Admission	-19.0% *	(-15% - -24%)
Weekend Admission	35.0% *	(27% - 43%)
Hospital Size		
Large	28.0% *	(10% - 48%)
Hospital Region		
West	34.0% *	(7% - 67%)
Teaching Hospital	-14.0% *	(-6.6% - -21.3%)

All data come from the NIS. All patients that underwent atlantoaxial fusion between 1998-2011 and that were 18 years or older at admission were included. Charges were log-transformed prior to analysis and reverse transformed when interpreting our results. Therefore, these results are listed as percent change. Linear regression was used and the variables in the table were included in the final model in addition to age.

* Denotes statistical significance at $p < 0.05$. CI is confidence interval. Reference variables were age <50 years, White race, Medicare as a primary payment source, emergent or urgent admission, Northeastern hospitals, and median incomes in the fourth (highest) quartile. CHF is congestive heart failure.

Table 5
Predictors of Discharge Disposition Following Atlantoaxial Fusion

Predictor	Discharge to Home (OR)	95% CI
Age		
50-59 Years	0.69 *	(0.56-0.85)
60-69 Years	0.5 *	(0.39-0.66)
70-79 Years	0.25 *	(0.19-0.33)
80+ Years	0.12 *	(0.09-0.17)
Race		
Black	0.69 *	(0.54-0.87)
Comorbidity		
Deficiency Anemia	0.56 *	(0.45-0.69)
Blood Loss Anemia	0.38 *	(0.16-0.91)
CHF	0.51 *	(0.38-0.68)
Coagulopathy	0.56 *	(0.37-0.84)
Electrolyte Disorder	0.51 *	(0.41-0.64)
Metastatic Cancer	0.6 *	(0.41-0.89)
Neurological Disorder	0.56 *	(0.44-0.72)
Paralysis	0.17 *	(0.13-0.23)
Psychiatric Disorder	0.51 *	(0.35-0.73)
Pulmonary Circulation Disorder	0.44 *	(0.23-0.83)
Pathological weight Loss	0.28 *	(0.19-0.42)
Primary Payment Source		
Private	1.74 *	(1.49-2.02)
Self	2.02 *	(1.44-2.83)
Other	1.88 *	(1.42-2.49)
Elective Admission	2.39 *	(2.06-2.78)
Weekend Admission	0.62 *	(0.51-0.76)
Hospital Region		
South	1.74 *	(1.32-2.29)

All data come from the NIS. All patients that underwent atlantoaxial fusion between 1998-2011 and that were 18 years or older at the time of admission were included. Statistical tests were performed using discharge disposition (discharge to home or to another care facility) as the outcome variable. Logistic regression was used and the variables in the table were included in the final model.

* Denotes statistical significance at $p < 0.05$. CI is confidence interval. OR is odds ratio. CHF is congestive heart failure. Reference variables were age <50 years, White race, Medicare as a primary payment source, emergent or urgent admission, Northeastern hospitals, and median incomes in the fourth (highest) quartile.