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Nonindex Readmission After Ruptured Brain Aneurysm Treatment is Associated With Higher Morbidity and Repeat Readmission

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Keywords

Care fragmentation; cerebral aneurysm; continuity of care; nonindex readmission; quality improvement; subarachnoid hemorrhage

Introduction

Aneurysmal subarachnoid hemorrhage (aSAH) affects approximately 30,000 Americans annually,[1,2] with estimated mortality rates in the 45% to 50% range.[2,3] Current surgical and endovascular treatments aim to control re-bleeding, ischemia, hydrocephalus, seizures, and other neurological sequelae.[3] However, despite advances in surgical and endovascular treatment, neurological impairment has been noted in up to 20% of aSAH survivors.[4] Fewer than 60% of individuals return to functional baseline.[2] Following treatment, patients remain at risk for both neurological (vasospasm, seizure, hydrocephalus, etc.)[5,6] and medical (natremia and glycemia abnormalities, fever, anemia)[5,7–9] complications. Prevention and

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treatment of these sequelae require multidisciplinary management and continuity of care. These patients are at high risk for readmission, with short-term estimates ranging from 7.5% to 26%.[10–14] Readmission to a hospital other than the original site of treatment (nonindex hospital) causes a discontinuity in care that may be particularly impactful for aSAH patients during perioperative and subacute follow-up periods. Detailed patient history and baseline neurological status are integral to the assessment of vasospasm risk factors, neurological status change, hydrocephalus, and management of resulting systemic medical complications. Therefore, it is important to identify factors associated with nonindex readmission and the impact of nonindex readmissions on outcomes for these patients.

The Medicare Hospital Readmission Reduction Program was instituted in 2012 as part of the Affordable Care Act in an effort to reduce short term readmissions and associated costs.[15] Subsequent research on patients that underwent surgical treatment of aortic aneurysms or general cancer reported that 20.0%–46.7% of short-term readmissions were to nonindex hospitals.[16–24] These studies cited worse outcomes and greater costs for these patients. The purpose of this study is to characterize nonindex readmission following treatment for ruptured aneurysms. Using a large national database, our aims were to: [1] determine the rate of readmission to nonindex hospitals, [2] evaluate patient and hospital factors associated with nonindex readmission, and [3] evaluate the association of readmission to nonindex (versus index) facility with patient outcomes following aSAH treatment. We hypothesized that illness severity and disadvantaged socioeconomic indicators are associated with nonindex hospital readmissions and that patients readmitted to nonindex hospitals have increased likelihood of patient morbidity and subsequent readmissions.

Materials and Methods

Study Design

A retrospective analysis of the Nationwide Readmissions Database (NRD) was performed from 2010–2014. The NRD is the Health Care Utilization Project's (HCUP) National Readmission Database that allows for analysis of patient admission and readmissions over the course of a given calendar year. The dataset includes patient and hospital demographic characteristics, disease diagnosis and procedure codes, and clinical outcome variables. Data tabulations with n-value of ten or fewer was suppressed in accordance with HCUP privacy guidelines; the present study was not subject to Institutional Review Board review. This article adhered to the Enhancing the QUAlity and Transparency Of health Research (EQUATOR) reporting guideline of Strengthening the Reporting of OBservational studies in Epidemiology (STROBE).[25]

Study Population

International Classification of Disease, Ninth Edition (ICD-9) codes were used to identify patients with aneurysmal subarachnoid hemorrhage (430.xx) that were treated with either endovascular embolization (39.79, 39.72, 39.52) or clip ligation via craniotomy (39.51). ICD-9 diagnosis methodology has been previously validated for sensitivity, specificity, and positive predictive value.[26] Patients without 90 days follow-up after admission within the calendar year were excluded. Patients who were under 18 years of age, experienced inpatient

hospital death, were admitted electively, or were missing mortality or length of stay records were also excluded from analysis. A nonindex readmission was defined as a readmission to a hospital other than the initial site of procedure. To evaluate the effect of non-index readmission on treatment outcomes, patients were stratified into either the index or non-index readmission groups.

Variables

Patient and hospital variables derived from the NRD were analyzed. Initial admission demographic variables included age, gender, primary insurance (Medicare, Medicaid, private, self-pay, no charge, other), residency status within the state of admission (yes/no), and median household income quartile (based on ZIP code). Patient age is included in the NRD as a continuous variable but was redefined as a categorical variable for analysis (18–44, 45–59, 60–74, 75+).[19]

The following clinical covariates were also included from patient admission records: initial procedure received (clip ligation, endovascular coiling, or multiple), Elixhauser comorbidity score (0, 1, 2, 3+), All Patient Refined – Diagnosis Related Group (APR-DRG) severity score (minor, moderate, major, extreme), discharge disposition (home versus another facility), discharge quarter (January-March, April-June, July-September), length of stay, major complication, neurological complication, treated hydrocephalus, and ventriculostomy placement. The Elixhauser comorbidity index is the aggregate of Agency for Healthcare Research and Quality's (AHRQ) defined comorbidities present in the NRD. APR-DRG is a classification system that includes sub-scores to stratify the risk of severity of illness.[27] Hospital factors, including hospital ownership (government nonfederal, private not-profit, private investor-owned), teaching status, bedsize (small, medium, large), and urban-rural designation (large metropolitan ≥ 1 million residents, small metropolitan < 1 million residents) were also determined from admission patient records. The presence of a major complication (by ICD-9 code) was defined as pneumonia (481–482), pulmonary embolism (415.1–415.9), renal failure (584.5–584.9), cerebrovascular accident (CVA, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91), myocardial infarction (410.00–410.90), cardiac arrest (427.5), sepsis (995.91), or septic shock (995.92) at admission. The presence of a neurological complication at admission was defined by ICD-9 codes for intracerebral hemorrhage (431, 998.11–12), seizures (345), or other neurological complications after procedure (997.01–997.09).

Readmission Outcomes

The outcomes of interest were major complication at readmission and incidence of a second readmission within the 90-day period, which were analyzed and compared between nonindex and index readmission groups. The presence of a major complication at readmission was defined using the identical set of ICD-9 code criteria as major complication at admission.

Statistical Analysis

90-day readmission rates for both index and nonindex hospital readmission groups were determined. Analysis of readmission at 90 days post-discharge (versus 30-days) was utilized

to capture delayed complications following neurosurgical or endovascular treatment of ruptured aneurysms.[28] Descriptive analyses were performed for all variables. Patient and hospital variables associated with index versus nonindex readmissions were determined using multivariable logistic regression incorporating NRD clustering. A p-value of 0.05 was used to assess for variables to include in the model. Patient and hospital variables included age, insurance status, APR-DRG severity at readmission, presence of major complication during hospital stay, length of stay, hospital ownership, hospital procedure volume, Elixhauser comorbidity score, residency of same state as procedure, hospital bed size, discharge disposition, and treated hydrocephalus. Sensitivity analysis was done using same variables, but using hospital level variables at readmission, and we got similar results.

We used multivariable logistic regression to evaluate association of patient readmission to nonindex versus index hospitals with categorical outcomes of major complication and second readmission. For each logistic model, adjusted covariates included all patient and hospital characteristics listed above. Missing data was insignificant (<5%) and excluded from analysis in accordance with complete case analysis methodology. Analysis was conducted using SAS 9.4 (Cary, NC) with a significance level set at 0.05.

Results

Study Group

Out of 9,254 patients admitted for treated ruptured aneurysms recorded in the NRD, 1,985 (21.5%) were readmitted within 90 days (Figure 1). 355 of readmissions were to a hospital other than that of original admission (17.9% nonindex readmission rate). The mean admission length of stay was 27.2 days (standard deviation=19.2). The rates of aneurysmal clip ligation (n=958, 48.3%) and endovascular embolization (n=961, 48.4%) for treatment were similar amongst readmissions Most readmissions were female (n=1,336, 67.3%), privately (n=759, 38.2%) or Medicare insured (n=638, 32.1%), and received neither ventriculostomy (n=1,405, 70.8%) nor treatment for hydrocephalus (n=1,389, 70.0%). Of the hospitals represented, most were private non-profit (n=1,419, 71.5%) teaching hospitals (n=1,732, 87.3%), located in a large metropolitan area with at least 1 million residents (n=1,345, 67.8%), and had a large patient bed capacity (n=1,676, 84.4%). Most readmissions lacked major (n=1,384, 69.7%) or neurological complications (n=1,549, 78.0%), and were discharged to another facility (1,298, 65.4%). A summary of patient and hospital variables found in index and nonindex readmission groups is included in Tables 1 and 2.

Associations with Nonindex Readmission

Multivariable regression analysis demonstrated covariates associated with readmission to a nonindex hospital. Patients initially treated at hospitals considered to be private and investor-owned (OR=1.70 [95% CI: 1.09 – 2.67], p =0.020) had greater odds of readmission to a nonindex hospital. Patients discharged to a skilled nursing or other facility after their primary admission (OR=1.70 [95% CI: 1.27 – 2.28], p=0.0004) were also more likely to be readmitted to a nonindex facility. Having private insurance was associated with decreased odds of nonindex readmission (OR=0.65 [95% CI: 0.46 – 0.92], p=0.014). Compared to

patients with an Elixhauser comorbidity score of 3 or greater, patients with Elixhauser comorbidity of 2 had lower odds of nonindex readmission (OR=0.66 [95% CI: 0.47 – 0.92], p=0.014). The results for all variables assessed for associations with 90-day nonindex readmission are summarized in Table 3.

Outcome comparisons between Index vs. Nonindex Readmission

When compared to those readmitted to index facilities, patients readmitted to nonindex facilities were associated with increased likelihood of major complication (OR=1.71 [95% CI: 1.18 – 2.48], p=0.005) and second readmission (OR=1.51 [95% CI: 1.17 – 1.96], p=0.002). Odds ratios for outcomes analyzed between nonindex and index readmissions are summarized in Table 4.

Discussion

This study characterized readmission after treatment for aneurysmal subarachnoid hemorrhage (aSAH) by identifying factors associated with readmission to a different hospital (nonindex), and the impact on clinical outcomes. Approximately 18% of readmissions occurred at non-index hospitals. Patients that were discharged from their primary admission to a nursing home or other facility were more likely to be readmitted to a nonindex hospital. Nonindex readmission was associated with a greater risk for major complications and second readmission when compared to index readmissions.

Nonindex readmissions following surgical or endovascular aSAH treatment creates interruptions in the follow-up care of complex and often critically ill patients. Discontinuity can place healthcare providers at a substantial disadvantage, lacking complete integration and understanding of the patients' prior clinical history and management plan. Increased continuity of care is generally known to be associated with fewer complications, better medication adherence, and better disclosure of clinically relevant medical history.[29–31] Systems of care that share health information have shown promise in improving efficiency and outcomes for nonindex readmissions.[29,32] Care fragmentation may contribute to secondary readmissions and complications associated with nonindex aSAH readmissions.

Studies of other surgical cohorts have noted nonindex readmission rates between 22.1% and 28.4%.[16–19] These investigations observed higher morbidity rates associated with nonindex readmissions. Zafar et al. investigated NRD patients undergoing major cancer surgery, and found an approximate 30% increase in major complication risk for patients readmitted to a nonindex hopsital.[19] A similar cohort of major cancer surgery patients from the State Inpatient Database of California was found to have 16% increased odds of having a second readmission following a nonindex readmission (when compared to index readmissions).[20]

While our findings parallel the trends of these general surgery investigations, the associations with poor outcomes noted with nonindex readmission following aSAH were much greater in magnitude. The complexity of treating aneurysmal hemorrhage may exacerbate the impact of care discontinuity as aneurysmal SAH patients require comprehensive follow-up by a multidisciplinary team.[3,6,9] Aneurysm rupture is often associated with a hypercoagulable state and multi-system complications.[33,34] Intracranial

blood may persist for weeks.[35,36] Fever, hyperglycemia, anemia, hyponatremia, hypernatremia, and DVT often occur at delayed time points.[3,9] Management of complex medical issues by a care team with access to the complete clinical history has previously been shown to improve outcomes during readmissions.[29,30,37]. If a previously treated aSAH patient is readmitted for new onset weakness, it is important to know whether they had suffered from cerebral vasospasm or seizures during the index admission, to guide diagnosis and treatment. Likewise, whether a patient presents with confusion, history of electrolyte abnormalities, or a CSF diversion procedure is important in guiding further management. Oftentimes, aSAH patients cannot recount their own medical histories and are not accompanied by their primary care provider. Post-treatment aSAH patients also take multiple medications that have complex interactions and specific indications for use. These issues can be difficult for an admitting physician/care team to resolve without prior knowledge of the patient, or at least familiarity with the protocols and management paradigms of the treating physician or hospital center.

In our dataset, discharge to a secondary care facility was identified as a risk factor for nonindex readmission. This finding highlights the heightened vulnerability of post-treatment aSAH patients at outside care facilities. Although these patients are generally sicker, surgical cancer studies have demonstrated that patients discharged to skilled nursing facilities are at increased risk for nonindex readmission, even after adjusting for disease severity.[18–20] By contrast, having private insurance was associated with a lower likelihood of readmission to a non-index hospital, which support prior studies that have demonstrated that private insurance payer status is associated with better patient outcomes following neurosurgical procedures.[38] The decreased readmission rate to non-index hospitals may impact morbidity or subsequent patient readmissions.

During initial model building for nonindex readmission outcomes, we found procedure volume at the readmission hospital to be an important confounder for nonindex hospitalization morbidity. Prior to the current model, omitting adjustment for readmission hospital procedure volume artificially inflated the impact of nonindex readmission on patient morbidity (previously OR = 2.12). This finding underscores the importance of hospital volume as a potential confounder in evaluating clinical readmission outcomes for ruptured aneurysm patients. Indeed, prior ischemic stroke studies suggest that transfer to a high-volume facility can improve outcomes, despite the potential detriments associated with the transfer.[3,39,40] The impact of procedure volume on nonindex readmission and subsequent outcomes warrants further investigation.

Retrospective cohort studies are inherently limited by their design. While large administrative datasets such as the NRD provide significant numbers of data points, they are restricted by coding accuracy,[41] and lack of disease specificity.[42,43] However, previous efforts at validation for use of ICD-9 coding in other administrative databases have shown high sensitivity and specificity, as well as positive predictive value estimates ranging from 80% to 94%.[26,44] The NRD does not contain information on patient neurological status and aneurysm size/location at presentation, which have been shown to correlate with surgical and endovascular outcomes.[11,45] The NRD lacks patient readmission data between calendar years and across state lines. Data on travel distance, which is generally associated with

greater nonindex readmission rates,[20,22,24] is also not available. Finally, NRD data is a projection of the unique American healthcare environment. Further investigation in other international settings may elucidate important driving forces for nonindex readmission unique to the variety of healthcare systems.

Conclusion

The current study demonstrates high nonindex readmission rates following initial hospitalizations for aneurysmal subarachnoid hemorrhage treatment. Approximately 18% of readmissions occurred to nonindex hospitals. Nonindex readmissions were associated with increased patient morbidity and risks of secondary readmission. These adverse outcomes may relate to disruption of care continuity. Future efforts targeting reduction in nonindex readmissions could potentially improve patient outcomes following treatment of ruptured aneurysms.

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Glossary

aSAH	aneurysmal subarachnoid hemorrhage
EQUATOR	Enhancing the QUAlity and Transparency Of health Research
STROBE	Strengthening the Reporting of OBservational studies in Epidemiology
ICD-9	International Classification of Disease, Ninth Edition
APR-DRG	All Patient Refined – Diagnosis Related Group
AHRQ	Agency for Healthcare Research and Quality
OR	Odds ratio

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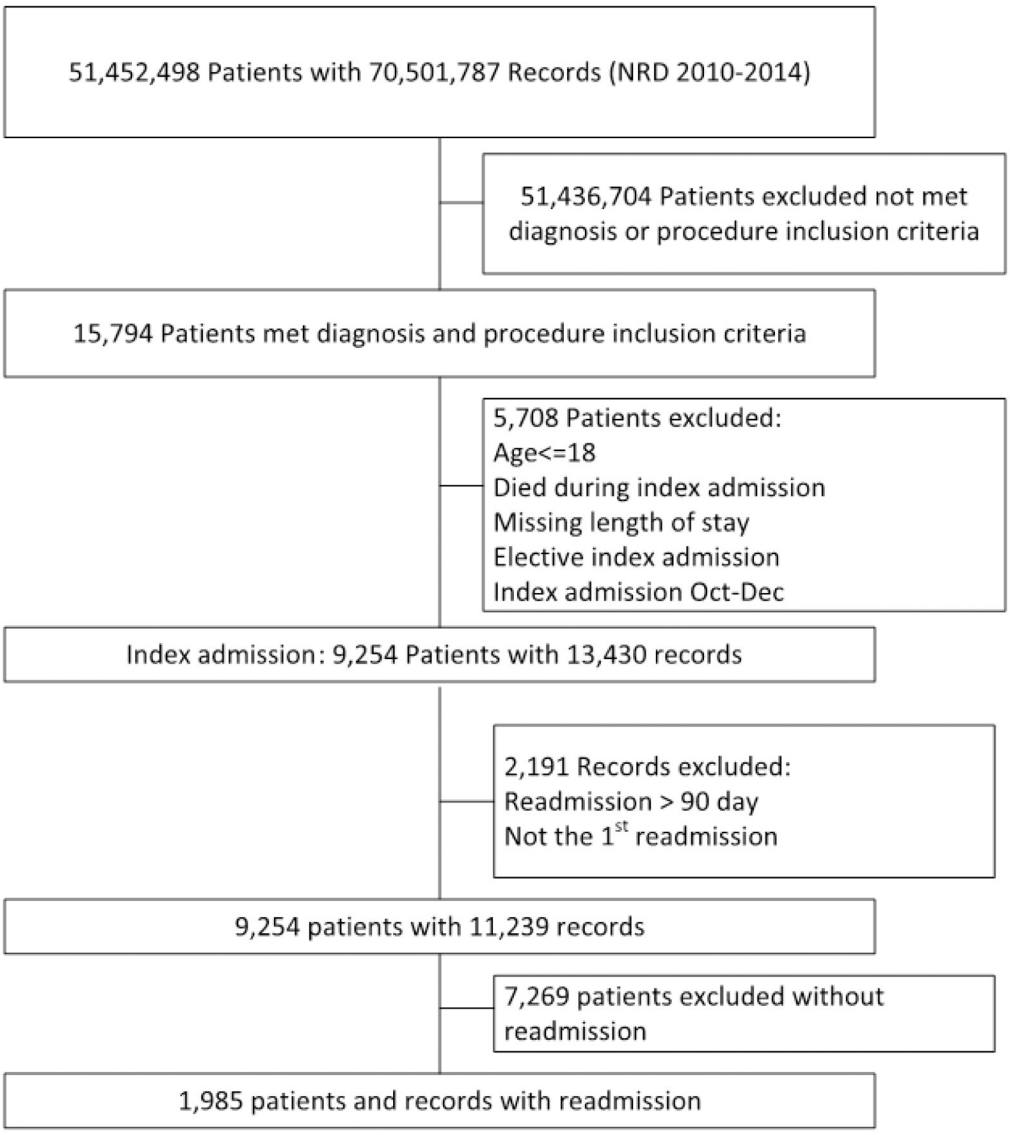

Figure 1.
Patient inclusion/exclusion flow chart from NRD 2010–2014. NRD, Nationwide Readmissions Database.

Table 1.

Patient Readmission Demographics

Variable	All Readmissions	Index	Nonindex	p-value
Total	1985	1630 (82.1%)	355 (17.9%)	
Procedure				
Clipping	958 (48.3%)	795 (48.8%)	163 (45.9%)	0.459
Coiling	961 (48.4%)	779 (47.8%)	182 (51.2%)	
Multiple	66 (3.3%)	56 (3.4%)	DS*	
Age				
18–44	395 (19.9%)	306 (18.8%)	54 (15.2%)	0.008 *
45–59	791 (39.8%)	665 (40.8%)	126 (35.5%)	
60–74	639 (32.2%)	512 (31.4%)	127 (35.8%)	
>=75	195 (9.8%)	147 (9.0%)	48 (13.5%)	
Gender				
Male	649 (32.7%)	519 (31.8%)	130 (36.6%)	0.082
Female	1336 (67.3%)	1111 (68.1%)	225 (63.4%)	
Primary insurance				
Medicare	638 (32.1%)	492 (30.2%)	146 (41.1%)	0.0003 *
Medicaid	375 (18.9%)	301 (18.5%)	74 (20.9%)	
Private insurance	759 (38.2%)	659 (40.4%)	100 (28.1%)	
Self-pay	123 (6.2%)	104 (6.4%)	19 (5.4%)	
No charge	11 (0.6%)	DS	DS	
Other	77 (3.9%)	63 (3.8%)	14 (3.9%)	
Missing	DS	DS	DS	
Elixhauser comorbidity score				
0	102 (5.1%)	87 (5.3%)	15 (4.2%)	0.0001 *
1	289 (14.6%)	255 (15.6%)	34 (9.6%)	
2	395 (19.9%)	341 (20.9%)	54 (15.2%)	
>= 3	1199 (60.4%)	947 (58.1%)	252 (71.0%)	
Median household income for patient’s ZIP code				
0–25 percentile	542 (27.3%)	441 (27.1%)	101 (28.5%)	0.262
26–50 percentile	505 (25.4%)	410 (25.2%)	95 (26.8%)	
51–75 percentile	467 (23.5%)	379 (23.3%)	88 (24.8%)	
76–100 percentile	438 (22.1%)	374 (22.9%)	64 (18.0%)	
Missing	33 (1.7%)	26 (1.6%)	DS	
All Patient Refined DRG: Severity of Illness Subclass				
Minor	51 (2.6%)	43 (2.6%)	DS	0.076
Moderate	174 (8.8%)	144 (8.8%)	30 (8.5%)	
Major	701 (35.3%)	595 (36.5%)	106 (29.9%)	
Extreme	1059 (53.4%)	848 (52.0%)	211 (59.4%)	
Resident of state where procedure was performed				

Variable	All Readmissions	Index	Nonindex	p-value
Nonresident	142 (7.2%)	135 (8.3%)	DS	<0.0001 *
Resident	1843 (92.8%)	1495 (91.7%)	348 (98.0%)	
Discharged to another facility				
Yes	1298 (65.4%)	1025 (62.9%)	273 (76.9%)	<0.0001 *
No	684 (34.5%)	603 (37.0%)	81 (22.8%)	
Missing	DS	DS	DS	
Discharge quarter				
Jan-March	703 (35.4%)	567 (34.8%)	136 (38.3%)	0.395
April-June	658 (33.1%)	542 (33.3%)	116 (32.7%)	
July-Sep	624 (31.4%)	521 (32.0%)	103 (29.0%)	
Admission major complication				
Yes	601 (30.3%)	465 (28.3%)	136 (38.3%)	0.0003 *
No	1384 (69.7%)	1165 (71.5%)	219 (61.7%)	
Admission neurological complication				
Yes	436 (22.0%)	357 (21.9%)	79 (22.25%)	0.885
No	1549 (78.0%)	1273 (78.1%)	276 (77.75%)	
Treated for hydrocephalus				
Yes	596 (30.0%)	471 (28.9%)	125 (35.2%)	0.019 *
No	1389 (70.0%)	1159 (71.1%)	230 (64.8%)	
Ventriculostomy				
Yes	580 (29.2%)	471 (28.9%)	109 (30.7%)	0.497
No	1405 (70.8%)	1159 (71.1%)	246 (69.3%)	

* Data suppressed (DS) for patient privacy considerations, in accordance with the Healthcare Cost and Utilization Project NRD guidelines for publishing privacy protections.

Table 2.

Hospital Demographics

Variable	All Readmissions	Index	Nonindex	p-value
Control/ownership of hospital				
Government, nonfederal	418 (21.1%)	342 (20.1%)	76 (21.4%)	0.002*
Private, not-profit	1419 (71.5%)	1182 (72.5%)	237 (66.7%)	
Private, investor-owned	148 (7.5%)	106 (6.5%)	42 (11.8%)	
Teaching status				
Teaching	1732 (87.3%)	1429 (87.7%)	303 (85.4%)	0.236
Non-teaching	253 (12.7%)	201 (12.3%)	52 (14.7%)	
Hospital bedsize				
Small	71 (3.6%)	55 (3.4%)	16 (4.5%)	0.006*
Medium	238 (12.0%)	179 (11.0%)	59 (16.6%)	
Large	1676 (84.4%)	1396 (85.6%)	280 (78.9%)	
Hospital urban-rural designation				
Large metropolitan area > 1 million residents	1345 (67.8%)	1102 (67.6%)	243 (68.5%)	0.758
Small metropolitan area < 1 million residents, or micropolitan	640 (32.2%)	528 (32.4%)	112 (31.6%)	

Table 3.

Predictors of 90-Day Nonindex Readmission

Variable	Nonindex N (%)	Odds Ratio (95% Confidence Interval)	p-value
Primary insurance			
Medicare	145 (41.0%)	1.09 (0.78 – 1.52)	0.609
Medicaid	74 (20.9%)	Reference	
Private insurance	100 (28.3%)	0.65 (0.46 – 0.92)	0.014*
Self-pay	19 (5.4%)	0.93 (0.53 – 1.63)	0.791
No charge	DS*	1.18 (0.24 – 5.73)	0.834
Other	14 (4.0%)	1.11 (0.58–2.12)	0.940
Control/ownership of hospital			
Government, nonfederal	76 (21.5%)	Reference	
Private, not-profit	236 (66.7%)	0.86 (0.64 – 1.15)	0.300
Private, investor-owned	42 (11.9%)	1.70 (1.09 – 2.67)	0.020*
Resident of state where procedure was performed			
Nonresident	DS	0.25 (0.12– 0.54)	0.0004*
Resident	347 (98.0%)	Reference	
Discharged to another facility			
Yes	347 (98%)	1.70 (1.27 – 2.28)	0.0004*
No	81 (22.9%)	Reference	
Comorbidity score			
0	15 (4.2%)	0.97 (0.54 – 1.75)	0.921
1	34 (9.6%)	0.68 (0.46 – 1.02)	0.062
2	53 (15.0%)	0.66 (0.47 – 0.92)	0.014*
>= 3	252 (71.2%)	Reference	

* Data suppressed (DS) for patient privacy considerations, in accordance with the Healthcare Cost and Utilization Project NRD guidelines for publishing privacy protections.

Table 4.

Multivariable Regression for Clinical Outcomes: Nonindex Readmission versus Index Readmission

Outcome	Nonindex N(%)	OR (95% Confidence Interval)	p-value
Major Complication	76 (23.5)	1.71 (1.18 – 2.48)	<.0001*
Second Readmission	108 (24.0)	1.51 (1.17 – 1.96)	0.002*