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Discharge Disposition After Anterior Cervical Discectomy and Fusion

Aditya V. Karhade[1], Paul T. Ogink[1], Quirina C.B.S. Thio[1], Thomas D. Cha[1], Stuart H. Hershman[1], Andrew J. Schoenfeld[2], Christopher M. Bono[1], Joseph H. Schwab[1]

■ OBJECTIVE: **Age and comorbidity burden of patients going anterior cervical discectomy and fusion (ACDF) have increased significantly over the past 2 decades, resulting in increased expenditures. Non-home discharge after ACDF contributes to increased direct and indirect costs of postoperative care. The purpose of this study was to identify independent prognostic factors for discharge disposition in patients undergoing ACDF.**

■ METHODS: **A retrospective review was conducted at 5 medical centers to identify patients undergoing ACDF for degenerative conditions. The primary outcome was non-home discharge. Additional outcomes considered included discharge to rehabilitation and home discharge with services. Bivariate and multivariable analyses were used to identify independent prognostic factors for non-home discharge.**

■ RESULTS: **Of 2070 patients undergoing ACDF, 114 (5.5%) had non-home discharge and 63 (3.0%) had discharge to inpatient rehabilitation. Factors independently associated with non-home discharge included older age, marital status, Medicare insurance, Medicaid insurance, previous spine surgery, myelopathy, preoperative comorbidities (hemiplegia/paraplegia, congestive heart failure, cerebrovascular accident), anemia, and leukocytosis. C-statistic for the overall model was 0.85. Results were relatively similar for patients younger than the age of 65 years as well as for discharge to inpatient rehabilitation and discharge home with services.**

■ CONCLUSIONS: **Numerous sociodemographic and clinical characteristics influence the risk of non-home discharge and discharge to inpatient rehabilitation in patients undergoing ACDF. Policy makers and payers should consider these factors when determining appropriate preoperative adjustment for risk-based reimbursements.**

INTRODUCTION

The number of anterior cervical discectomy and fusion (ACDF) procedures for degenerative conditions has increased significantly over the past 2 decades.[1-6] Patient age and comorbidity burden also have increased during this time, resulting in increased health care expenditures. These trends are expected to continue in line with anticipated shifts in the United States toward an older demographic.[1-3,6-9] In spine surgery overall, postoperative care is a driver of increased resource use. In the setting of risk-based reimbursements, such as Accountable Care or bundled payment models, an increased emphasis must be placed on accurate preoperative risk assessment for expensive postdischarge events such as the use of inpatient rehabilitation or skilled nursing facilities.[10-12]

Efficient preoperative discharge planning has been shown to reduce hospital length of stay and unplanned readmission.[13] Conversely, unanticipated non-routine discharge adversely influences the length of an admission.[14,15] Patients remain in the hospital after being medically cleared for discharge while awaiting administrative approval for transfer to a skilled nursing facility or inpatient rehabilitation.[14,15] Previous studies of spine surgery have used national administrative databases to identify risk factors for non-home discharge.[16-19] However, these registries frequently lack important clinical, surgical, and

Key words
- Anterior cervical discectomy and fusion
- Discharge disposition
- Prediction
- Spine surgery

Abbreviations and Acronyms
ACDF: Anterior cervical discectomy and fusion

From the [1]Department of Orthopedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston; and [2]Department of Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, USA

To whom correspondence should be addressed: Joseph H. Schwab, M.D., M.S. [E-mail: jhschwab@mgh.harvard.edu]

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Table 1. Baseline Characteristics of Study Population, $n = 2070$

Variable	*n* (%) or Median (IQR)
Age, years	51.0 (43.2—58.0)
Female sex	1073 (51.8)
Race	
White	1770 (88.4)
Non-white	232 (11.6)
Ethnicity	
Hispanic	43 (2.1)
Non-Hispanic	1959 (97.9)
Marital status	
Married	1264 (64.0)
Not married	711 (36.0)
Veteran	139 (7.0)
Neighborhood characteristics	
Median household income, $	79,572 (61,527—95,665)
Median age, years	41.3 (37.9—44.3)
High school graduation rate, %	26 (17—31)
Unemployment rate, %	5.9 (4.7—7.5)
Population density, per square mile	1848 (770—5766)
Neurologic deficit	
Myelopathy	563 (27.2)
Radiculopathy	658 (31.8)
Surgical factors	
Multilevel	969 (46.8)
Previous spine surgery	117 (5.7)
Laboratory values	
Hemoglobin, g/dL	
≥13	1427 (80.6)
<13	343 (19.4)
White blood cell, $\times 10^3/\mu L$	
<11	1618 (91.3)
≥11	154 (8.7)
Platelet, $\times 10^3/\mu L$	
150—450	1702 (82.2)
<150	39 (1.9)
>450	27 (1.3)
Creatinine, mg/dL	
<1.0	1216 (70.0)
≥1.0	520 (30.0)
Insurance	
Medicaid	184 (8.9)
Medicare	363 (17.5)
Uninsured	48 (2.3)
Private	1475 (71.3)
Comorbidities	
Tobacco use	304 (14.7)
Drug abuse	61 (2.9)
Diabetes	260 (12.6)
Renal failure	28 (1.4)
Metastasis	11 (1.0)
Solid tumor	37 (3.4)
Depression	405 (19.6)
Hemiplegia/paraplegia	67 (3.2)
Psychoses	22 (1.1)
Myocardial infarction	52 (2.5)
Congestive heart failure	37 (1.8)
Peripheral vascular disease	51 (2.5)
Cerebrovascular accident	69 (3.3)
Chronic obstructive pulmonary disease	373 (18.0)
Arrhythmias	210 (10.1)
Valvular disease	68 (3.3)
Liver disease	73 (3.5)
Discharge	
Non-home	114 (5.5)
Home with services	124 (6.0)
Discharge to inpatient rehab	63 (3.0)

IQR, interquartile range.

socioeconomic details necessary for adequate evaluation of the true parameters influencing non-home discharge.

The purpose of this study was to identify sociodemographic and clinical characteristics associated with non-home discharge in patients undergoing ACDF at 5 medical centers. Secondarily, we assessed factors associated with discharge to inpatient rehabilitation and discharge home with services.

PATIENTS AND METHODS

Guidelines

The following guidelines were used to support the design and reporting of this investigation: Strengthening the Reporting of Observational studies in Epidemiology (STROBE) and the Transparent Reporting of a Multivariable Prediction Models for Individual Prognosis or Diagnosis (TRIPOD).[20,21]

Table 2. Bivariate Analysis of Non-home Discharge

Variable	Odds Ratio	95% CI	*P* Value
Age	1.08	1.06–1.10	<0.001
Female sex	0.86	0.59–1.26	0.45
Non-white race	0.41	0.26–0.66	<0.001
Hispanic ethnicity	1.18	0.28–4.96	0.82
Veteran	0.79	0.34–1.84	0.59
Not-married	2.23	1.52–3.26	<0.001
Insurance			
Medicaid	3.76	2.38–5.93	<0.001
Medicare	5.19	3.52–7.64	<0.001
Uninsured	1.58	0.56–4.48	0.39
Neighborhood characteristics			
Median household income	1	1.00–1.00	0.44
High school graduation rate	3.43	0.44–26.8	0.24
Unemployment rate	238.56	0.17 –340,367	0.14
Neurologic deficit			
Myelopathy	2.11	1.44–3.11	<0.001
Radiculopathy	0.36	0.21–0.61	<0.001
Surgical factors			
Multilevel	1.54	1.05–2.26	0.03
Previous spine surgery	2.75	1.54–4.91	<0.001
Laboratory values			
Hemoglobin, g/dL <13	3.02	1.95–4.66)	<0.001
White blood cell, $\times 10^3/\mu L$, ≥11	2.98	1.75–5.08	<0.001
Platelet, $\times 10^3/\mu L$, <150	1.53	0.46–5.06	0.49
Platelet, $\times 10^3/\mu L$, >450	0.71	0.09–5.25	0.73
Creatinine, mg/dL ≥1.0	1.44	0.93–2.22	0.1
Comorbidities			
Tobacco use	1.09	0.65–1.84	0.73
Alcohol abuse	3.14	1.51–6.54	0.002
Diabetes	2.42	1.55–3.79	<0.001
Renal failure	7.31	3.14–17.0	<0.001
Metastasis	3.5	1.00–12.26	0.05
Solid tumor	3.27	1.56–6.82	0.002
Hemiplegia/paraplegia	9.38	5.37–16.4	<0.001
Depression	1.43	0.93–2.22	0.11
Psychoses	8.47	3.38–21.2	<0.001
Myocardial infarction	2.78	1.22–6.31	0.01
Congestive heart failure	11.9	5.88–23.6	<0.001
Peripheral vascular disease	2.36	0.98–5.65	0.05

Continues

Table 2. Continued

Variable	Odds Ratio	95% CI	*P* Value
Cerebrovascular accident	8.28	4.73–14.5	<0.001
Chronic obstructive pulmonary disease	1.68	1.09–2.59	0.02
Arrhythmias	2.85	1.79–4.52	<0.001
Valvular disease	3.15	1.56–6.33	0.001
Liver disease	1.87	0.84–4.18	0.13

CI, confidence interval.

Data Source

Health records review was approved by the institutional review board at our institutions. The study was limited to retrospective review, and individual patient consent was waived. Electronic health records (procedural codes, *International Classification of Diseases* codes, and operative notes) from 5 medical centers between January 1, 2000, and May 30, 2018, were reviewed to identify adult patients (age ≥18 years) undergoing ACDF for an operative diagnosis of cervical disc degeneration, herniation, stenosis, and/or other spondylotic condition. Exclusion criteria consisted of procedures that incorporated thoracic or lumbar levels and interventions performed for tumor, trauma, infection, and spinal deformity (e.g., scoliosis, kyphosis).

Outcomes

The primary outcome in this study was discharge disposition. Non-home discharge was defined as any disposition other than home. Secondary outcomes included discharge to inpatient rehabilitation and discharge home with services.

Variables

The following variables were assessed: age (years), sex, race, ethnicity (Hispanic or non-Hispanic), veteran status, marital status (established as married if legally married or in a common law partnership), insurance status (Medicare, Medicaid, uninsured, private insurance), neighborhood characteristics based on the U.S. Census Bureau American Community Survey (median household income, high school graduation or General Equivalency Diploma attainment, unemployment rate), preoperative neurologic deficit (myelopathy, radiculopathy), multilevel surgery, history of any previous spine surgery, laboratory values (white blood cell count [$\times 10^3$ per microliter {μL}]), hemoglobin [grams per deciliter {g/dL}], platelet count [$\times 10^3/\mu L$], creatinine [mg/dL]), and preoperative comorbidities (tobacco use, alcohol abuse, diabetes, renal failure, solid tumor, metastatic cancer, depression, hemiplegia or paraplegia, psychoses, myocardial infarction, congestive heart failure, peripheral vascular disease, chronic obstructive pulmonary disease, arrhythmias, valvular disease, liver disease).[22-26]

Missing Data

Rates of missing data were: race = 68 (3.3%), marital status = 95 (4.6%), white blood cell count = 298 (14.4%), hemoglobin = 300 (14.5%), platelet = 302 (14.6%), creatinine = 334 (16.1%), median household income = 41 (2.0%), high school attainment = 28 (1.4%),

Table 3. Multivariate Analysis of Non-home Discharge, $n = 2070$

Variable	Odds Ratio	95% CI	*P* Value
Age, years	1.06	1.04–1.08	<0.001
Not married	2.32	1.47–3.66	<0.001
Medicaid	2.60	1.47–4.57	<0.001
Medicare	1.76	1.06–2.91	0.03
Myelopathy	1.69	1.09–2.63	0.02
Previous spine surgery	2.23	1.14–4.36	0.02
Hemoglobin (g/dL) < 13	1.77	1.10–2.85	0.02
White blood cell, $\times 10^3/\mu L$, ≥11	2.61	1.38–4.93	0.003
Congestive heart failure	4.93	2.15–11.3	<0.001
Cerebrovascular accident	4.47	2.30–8.69	<0.001
Hemiplegia/paraplegia	7.21	3.65–14.3	<0.001

CI, confidence interval.

and unemployment rate = 28 (1.4%). Multiple imputation with the missForest machine learning methodology of random forests was used to impute variables with less than 30% missing data.[27]

Statistics

Descriptive statistics were generated for the baseline characteristics of the study population. Bivariate logistic regression was used to identify unadjusted factors associated with non-home discharge and risk factors identified were considered for inclusion in the multivariable analysis. Multivariable logistic regression with backward stepwise selection was used to identify independent prognostic factors for non-home discharge. Model fit was assessed with discrimination (c-statistic). A sensitivity test was subsequently performed, limiting inclusion to patients younger than the age of 65 years. Statistical significance was set, a priori, for variables that possessed $P < 0.05$ and odds ratios with 95% confidence intervals exclusive of 1.0 following multivariable adjusted analysis.

RESULTS

Descriptive Statistics

We identified 2070 patients with ACDF in this investigation. One thousand seventy-three (51.8%) were female and the median age was 51 (interquartile range = 43–58; Table 1). Overall, 114 (5.5%) experienced non-home discharge after ACDF. In addition, 63 (3.0%) were discharged to inpatient rehabilitation and 124 (6.0%) were discharged home with services.

Multivariable Analysis of Non-home Discharge

Factors associated with non-home discharge on bivariate analysis (Table 2) were considered candidates in the multivariable analysis. After multivariable analysis, the following independent prognostic factors for non-home discharge were: older age, marital status, Medicaid insurance, Medicare insurance, myelopathy, previous spine surgery, anemia (hemoglobin <13 g/dL), preoperative leukocytosis (white blood cell count ≥11 × $10^3/\mu L$), congestive heart failure, cerebrovascular accident, and hemiplegia or paraplegia (Table 3). The c-statistic for the final model was 0.85.

Among patients younger than the age of 65 years, n = 1820, the rate of non-home discharge was 75 (4.1%), and independent prognostic factors for non-home discharge were older age, Medicaid insurance, myelopathy, preoperative hemoglobin (anemia), preoperative leukocytosis, cerebrovascular accident, and hemiplegia/paraplegia (Supplementary Table 1). The c-statistic for the final model was 0.80.

Table 4. Multivariate Analysis of Discharge to Inpatient Rehabilitation, $n = 2070$

Variable	Odds Ratio	95% CI	*P* Value
Age, years	1.07	1.05–1.10	<0.001
Not married	2.89	1.65–5.08	<0.001
White blood cell, $\times 10^3/\mu L$, ≥11	2.49	1.12–5.51	0.03
Congestive heart failure	5.57	2.18–14.3	<0.001
Cerebrovascular accident	3.99	1.83–8.71	<0.001
Hemiplegia/paraplegia	10.63	5.20–21.7	<0.001

CI, confidence interval.

Multivariable Analysis of Inpatient Rehabilitation Discharge

On multivariable analysis, independent prognostic factors for discharge to inpatient rehabilitation were older age, marital status, leukocytosis, and comorbidities (congestive heart failure, cerebrovascular accident, and hemiplegia or paraplegia) (Table 4). The c-statistic for the final model was 0.85.

Multivariate Analysis of Home Discharge with Services

On multivariable analysis of patients discharged home with services, independent prognostic factors were older age, Medicaid insurance, Medicare insurance, myelopathy, multilevel surgery, and comorbidities (diabetes, psychoses, cerebrovascular accident, valvular disease, liver disease, peripheral vascular disease) (Table 5). The c-statistic for the final model was 0.77.

DISCUSSION

Eleven independent prognostic factors (older age, marital status, Medicare insurance, Medicaid insurance, myelopathy, previous spine surgery, hemoglobin <13 g/dL, white blood cell count ≥11 × $10^3/\mu L$, congestive heart failure, cerebrovascular accident, and hemiplegia or paraplegia) for non-home discharge after ACDF were identified with a c-statistic for the final model of 0.85. In addition, subanalyses of this study identified similar influential factors for non-home discharge in patients younger than the age of 65 years, discharge to inpatient rehabilitation, and home discharge with services.

Others have previously studied preoperative estimation of non-home discharge following spine surgery. McGirt et al.[28] developed the Carolina-Semmes Grading Scale for preoperative estimation of discharge disposition after elective lumbar spine surgery by studying 6921 patients from the Quality and Outcomes Database. Overall, 9.4% had postoperative discharge to a facility other than home and

Table 5. Multivariate Analysis of Discharge Home With Services, $n = 1956$

Variable	Odds Ratio	95% CI	*P* Value
Age, years	1.04	1.02—1.06	<0.001
Medicaid	3.88	2.32—6.49	<0.001
Medicare	1.71	1.06—2.76	0.03
Myelopathy	1.48	0.99—2.23	0.06
Multilevel	1.92	1.29—2.86	0.001
Diabetes	1.53	0.93—2.50	0.09
Psychoses	5.42	1.59—18.44	0.007
Cerebrovascular accident	2.00	0.86—4.64	0.11
Valvular disease	2.89	1.37—6.11	0.005
Liver disease	2.05	0.95—4.42	0.07
Peripheral vascular disease	1.73	0.74—4.04	0.20

CI, confidence interval.

independent prognostic factors included fusion, greater co-morbidity burden as measured by the American Society of Anesthesiologists Classification, older age greater and preoperative ambulatory status.[28] The discriminative capacity of their final model was c = 0.731. Similarly, Di Capua et al.[19] studied 14,602 patients undergoing ACDF from the National Surgical Quality Improvement Program. Factors associated with non-home discharge were race, ethnicity, age, obesity, diabetes, functional status, operative time, cardiac conditions, and comorbidity burden (American Society of Anesthesiologists score) with a discriminative capacity of c = 0.79.

In comparison with the work of McGirt et al., which used only preoperative factors, Di Capua et al. also considered intraoperative variables (specifically operative time). Both approaches are important to characterize risk factors for non-home discharge but, in this study, we followed the route of using only factors available before surgery, as the ultimate purpose was to establish independent prognostic factors that could be used for risk adjustment. The increased discriminative capacity of our estimations may be attributed to the enhanced clinical granularity of our data.

Although others previously identified race and ethnicity as predictors for non-home discharge,[19,29] these factors were not found to be prognostic in this study after the inclusion of other variables such as insurance status, marital status and a comprehensive set of medical comorbidities.[19,30] Preoperative anemia and leukocytosis also were identified as independent prognostic factors, and this may be secondary to an additive effect of both number and severity of comorbidities on these laboratory values. This synergistic effect likely contributes to the value of these laboratory measures as markers of increased health care use following spine surgery.[29,31-33]

There are several limitations that must be acknowledged to appropriately interpret our study findings. Although granular data were assessed from 5 medical centers, the study was retrospective in design and these medical centers are part of a single health care entity with shared institutional practices. Given the sample size, there also may be some concern for estimates to be parochial to the cohort under study. As a result, prospective, external validation of the factors identified here is warranted. Patient-reported functional measures, have been identified previously as predictors of non-routine discharge in lumbar spine surgery but could not be assessed in this study because our institutions began consistently recording these measures only recently. Future studies are envisioned that will incorporate the role of patient-reported functional capacity in influencing discharge destination.

Despite these limitations, this study remains one of the largest multi-institutional series of consecutive patients undergoing ACDF with granular clinical, surgical, and socioeconomic data. The additional factors available from institutional electronic health records relative to national administrative databases allowed us to build on estimates from previous work in this arena. Although validation in external independent samples is necessary before definitive conclusions, the overall model discriminative properties specific to non-routine discharge achieved here are the greatest reported in the spine surgical literature to date. Finally, this is the first study to report several novel independent prognostic variables for non-home discharge after ACDF including marital status, preoperative laboratory characteristics, and Medicaid insurance.

At a time when policy makers and payors are critical of increased health care costs, the demand for cervical spine surgery will continue to rise with increases in the aging population in the United States.[6,9] Increasing comorbidity burden and age at time of cervical spine surgery will compound the challenge of containing the costs associated with postoperative care, but preoperative discharge planning can be one method by which spine surgeons increase the value of post-acute care. Predictive analytics in spine surgery will play an increasingly significant role in response to these challenges.

CONCLUSIONS

In this investigation, we found that numerous sociodemographic and clinical characteristics influence the risk of non-home discharge and discharge to inpatient rehabilitation in patients undergoing ACDF. At a minimum, hospitals can use these parameters as a means to identify patients who may necessitate a greater level of care at the time of discharge following ACDF. Furthermore, policy makers and payers should consider these factors when determining appropriate preoperative adjustment for the purposes of risk-based reimbursement.

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APPENDIX

Supplementary Table 1. Multivariate Analysis of Non-home Discharge in Patients Younger than the Age of 65 Years, $n = 1820$

Variable	Odds Ratio	95% CI	*P* Value
Age, years	1.06	1.03—1.10	<0.001
Medicaid	4.50	2.54—7.99	<0.001
Myelopathy	1.96	1.18—3.27	0.01
Hemoglobin	1.47	0.81—2.66	0.20
White blood cell, $\times 10^3$ /μL, ≥11	3.38	1.77—6.45	<0.001
Cerebrovascular accident	6.21	2.86—13.48	<0.001
Hemiplegia/paraplegia	6.25	2.98—13.11	<0.001

CI, confidence interval.