Readmission After Aneurysmal Subarachnoid Hemorrhage
A Nationwide Readmission Database Analysis

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Background and Purpose—The goal of this nationwide study is to evaluate the suitability of readmission as a quality indicator in the aneurysmal subarachnoid hemorrhage (SAH) population.

Methods—Patients with aneurysmal SAH were extracted from the Nationwide Readmission Database (2013). Multivariable Cox proportional hazard regression was used to evaluate predictors of a 30-day readmission, and multivariable linear regression was used to analyze the association of hospital readmission rates with hospital mortality rates. Predictors screened included patient demographics, comorbidities, severity of SAH, complications from the SAH hospitalization, and hospital characteristics.

Results—The 30-day readmission rate was 10.2% (n=346) among the 3387 patients evaluated, and the most common reasons for readmission were neurological, hydrocephalus, infectious, and venous thromboembolic complications. Greater number of comorbidities, increased severity of SAH, and discharge disposition other than to home were independent predictors of readmission ($P \leq 0.03$). Although hydrocephalus during the SAH hospitalization was associated with readmission for the same diagnosis, other readmissions were not associated with having sustained the same complication during the SAH hospitalization. Hospital mortality rate was inversely associated with hospital SAH volume ($P=0.03$) but not significantly associated with hospital readmission rate; hospital SAH volume was also not associated with SAH readmissions.

Conclusions—In this national analysis, readmission was primarily attributable to new medical complications in patients with greater comorbidities and severity of SAH rather than exacerbation of complications from the SAH hospitalization. Additionally, hospital readmission rates did not correlate with other established quality metrics. Therefore, readmission may be a suboptimal quality indicator in the SAH population. **(*Stroke*. 2017;48:2383-2390. DOI: 10.1161/STROKEAHA.117.016702.)**

Key Words: aneurysm ■ hospital mortality ■ length of stay ■ stroke ■ subarachnoid hemorrhage

Thirty-day readmission has become a commonly used quality indicator—an easily quantifiable metric that is intended to serve as a proxy for the quality of care physicians and hospitals provide. Thus, in addition to being an adverse event, readmissions have become a focus of clinicians, hospital administrators, and policy makers because of data showing that patients are often readmitted for exacerbations of conditions from their initial hospital stay (referred to as the index hospitalization), and research suggesting the quality of patient education and postdischarge care impact readmission rates.[1] Additionally, hospital readmission rates have been shown to correlate directly with hospital mortality rates[2] and other quality measures[3] and inversely with overall surgical volume.[2]

The suitability of readmission as a quality metric, however, is debated, and its use as such may partially vary by the indication for hospitalization.[4] Although the aneurysmal subarachnoid hemorrhage (SAH) population may be a good population to evaluate readmissions, because these patients are at risk for complications impacting multiple organ systems, some of which may transpire in a delayed fashion, there remains limited data evaluating readmission after SAH.[5,6] The Nationwide Readmission Database (NRD) is a recently released administrative claims database that longitudinally tracks patients within 21 states and is the largest all-payer, nationally accrued database constructed to specifically capture readmissions. The goal of this NRD analysis was to (1) evaluate the rate, indications, and predictors of 30-day readmission after aneurysmal SAH; 2) examine whether patients are readmitted for the same complications as were sustained during the SAH hospitalization; and (3) analyze the degree to which hospital variability in post-SAH readmission correlates with other quality indicators.

Methods

Data Source

The NRD (Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality), a longitudinal administrative claims database, was used for the year 2013. All hospitalizations from 21 states are tracked longitudinally by the NRD to capture

Received January 11, 2017; final revision received June 9, 2017; accepted June 27, 2017.

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readmission to any acute care facility within that state, which are linked by patient using a deidentified indicator. Our institutional review board determined that studies using the NRD are not classified as human subjects research, because it constitutes publically available, deidentified data and, hence, are exempt from individual review.

Inclusion and Exclusion Criteria

Patients aged at least 18 years were included if they (1) had a documented *International Classification of Diseases, 9th Revision, Clinical Modification* (*ICD-9-CM*) diagnosis code of SAH (430) or intracerebral hemorrhage (431 and 432.9) and underwent cerebral aneurysm repair via microsurgical clipping (39.51) or endovascular embolization (39.72, 39.75, 39.76, and 39.79) during the index (SAH) hospitalization; (2) the SAH admission was nonelective; and (3) the patient was discharged from the SAH hospitalization alive (and therefore at risk for readmission). Patients with a diagnosis of a cerebrovascular malformation (747.81) and cerebral arteritis (437.4) or who underwent treatment of an arteriovenous malformation surgically (39.53) or through stereotactic radiosurgery (923.x) were excluded.

Patient Stratification

Patients were stratified by readmission, defined as any repeated hospitalization within 30 days of discharge from the SAH hospitalization. Only readmissions of at least 1 day were included, to distinguish readmissions from extended observation (n=12). The primary diagnosis at the time of readmission was determined from *ICD-9-CM* identifiers.

Predictors of Readmission

Patient age, sex, insurance status, and socioeconomic status (estimated by the median income in the patient's Zone Improvement Plan code of residence) were extracted. The total number of comorbidities were analyzed using the Elixhauser index[7]; however, neurological deficits, paralysis, and electrolyte complications were not included in the comorbidity score, given the potential misclassification with SAH and its associated complications. The Nationwide Inpatient Sample-SAH severity scale, a logarithmic-based, weighted scale was used for severity adjustment, which has been externally validated and shown to have strong concordance with Hunt–Hess grade.[8] The scale is based on *ICD-9-CM* codes denoting severity of neurological disease—the diagnosis codes for coma, hydrocephalus, hemiparesis, aphasia, and cranial nerve deficits, as well as the procedure codes for cerebrospinal fluid diversion and mechanical ventilation. The treatment modality selected for aneurysm repair, decompressive craniectomy (01.25), cerebral herniation (348.4), and cerebral edema (348.5) were also extracted.

Complications, length of stay, and discharge disposition from the SAH hospitalization were evaluated; the complications analyzed were neurological (433.xx-435.xx, 997.01, and 997.09), cardiac (410.xx, 248.xx, 427.5, and 785.xx), pulmonary (514.x, 518.xx, and 512.x), renal (584.x), gastrointestinal (578.x, 5601, and 00845), venous thromboembolic (453.x and 415.x), hematologic (285.x and 998.1x), and infectious (595.0, 996.64, 481–486, 507.0, 997.31, 38.x, 995.9x, 320.x, 041.x, 324.1, 790.7, 999.31, and 998.59). Tracheostomy (311, 312.1, and 312.9) and gastrostomy or jejunostomy (431.1, 431.9, and 463.2) placement during the SAH hospitalization was also evaluated. Discharge disposition was dichotomized as to home or to any destination other than to home (including acute rehabilitation, institutional care, or hospice).

Finally, hospital bed size, teaching status, and control were extracted, which are encoded in the NRD using their respective Healthcare Cost and Utilization Project classifications. All discharges at each included hospital are recorded in the NRD. Therefore, hospital volume of patients with aneurysmal SAH during the year 2013 was calculated using the hospital identification number and evaluated categorically by quartile.

Statistical Analysis

Statistical analyses were conducted in STATA 13 (StataCorp, College Station, TX) accounting for the survey design of the NRD, with the hospital identification as the sampling unit, the discharge weight as the sampling weight variable, and the NRD stratum as the strata. Predictors of readmission were screened using univariable Cox proportional hazards regression (accounting for the time to readmission), and those with a $P<0.20$ in any strata in the univariable screen were entered into a multivariable Cox proportional hazard regression model and retained regardless of the final probability value. Total mortality and readmission rates were calculated for each hospital using the unique hospital identifier. Multivariable linear regression evaluated the association of hospital SAH volume and SAH readmission rates with hospital mortality rates (during the SAH hospitalization). A probability value <0.05 was deemed statistically significant.

Results

SAH Hospitalization

A total of 3806 patients were evaluated, in whom 11.0% (n=419) died during the SAH hospitalization. Therefore, 3387 patients were discharged from the SAH hospitalization alive and at risk for readmission. The median length of the SAH hospitalization was 17 days (interquartile range [IQR], 12–26 days), median hospital charge was $266 304.5 (IQR, $178 209–430 044), and 32.8% (n=1111) of patients discharged alive had a discharge destination other than to home.

Readmission Rate

Among the patients discharged from the SAH hospitalization alive, the 30-day readmission rate was 10.2% (n=346; 95% confidence interval [CI], 9.2%–11.2%), and the demographics of the study population are stratified by readmission in Table 1. The 30-day readmission rate was 11.3% (95% CI, 9.4%–13.3%) for patients treated surgically and 9.7% (95% CI, 8.5%–10.9%) for those treated endovascularly, and readmissions did not differ by treatment modality (P=0.16).

Time to Readmission

The median time from discharge to readmission was 10 days (IQR, 4–18 days). Among readmissions, 43.4% occurred in the first week, 65.6% in the first 2 weeks, and 82.4% within the first 3 weeks after discharge; Kaplan–Meier curves depict the time to readmission within the total study population (Figure 1).

Predictors of Readmission

A multivariable Cox proportional hazards model was constructed evaluating the predictors of readmission (Table 2). Statistically significant independent predictors were a total comorbidity score of at least 3, greater severity of SAH, and a hospital discharge other than to home (Figure 2). These 3 predictors can be used to risk stratify patients with SAH because patients with more predictors had increased readmission rates (Table 3).

Reasons for Readmission

The primary diagnosis at the time of readmission is reported in Table 4. The most common reasons for readmission were hydrocephalus, other neurological, infectious, other medical,vand venous thromboembolic complication. Among patients with an admission diagnosis of cerebral ischemia, the majority (n=13, 3.8% of readmissions) were

Table 1. Demographics of the Study Population Stratified by 30-Day Readmission

Characteristic	Total Population (n=3388)	− Readmitted (n=3042)	+ Readmitted (n=346)	Readmission Rate (%)	*P* Value
Age, y					
Lower quartile	28.8	29.6	22.0	7.8	Ref.
Second quartile	24.9	24.9	24.9	10.2	**0.03**
Third quartile	25.7	25.6	26.9	10.7	0.18
Upper quartile	20.5	19.9	26.3	13.1	**0.001**
Female sex	69.6	70.0	66.8	9.8	0.80
Insurance status					
Private/other	46.5	47.1	40.5	8.9	Ref.
Medicare	26.7	25.8	34.7	13.3	**0.001**
Medicaid	14.6	14.6	15.3	10.7	0.49
Self-pay	12.2	12.5	9.5	7.8	0.58
Socioeconomic status					
Lower quartile	27.5	27.7	26.0	9.7	Ref.
Second quartile	24.7	24.7	25.4	10.5	0.45
Third quartile	24.5	24.1	27.5	11.5	0.26
Upper quartile	21.3	21.6	19.1	9.1	0.92
Missing	2.0	1.9	2.0	10.6	0.80
Number of comorbidities					
0	13.6	14.0	9.8	7.4	Ref.
1	29.7	30.6	22.0	7.6	0.34
2	25.4	25.3	26.6	10.7	**0.048**
≥3	31.3	30.1	41.6	13.6	**<0.001**
NIS-SAH severity scale					
Lower quartile	14.4	15.0	9.0	6.4	Ref.
Second quartile	30.7	31.8	21.7	7.2	0.79
Third quartile	30.4	29.9	35.6	11.9	**0.003**
Upper quartile	24.4	23.4	33.8	14.1	**<0.001**
Intracerebral hemorrhage	5.6	5.4	8.1	14.7	0.11
Microsurgical clipping	31.0	30.6	34.4	11.3	0.16
Cerebral edema	22.3	21.4	30.1	13.8	**0.009**
Cerebral herniation	8.2	8.0	10.1	12.6	0.28
Decompressive craniectomy	1.0	0.9	1.7	17.7	0.06
Hospital control					
Government, nonfederal	21.2	21.3	20.2	9.8	Ref.
Private, not-for-profit	70.7	70.4	73.1	10.6	0.35
Private, investor owned	8.1	8.3	6.7	8.4	0.77
Hospital bed size					
Small/medium	15.4	15.0	18.5	12.3	Ref.
Large	84.7	85.0	81.5	9.8	**0.04**
Teaching hospital	88.1	88.5	85.0	9.9	0.16
Annual hospital volume of SAH					
Lower quartile	24.5	23.7	30.9	12.9	Ref.

(*Continued*)

Table 1. Continued

Characteristic	Total Population (n=3388)	− Readmitted (n=3042)	+ Readmitted (n=346)	Readmission Rate (%)	*P* Value
Second quartile	25.9	25.7	27.2	10.7	0.11
Third quartile	24.8	25.3	20.5	8.5	**0.02**
Upper quartile	24.9	25.3	21.4	8.8	**0.01**
Complications during the SAH hospitalization					
Neurological	38.2	37.5	44.5	11.9	**0.04**
Cardiac	7.9	7.6	10.7	13.8	0.06
Pulmonary	34.8	33.9	42.8	12.6	**0.006**
Gastrointestinal	5.4	5.0	8.7	16.4	**0.03**
Renal	5.8	5.4	9.5	16.7	**0.007**
Hematologic	25.7	24.9	33.0	13.1	**0.02**
Venous thromboembolic	4.8	4.5	6.9	14.9	0.19
Infectious	30.3	29.0	42.2	14.2	**<0.001**
Tracheostomy or gastrostomy	14.5	13.5	23.4	16.7	**<0.001**
Length of SAH hospitalization					
Lower quartile	20.3	20.7	17.3	8.7	Ref.
Second quartile	25.9	26.7	19.1	19.1	0.70
Third quartile	27.4	27.2	28.6	28.6	0.19
Upper quartile	26.4	25.4	35.0	35.0	**0.005**
Discharge other than to home	32.8	30.8	50.3	15.7	**<0.001**

All data are presented as percentages. Statistically significant differences with univariable Cox proportional hazards are bolded. Age divisions: lower quartile: 18–48 y, second quartile: 49–56 y, third quartile: 57–66 y, and upper quartile: >66 y. NIS-SAH severity scale divisions: lower quartile: ≤1, second quartile: 1, third quartile: 1.10–7.5, upper quartile: ≥7.5. NIS-SAH severity scale scores of the third and upper quartile approximate those of Hunt–Hess grade ≥3.[8] Hospital volume: lower quartile: ≤16, second quartile: 16–30, third quartile: 32–46, and upper quartile: ≥46 SAH hospitalizations/y. Length-of-stay divisions (accounting for all patients with SAH, including those who died during the SAH hospitalization): lower quartile: 0–11, second quartile: 12–16, third quartile: 17–25, and upper quartile: ≥25 days. Hospital bed size is designated by the Agency for Healthcare Research & Quality based on hospital location, region, and teaching status, and is not strictly dependent on the total number of beds. NIS indicates nationwide inpatient sample; and SAH, subarachnoid hemorrhage.

for a transient ischemic attack, whereas the minority (n=3, 0.9% of readmissions) were for infarction. Other medical complications included gastrointestinal (n=28, 8.1% of readmissions), cardiac (n=8, 2.3%), pulmonary (n=5, 1.4%), hematologic (n=3, 0.9%), and renal (n=2, 0.6%) complications.

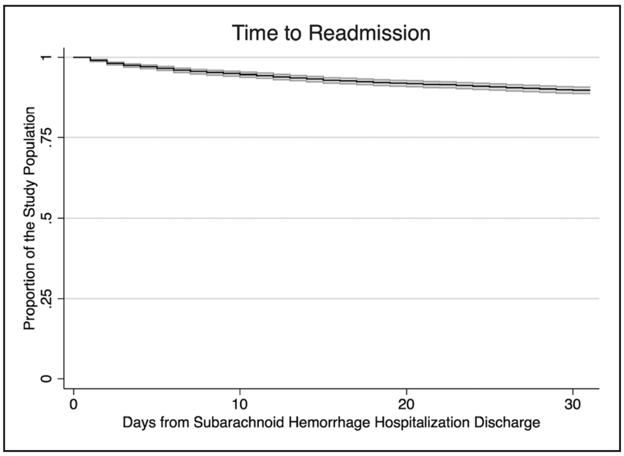

Figure 1. Kaplan–Meier curve depicting the time to readmission (and the 95% confidence interval) among the total study population.

Major operations performed during the readmission were microsurgical clipping of an aneurysm in 1.4% of readmitted patients (n=5), endovascular coil embolization in 3.5% (n=12), and other cranial surgery (including for surgical site infection) in 3.8% (n=13). Additional operations were ventricular shunt placement (13.0% of readmitted patients, n=45), ventricular shunt revision (2.0%, n=7), and cranioplasty (3.2%, n=11); other procedures included ventriculostomy (2.6%, n=9), diagnostic cerebral angiography (6.9%, n=24), and inferior vena cava filter placement (5.5%, n=19).

Subsequently, regression models evaluated the association of sustaining a complication during the SAH hospitalization with readmission for the same complication. Models were constructed for hydrocephalus, other neurological, infectious, gastrointestinal, and venous thromboembolic complications—the most common indications for readmission—after including patient age, number of comorbidities, and Nationwide Inpatient Sample-SAH severity scale as covariates. Hydrocephalus during the index hospitalization was associated with increased odds of readmission for hydrocephalus

Table 2. Multivariable Cox Proportional Hazard Regression Model Evaluating Predictors of 30-Day Readmission

Characteristic	Hazard Ratio	95% CI	*P* Value
Age, y			
Lower quartile	Ref.	…	…
Second quartile	1.26	0.94–1.68	0.09
Third quartile	0.99	0.67–1.45	0.94
Upper quartile	0.96	0.60–1.52	0.86
Insurance status			
Private/other	Ref.	…	…
Medicare	1.27	0.92–1.79	0.13
Medicaid	0.95	0.65–1.40	0.80
Self-pay	1.01	0.68–1.49	0.97
Socioeconomic status			
Lower quartile	Ref.	…	…
Second quartile	1.14	0.87–1.50	0.34
Third quartile	1.21	0.93–1.56	0.16
Upper quartile	1.01	0.72–1.42	0.95
Missing	1.01	0.43–2.40	0.98
No. of comorbidities			
0	Ref.	…	…
1	1.07	0.70–1.63	0.77
2	1.24	0.79–1.94	0.36
≥3	**1.53**	**1.03–2.30**	**0.03**
NIS-SAH severity scale			
Lower quartile	Ref.	…	…
Second quartile	1.20	0.79–1.91	0.44
Third quartile	**1.63**	**1.09–2.44**	**0.02**
Upper quartile	**1.70**	**1.13–2.57**	**0.01**
Intracerebral hemorrhage	1.18	0.75–1.84	0.47
Microsurgical clipping	1.13	0.90–1.42	0.30
Cerebral edema	1.15	0.87–1.54	0.31
Decompressive craniectomy	1.71	0.74–3.92	0.21
Hospital bed size			
Small/medium	Ref.	…	…
Large	0.79	0.58–1.10	0.16
Teaching hospital	0.98	0.68–1.42	0.92
Annual hospital volume of SAH			
Lower quartile	Ref.	…	…
Second quartile	0.87	0.62–1.22	0.42
Third quartile	0.78	0.55–1.11	0.17
Upper quartile	0.76	0.55–1.06	0.10
Complications during the SAH hospitalization			
Neurological	1.10	0.86–1.41	0.43
Cardiac	1.12	0.75–1.67	0.58
Pulmonary	0.82	0.59–1.13	0.22
Gastrointestinal	1.10	0.70–1.71	0.68
Renal	1.24	0.85–1.80	0.27
Hematologic	1.04	0.80–1.36	0.77
Venous thromboembolic	1.10	0.57–2.11	0.78
Infectious	1.31	0.99–1.75	0.05
Tracheostomy or gastrostomy	1.08	0.76–1.53	0.67
Length of SAH hospitalization			
Lower quartile	Ref.	…	…
Second quartile	0.76	0.52–1.12	0.17
Third quartile	0.74	0.53–1.05	0.09
Upper quartile	0.76	0.50–1.16	0.21
Discharge other than to home	**1.70**	**1.28–2.26**	**≤0.001**

Statistically significant differences are from the multivariable Cox proportional hazard regression model are bolded. Age divisions: lower quartile: 18–48 y, second quartile: 49–56 y, third quartile: 57–66 y, and upper quartile: >66 y. NIS-SAH severity scale divisions: lower quartile: ≤1, second quartile: 1, third quartile: 1.10–7.5, upper quartile: ≥7.5. NIS-SAH severity scale scores of the third and upper quartile approximate those of Hunt–Hess grade ≥3.[8] Hospital volume: lower quartile: ≤16, second quartile: 16–30, third quartile: 32–46, and upper quartile: ≥46 SAH hospitalizations/y. Length-of-stay divisions (accounting for all patients with SAH, including those who died during the SAH hospitalization): lower quartile: 0–11, second quartile: 12–16, third quartile: 17–25, and upper quartile: ≥25 days. Hospital bed size is designated by the Agency for Healthcare Research & Quality based on hospital location, region, and teaching status, and is not strictly dependent on the total number of beds. CI indicates confidence interval; NIS, Nationwide Inpatient Sample; and SAH, subarachnoid hemorrhage.

(hazard ratio, 2.47; 95% CI, 1.12–5.45; *P*=0.03). However, other neurological, infectious, gastrointestinal, and venous thromboembolic complications during the SAH hospitalization were not associated with readmission for the respective complication (data not shown).

Outcomes at Readmission

The in-hospital mortality rate during the readmission hospitalization was 1.7% (n=6), the median length of stay was 5 days (IQR, 2–9 days), and charge was \$45 091 (\$24 329–77 976). Among patients discharged from the SAH hospitalization to home, the discharge disposition after the readmission was other than to home in only 11.1%, whereas among those initially discharged other than to home, 75.3% had a disposition after readmission, which remained other than to home, and 24.7% were discharged home.

To evaluate the association of readmission with total patient charges (from both the SAH hospitalization and when applicable, the readmission), a multivariable linear regression

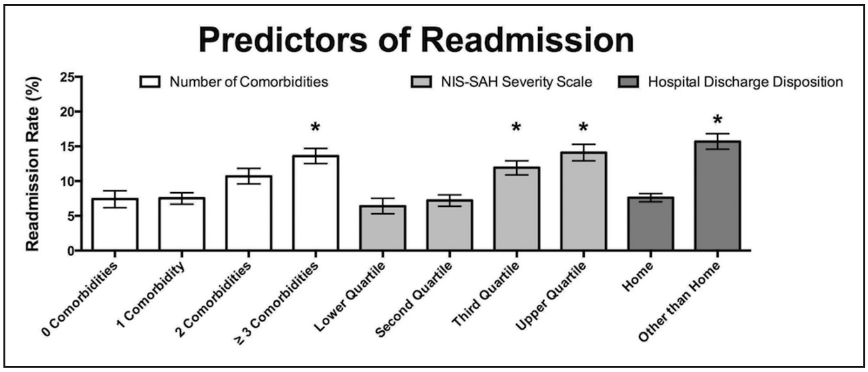

Figure 2. Differences in the crude rates and associated SEs of 30-day readmission rates by number of comorbidities, the Nationwide Inpatient Sample-subarachnoid hemorrhage severity scale, and hospital discharge disposition. Statistically significant differences by multivariable logistic regression are indicated by asterisk.

model was constructed accounting for all patient characteristics, hospital factors, and complications as covariates. Readmission was associated with significantly higher total charges (by \$47 565.63, 95% CI, \$21 375.75–\$73 893.52; P<0.001).

Variance in Hospitalization Readmission Rates

A total of 266 hospitals were included. The median hospital mortality rate during the SAH hospitalization was 9.5% (IQR, 5.4%–14.8%), and the median hospital SAH readmission rate was 8.1% (IQR, 4.2%–11.1%). A multivariable linear regression model evaluated the association of hospital volume of SAH and readmission rate with hospital mortality rate, after including hospital teaching status, bed size, control (government versus private), and the mean hospital-level of patient characteristics (age, number of comorbidities, and Nationwide Inpatient Sample-SAH severity scale) as covariates. Hospital mortality rate was inversely associated with hospital volume (after logarithmic conversion because of non-normal distribution, −1.35%; 95% CI, −2.62 to −0.09; P=0.03) but was not associated with hospital readmission rate (0.32%; 95% CI, −8.55% to 9.19%; P=0.94; R^2=0.17). Additionally, univariable (P=0.28) and multivariable (P=0.49) linear regression revealed no significant association between hospital volume of SAH and hospital SAH readmission rate.

Table 3. Predictors of Readmission After SAH

Predictors of Readmission		
≥3 total comorbidities		
Higher NIS-SAH severity scale*		
Discharge destination other than to home		
Readmission rate by number of predictors		
No. of predictors	Readmission rate, %	95% CI, %
No predictors	5.8	4.4–7.2
One predictor	9.6	7.9–11.3
Two predictors	14.9	12.5–17.2
Three predictors	18.3	12.8–23.6

CI indicates confidence interval; NIS, Nationwide Inpatient Sample; and SAH, subarachnoid hemorrhage.

*A higher severity of SAH as measured by the NIS-SAH severity scale (in the third or upper quartile of the total SAH population), approximately indicative of a Hunt–Hess grade of at least 3.

Discussion

Although readmission is increasingly used as a quality metric, a recent systematic review reported that there remains a dearth of research evaluating the indications for and predictors of readmission in stroke patients[9]—particularly those with aneurysmal SAH. Singh et al[6] published a single-institution study of 283 patients with SAH, reporting an 8% hospital readmission rate, of which the most common reasons were infection, headache, and hydrocephalus, and the only independent predictors were length of hospital stay and ventriculostomy. Moreover, Greenberg et al[5] evaluated 30-day readmission in patients at a single institution, finding that the most common reasons for readmission (11.4%) were hydrocephalus, infections, and thromboembolic events, and the only independent predictor was discharge to a nursing home.[10] However, as single-institution studies, they had limited power to discern predictors of readmission or evaluate whether readmission was related to the same complications from the SAH hospitalization. Additionally, they could not analyze variability in readmission rates across hospitals or examine its relationship with other quality metrics and, therefore, could not assess the suitability of readmission as a quality metric in this population.

In this NRD analysis, 3387 patients from across the United States were extracted to evaluate the rate, associated diagnoses, and predictors of 30-day readmission after aneurysmal SAH in the United States. Readmissions were common, and the total 30-day readmission rate was 10.2%. The most frequent indications for readmission were the development of new neurological or medical complications, and the patients at the highest risk were those with baseline comorbidities or greater severity of SAH.

How Serious Are Readmissions After SAH?

Although readmissions were common, they were rarely associated with untoward outcomes. Notably, the readmission hospitalization was associated with low mortality (1.7%), the indication for rehospitalization was recurrent intracranial hemorrhage or cerebral infarction in only 3.5% of readmitted patients, repeated aneurysm repair or a cranial operation was only required in 8.7%, and only 11.1% of readmitted patients who were initially discharged to home required a subsequent discharge other than to home. Although administrative claims databases do not include neurological severity scales, some have argued that discharge disposition (as a maker of functional independence) is a partial proxy for neurological assessment, and discharge to institutional care or the use of a tracheostomy

Table 4. Reasons for 30-Day Readmission After Aneurysmal SAH

	Clipping (n=119)	Coiling (n=227)	Total Population: by System (n=346, %)	Total Population: by Indications, %	Time to Readmission (Median, IQR)
Total neurological	53	79	132 (38.2)		
Hydrocephalus	23	28		51 (14.7)	11 (3–8)
TIA/CVA	5	11		16 (4.6)	3 (2–17)
Headache	0	14		14 (4.0)	4.5 (3–13)
Hemorrhage	4	5		9 (2.6)	7.5 (5.5–13.5)
Seizure	1	5		6 (1.7)	2 (1–3)
Other neurological	20	16		36 (10.4)	7 (3–15.5)
Total infectious complications	23	43	66 (19.1)	…	…
Sepsis	9	22	…	31 (9.0)	10 (6–16)
Other infectious	14	21	…	35 (10.1)	7 (3–12)
Meningitis/other infections	3	6	…	…	…
Pneumonia	3	4	…	…	…
Surgical site infections	5	2	…	…	…
Urinary tract infection	3	9	…	…	…
Other medical complications	15	31	46 (13.3)	…	5 (1–15)
Venous thromboembolism	11	13	24 (6.9)	…	9 (5–19)
Rehabilitation placement	6	9	15 (4.3)	…	21 (9–27)
Electrolyte abnormalities	3	9	12 (3.5)	…	13 (4–17.5)
Cranioplasty	3	5	8 (2.3)	…	14 (8–19)
Other indications	5	36	41 (11.8)	…	12 (4–18)

Numbers represent number of patients, and percentages are reported in parentheses. Other neurological complications include altered mental status, neurological deficits, syncope, and malaise. Other medical complications include cardiac, pulmonary, gastrointestinal, renal, and hematologic. CVA indicates cerebrovascular accident; IQR, interquartile range; SAH, subarachnoid hemorrhage; and TIA, transient ischemic attack.

or gastrostomy has been shown to have good concordance with a modified Rankin Scale score of >3—at least moderate to severe disability.[8] Therefore, readmission in this population was not associated with significant mortality or morbidity.

Is Readmission an Optimal Quality Indicator?

This NRD analysis suggests that readmission may be a suboptimal quality indicator in the SAH population. First, the independent predictors of readmission were baseline comorbidities and severity of SAH and not complications from the SAH hospitalization. Additionally, with the exception of hydrocephalus, developing a complication during the index hospitalization was not associated with readmission for that diagnosis—arguing that patients are primarily readmitted for new postdischarge complications and not because of poor surveillance of established complications. Delayed hydrocephalus after aneurysmal SAH creates a unique scenario, as extended hospitalizations evaluating the potential requirement for ventricular shunt placement are perhaps of greater patient detriment (and cost) than a subsequent readmission if cerebrospinal fluid diversion is required. Additionally, there was no significant correlation between hospital readmission rates and hospital volume of SAH—a well-described marker of superior outcomes, including in the SAH population.[11] Finally, hospital readmission rates were not associated with mortality rates. Therefore, readmission was primarily attributable to new complications in patients who are at risk for them because of greater burden of comorbidities and increased severity of SAH, and readmission was not associated with other quality metrics evaluated.

Can Readmissions After SAH Be Prevented?

The preventability of readmission based on administrative claims data is difficult to discern, and simply extracting the diagnosis is not sufficient to appreciate if there was a deviation from the standard of care.[5] However, the present analysis provides insight into 3 factors that contribute to readmission—the potential importance of early posthospitalization surveillance, extending readmission reduction programs to patients discharged to medical care, and identifying high-risk patients. First, the frequency of early readmission after hospital discharge (43.4% within the first week and 65.6% within 2 weeks) highlights the importance of early surveillance after discharge. Although the ideal timing of follow-up after hospitalization is debated, some data suggest that an early follow-up telephone calls may improve the posthospital transition of care and reduce readmission[12]; however, this intervention has primarily been evaluated in medical patients discharged to home. Additionally, although readmission reduction programs (including for stroke patients) have primarily targeted patients discharged to home,[13] in this study, a discharge disposition other than to home was an independent predictor of 30-day readmission, highlighting the need for longitudinal care with patients discharged to medical facilities. Finally, the multivariable Cox regression models in this analysis identify patients with the highest hazard of readmission—those with at least 3 total comorbidities, greater SAH severity (approximately those with a Hunt–Hess grade of ≥3), and who had a discharge disposition other than to home—and provides data on readmission rates based on the number of high-risk features.

Limitations and Advantages of the Study Design

The limitations of this study merit further elaboration. First, the NRD identifies readmission of an individual patient using a state-specific identifier; however, if a patient was readmitted to a hospital in a different state from the SAH hospitalization, this would not be captured, thereby potentially underestimating the total readmission rate. Additionally, the NRD does not explicitly denote if a readmission was planned or unplanned, and research has shown that administrative data may not fully account for planned readmissions, thereby overestimating unplanned readmission rates.[14] However, few of the associated diagnoses in this analysis (with the exception of cranioplasty, denoted in 2.3% of readmitted patients) suggested a planned readmission. Moreover, clinical data are encoded in the NRD using *ICD-9-CM* identifiers. Although the Nationwide Inpatient Sample-SAH severity score has been previously validated as a means for severity adjustment in analyses of administrative claims data because of its concordance with Hunt–Hess grade, the scale itself is not used in clinical practice; additionally, other important characteristics in patients with aneurysmal SAH such as World Federation of Neurological Surgeons, Fisher grade, aneurysm location or size, a nuanced assessment of delayed cerebral ischemia, and modified Rankin Scale were not available because of the lack of corresponding *ICD-9-CM* identifier.

Conclusions

As the largest all-payer longitudinal database in the United States designed to specifically capture readmissions, the NRD provides a unique perspective on the indications for and variability in readmission nationally. The broad accruement of patients from 21 states admitted to different types of hospitals increases the generalizability of the findings and allows for a hospital-level analysis of readmission. This NRD analysis highlights patients with the greatest hazard of readmission after SAH and may be used to shape future SAH-specific readmission reduction programs. Additionally, the present study suggests that readmission may be a suboptimal quality indicator in the SAH population. Although readmissions have many desired characteristics of a quality indicator—they are common, objective, and easily quantifiable[15]—the fact that readmissions were not associated with significant mortality or morbidity, as well as the lack of correlation with other quality metrics, argues against its use as a quality indicator.

Disclosures

Dr Gormley is a proctor for Codman. Dr Aziz-Sultan is a proctor for Covidien and Codman. The other authors report no conflicts.

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Stroke. 2017;48:2383-2390; originally published online July 28, 2017;
doi: 10.1161/STROKEAHA.117.016702
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0039-2499. Online ISSN: 1524-4628