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Preventable Readmissions and Predictors of Readmission After Subarachnoid Hemorrhage

John W. Liang[1,2,3*†], Laura Cifrese[2†], Lili Velickovic Ostojic[3], Syed O. Shah[1] and Mandip S. Dhamoon[4]

Abstract

Objective: To estimate rates of all-cause and potentially preventable readmissions up to 90 days after discharge for aneurysmal subarachnoid hemorrhage (SAH) and medical comorbidities associated with readmissions

Background: Readmission rate is a common metric linked to compensation and used as a proxy to quality of care. Prior studies in SAH have reported 30-day readmission rates of 7–17% with a higher readmission risk among those with the higher SAH severity, ≥ 3 comorbidities, and non-home discharge. Intermediate-term rates, up to 90-days, and the proportion of these readmissions that are potentially preventable are unknown. Furthermore, the specific medical comorbidities associated with readmissions are unknown.

Methods: Index SAH admissions were identified from the 2013 Nationwide Readmissions Database. All-cause readmissions were defined as any readmission during the 30-, 60-, and 90-day post-discharge period. Potentially preventable readmissions were identified using Prevention Quality Indicators developed by the US Agency for Healthcare Research and Quality. Unadjusted and adjusted Poisson models were used to identify factors associated with increased readmission rates.

Results: Out of 9987 index admissions for SAH, 7949 (79%) survived to discharge. The percentage of 30-, 60-, and 90-day all-cause readmissions were 7.8, 16.6, and 26%, respectively. Up to 14% of readmissions in the first 30 days were considered potentially preventable and acute conditions (dehydration, bacterial pneumonia, and urinary tract infections) accounted for over half, whereas acute cerebrovascular disease was the most common cause for neurological return. In multivariable analysis, significant predictors of a higher readmission rate included diabetes (rate ratio [RR] 1.09, 95% confidence interval [CI] 1.03–1.15), congestive heart failure (RR 1.09, 1.003–1.18), and renal impairment (RR 1.35, 1.13–1.61). Only discharge home was associated with a lower readmission rate (RR 0.89, 0.85–0.93).

Conclusions: SAH has a 30-day readmission rate of 7.8% which continues to rise into the intermediate-term. A low but constant proportion of readmissions are potentially preventable. Several chronic medical comorbidities were associated with readmissions. Prospective studies are warranted to clarify causal relationships.

Keywords: Subarachnoid hemorrhage, Readmission, Predictors, Aneurysm, Quality

*Correspondence: john.liang@jefferson.edu
†John W. Liang and Laura Cifrese are co-first authors.
2 Department of Neurology, Thomas Jefferson University, Philadelphia, PA, USA
Full list of author information is available at the end of the article

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Introduction

Hospital readmission rate after aneurysmal subarachnoid hemorrhage (SAH) is an important quality measurement because of an increasing emphasis on safe, effective, and patient-centered health care [1]. Policy makers have focused on readmission rates, specifically preventable readmissions, as a way to quantify and track health care quality. This has translated into penalties for hospitals for readmissions, as illustrated in the Patient Protection and Affordable Care Act and Hospital Readmissions Reduction Program. The recent legislation changes aim to reduce overall costs of care by providing financial incentives for institutions that can the lower readmission rates. Despite the ongoing debate on the appropriateness of these policies, it is important to have nationwide data on readmission rates associated with modern-day management of SAH to inform meaningful discussion and implement changes.

SAH accounts for 5–10% of strokes annually and is associated with significant morbidity and mortality [2, 3]. It accounts for up to 27% of all stroke-related years of potential life lost before age 65 [4]. SAH is associated with significant depression, poor quality of life, and the higher occupational disability compared to ischemic stroke [5, 6]. Disparities exist in the risk of developing SAH and its in-hospital mortality based upon gender, age, race-ethnicity, and treating hospital size [2, 7–9]. Prior studies on 30-day readmission rates were reported to be in the range of 8–17%; however, these studies were limited by small sample sizes, [10, 11] single-center design, [10–12] or restriction to Medicare beneficiaries age $\geq$ 65 [13]. An analysis on the recently released Nationwide Readmissions Database (NRD) reports a national 30-day rate of 10.2%, and the most common reasons for readmission were neurological, hydrocephalus, infectious, and venous thromboembolic complications [14]. The authors conclude that the all-cause readmission rate is a suboptimal quality indicator because most patients were primarily readmitted for new post-discharge complications rather than exacerbations of complications from the hospitalization, thus questioning the preventability of readmissions.

To understand the magnitude of preventable readmissions, the Prevention Quality Indicators (PQIs), developed by the Agency for Healthcare Research and Quality (AHRQ), have previously been used in other conditions such as acute ischemic stroke and sepsis [15–17]. The PQIs are a set of common ambulatory care sensitive conditions that are considered manageable with effective outpatient care to avoid hospitalizations and are arguably a better quality metric than all-cause readmissions. Broadly these conditions are divided into four groups: diabetes-related indicators, cardiovascular-related indicators, chronic lung condition indicators, and acute-condition indicators. The PQI software modules are publically available (qualityindicators.ahrq.gov).

The goal of this NRD analysis was to (1) estimate national rates of all-cause readmissions and the proportion of which are potentially preventable readmissions at 30, 60, and 90 days after discharge for SAH and (2) identify common medical comorbidities that are predictors of readmission.

Methods

The Nationwide Readmissions Database (NRD) is a national database of readmissions for all payers and the uninsured with data on more than 14 million US admissions during the year 2013. It is one of seven publically available databases in the Healthcare Cost and Utilization Project (HCUP) developed by the AHRQ. The NRD is derived from State Inpatient Databases from 21 geographically dispersed states, comprising data from 49.1% of all US hospitalizations. It includes all discharge records from US hospitals, excluding rehabilitation and long-term acute-care facilities. The NRD allows analysis of readmissions with the use of a verified linkage identifier for each individual, which has been anonymized to comply with privacy guidelines. The Mount Sinai Institutional Review Board reviewed and approved this project, and all analyses comply with the HCUP data use agreement.

We used International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) codes to identify index aneurysmal subarachnoid hemorrhage SAH as in prior publications [13, 18–20]. Patients were included if they had ICD-9-CM diagnosis code of SAH (430) in the primary position, which has been previously validated to have a sensitivity of 92–98% and specificity of 98% [21, 22]. Patients were additionally excluded if they had ICD-9-CM codes for ruptured syphilitic aneurysm (094.87), cerebral arteritis (437.4), head trauma (800.0–801.9, 803.0–804.9, 850.0–854.1, 873.0–873.9), or arteriovenous malformation and/or fistula (ICD-9-CM 747.81; procedure code 39.53, 92.30). Data on demographics (age, gender, income quartile for zip code, primary expected payer), comorbidities (atrial fibrillation/flutter, congestive heart failure [CHF], diabetes, hypertension, hyperlipidemia, renal impairment, chronic obstructive pulmonary disease [COPD], smoking), and hospitalization outcomes (tracheostomy, percutaneous endoscopic gastrostomy [PEG], discharge disposition, length of stay, and total hospitalization costs) were abstracted. Characteristics of the index hospitalization were defined by HCUP and included hospital bed size (small, medium, or large), teaching hospital status (metropolitan non-teaching, metropolitan teaching, and non-metropolitan hospital), and National Center for Health Statistics urban–rural location classification ("central" counties

of metro areas of ≥ 1 million population, "fringe" counties of metro areas of ≥ 1 million population, counties in metro areas of 250,000–999,999 population, counties in metro areas of 50,000–249,999 population, micropolitan counties, and not metropolitan or micropolitan counties).

We defined all-cause readmission as any admission within 30, 60, and 90 days after index hospitalization discharge. Reasons for readmission were identified using the HCUP clinical classification software, which collapses readmission ICD-9 diagnosis and procedure codes into smaller and clinically meaningful categories. Potentially preventable readmissions were identified according to PQI methodology [17]. Clinical data relevant to SAH (such as Hunt and Hess) are not encoded through ICD-9 codes. The National Institutes of Health–SAH Severity Scale (NIS–SSS), a validated severity scale using administrative datasets with strong correlation to Hunt and Hess grade, was calculated for each patient based on the diagnosis and procedure codes for coma, hydrocephalus, paresis/plegia, aphasia, cranial nerve deficits, treatment of hydrocephalus, and mechanical ventilation in accordance with published methodology [18]. Similarly, the validated NIS–SAH Outcome Measure (NIS–SOM) was used as a proxy for discharge modified Rankin Scale (mRS) [18]. NIS–SOM is a dichotomous variable with good outcome defined as discharge to home or rehab facility and/or hospital. Poor outcome is defined as in-hospital mortality, discharge to nursing facility, extended care facility, hospice, placement of tracheostomy and/or PEG. It has 85% agreement when poor outcome defined as mRS > 2 and 95% agreement when poor outcome defined as mRS > 3.

Statistical Analysis

We calculated all-cause readmission rates as the number of readmissions within 30, 60, and 90 days of discharge from the index hospitalization, and reported rates per 100,000 index admissions. Similarly, we calculated preventable readmission rates as the number of all-cause readmissions that fulfilled PQI criteria. Readmission rates are reported per 100,000 index admissions. Due to the time restriction of the NRD from January 1, 2013 to December 31, 2013, we excluded any index hospitalizations that began in December for the 30-day readmission rates calculation due to concern that patients may be readmitted within 30 days but lie outside the range of the 2013 NRD dataset. Similarly, to calculate 60-day rates, we excluded index hospitalizations in November and December; and to calculate 90-day rates, we excluded index hospitalizations in October, November, and December. We compared cost of re-hospitalization among preventable and non-preventable readmissions.

We first ran a univariate Poisson regression analysis using demographics, comorbidities, hospitalization outcomes, and hospital characteristics to determine variables that are independently associated with readmissions. We also included NIS–SOM and NIS–SSS as a proxy for Hunt & Hess grade and mRS. We accounted for the risk of mortality based on the subclass assigned by 3 M's All Patient Refined Diagnosis Related Group (APR-DRG) software, based on likelihood of dying, with 1 = minor, 2 = moderate, 3 = major, 4 = extreme. Lastly, we included severity of illness based on the subclass assigned by 3 M's APR-DRG software and classified similarly as the APR-DRG risk of mortality. After the univariate analysis, a multivariate Poisson regression analysis was performed to assess all variables with $p = 0.10$ in the univariate analysis. We did not include NIS–SOM and Charlson comorbidity index (CCI) into the multivariate model due to collinearity with other significant predictors. Rate ratios were calculated for all categorical variables. Subgroup analysis was performed for the outcomes of PQI ("preventable") readmissions and non-PQI ("unpreventable") readmissions. Analyses were performed in SAS version 9.4 and R version 3.3.1.

Results

Baseline Characteristics and Discharge Dispositions

Table 1 shows baseline characteristics for the 9987 index SAH admissions. The mean age of the patients was 59.9 ± 15.6 years, and 62% were women. Socioeconomic status, measured by median income by zip code, was evenly distributed. The mean CCI was 1.86 ± 1.93, and there was a high prevalence of comorbid vascular risk factors. Patients were treated mostly in large, teaching, metropolitan hospitals with an average length of stay (LOS) of 13.97 ± 15.73 days and average hospitalization cost of $\$225,273 \pm \$261,942$. A total of 4276 (42.8%) patients were discharged home, 2217 (22.2%) discharged to skilled nursing facility, and 2038 (20.4%) died during the index admission.

Total and Preventable Readmission Rates

Among the 7949 patients who survived to discharge, there were a total of 2639 readmissions (33.2%) up to 1 year. There was a progressive rise in readmission rate (per 100,000 index admissions) for all-causes into the intermediate follow-up period: 7851 at 30 days, 16,643 at 60 days, and 26,036 at 90 days (Table 2). Over 20% of readmissions in the first 30 days were due to acute cerebrovascular disease; this was followed by septicemia at 5.25% (Table 3). The proportion of potentially preventable readmission was highest at 14% by 30 days and declined to 10.8% by 90 days. Acute conditions (dehydration, bacterial pneumonia, and urinary tract infections)

Table 1 Baseline characteristics of study population at index event

	aSAH
Number of participants	9987
Age, mean (SD)	59.87 (15.56)
Female, no. (%)	6206 (62.14)
Primary expected payer, no. (%)	
Medicare	3910 (39.26)
Medicaid	1271 (12.76)
Private insurance	3405 (34.19)
Self-pay	856 (8.6)
No charge	77 (0.77)
Other	440 (4.42)
Median income for zip code, no. (%)	
0–25th percentile	2653 (27.1)
26th–50th percentile	2422 (24.74)
51st–75th percentile	2483 (25.37)
76th–100th percentile	2231 (22.79)
Hospital characteristics, no. (%)	
Bed size	
Small	426 (4.27)
Medium	1533 (15.35)
Large	8028 (80.38)
Urban–rural designation	
Large metropolitan	6506 (65.14)
Small metropolitan	3314 (33.18)
Micropolitan	137 (1.37)
Non-urban	30 (0.3)
Teaching status	
Metropolitan teaching	7835 (78.45)
Metropolitan non-teaching	1985 (19.88)
Non-metropolitan	167 (1.67)
APR-DRG* mortality risk, no. (%)	
Minor likelihood	1170 (11.72)
Moderate likelihood	2134 (21.37)
Major likelihood	3133 (31.37)
Extreme likelihood	3549 (35.54)
APR-DRG* illness severity subclass, no. (%)	
No or minor loss of function	231 (2.31)
Moderate loss of function	593 (5.94)
Major loss of function	5394 (54.02)
Extreme loss of function	3768 (37.73)
Medical history, no. (%)	
Atrial fibrillation or atrial flutter	957 (9.58)
Congestive heart failure	657 (6.58)
Diabetes	1790 (17.92)
Hypertension	6148 (61.56)
Hyperlipidemia	2763 (27.67)
Renal impairment	115 (1.15)
Chronic obstructive pulmonary disease	809 (8.10)
Smoking	3033 (30.37)
Charlson comorbidity index, mean (SD)	1.86 (1.93)

Table 1 continued

	aSAH
NIS–SSS, no. (%)	
0–5	6174 (61.82)
5–10	2834 (28.38)
>10	979 (9.80)
NIS–SOM, no. (%)	
Good outcome	4445 (44.73)
Tracheostomy	677 (6.78)
PEG	821 (8.22)
Disposition, no. (%)	
Home	4276 (42.82)
Short-term hospital	230 (2.3)
Skilled nursing facility	2217 (22.2)
Home health care	1072 (10.74)
Died in hospital	2038 (20.41)
Length of stay, day, mean (SD)	13.97 (15.73)
Total hospitalization cost ($), mean (SD)	225,273 (261,942)

APR-DRG All Patient Refined Diagnosis Related Group; *aSAH* Aneurysmal Subarachnoid Hemorrhage; *NIS–SSS* Nationwide Inpatient Sample–Subarachnoid Severity Scale; *NIS–SOM* Nationwide Inpatient Sample–Subarachnoid Outcome Measure; *PEG* Percutaneous Endoscopic Gastrostomy

accounted for over half of the preventable readmissions, followed by cardiovascular-related conditions (hypertension and heart failure). Readmissions identified as potentially preventable, compared to those that were not, had the lower mean hospitalization cost for the readmission ($38,438 ± 49,499 vs. $76,256 ± 130,388, $p < 0.0001$).

Predictors of Readmission

In univariate analysis, variables associated with increased readmission rate include age, atrial fibrillation, CHF, diabetes, renal impairment, COPD, tracheostomy, PEG, high NIS–SSS, discharge to facility other than home, and greater LOS (Table 4). Sex, socioeconomic status, medical insurance, and hospital type were not associated with readmission. In multivariable analysis, significant predictors of the higher readmission rate included CHF (rate ratio [RR] 1.09), diabetes (RR 1.09), and renal impairment (RR 1.35). The only factor associated with the lower readmission rate was discharge home (RR 0.89). Increasing age, longer LOS, SAH severity measured by NIS–SSS, and PEG/Trach was not associated with readmission (Table 5). In subgroup analysis of unpreventable readmissions, renal impairment and non-home discharge maintained strong associations with increase readmission risk; however, CHF and diabetes were no longer significant (Supplemental Tables 3–4).

Discussion

Hospital readmission has gained significant momentum as a health care benchmark over recent years. In this

Table 2 Potentially preventable and all-cause readmission rates (per 100,000) after aneurysmal subarachnoid hemorrhage

	30 days	60 days	90 days
All-cause readmission rate, per 100,000 index admission (%)	7851.07 (7.85)	16,643.66 (16.64)	26,036.63 (26.04)
Preventable rate, per 100,000 index admission (%)*	1101.66 (14.03)	1902.13 (11.43)	2816.17 (10.82)
Diabetes related	112	138	259
Cardiovascular related	363	552	743
Chronic lung conditions	14	77	138
Acute-conditions	614	1135	1676

*Diabetes-related indicators (diabetes short-term complications, diabetes long-term complications, uncontrolled diabetes, lower-extremity amputation); cardiovascular-related indicators (hypertension, heart failure); chronic lung conditions (COPD, asthma), acute-conditions (dehydration, bacterial pneumonia, urinary tract infection, perforated appendix)

Table 3 Absolute and cumulative proportions for the top 10 causes of 30-day hospital readmissions for patients with aneurysmal subarachnoid hemorrhage

Rank	Diagnosis and procedure related category	Frequency	Absolute proportion
1	Acute cerebrovascular disease	119	23.15
2	Septicemia (except in labor)	27	5.25
3	Other hereditary and degenerative nervous system conditions	25	4.86
4	Headache including migraine	22	4.28
5	Urinary tract infections	18	3.5
6	Complications of surgical procedures or medical care	18	3.5
7	Other nervous system disorders	14	2.72
8	Other and ill-defined cerebrovascular disease	14	2.72
9	Epilepsy; convulsions	13	2.53
10	Transient cerebral ischemia	13	2.53

nationally representative, retrospective study on 9987 SAH admissions using administrative data, we found that the percentage of patients readmitted progressively increased from 7.8% at 30 days, 16.6% at 60 days, to an alarming 26% at 90 days, equating to about one out of every four SAH discharges. Though the percentage of readmissions increased with each time period, the percentage of preventable admissions was highest during the first 30 days post-discharge.

We examined common medical comorbidities and report previously unrecognized conditions that are associated with higher readmissions. Hypertension and smoking are two of the most important risk factors for SAH [23, 24]. A recent study also identified these as risk factors for dying before hospital admission (pre-hospital mortality) [25]. However, these are not significantly associated with readmissions. Conversely, the comorbidities that were identified in this study as significant predictors of readmission have not been found to be risk factors for developing SAH. In fact, diabetes has been shown to be associated with reduced risk of SAH [23, 26], although the biological basis is not well understood. Increasing age, longer LOS, SAH severity, and PEG/Trach were

not associated with readmissions countering the common assumption that neurologically sicker patients with a more complicated hospital course are at risk. Hospital administration should take caution when implementing campaigns to reduce LOS in SAH patients for perceived financial savings in that it potentially may have the unintended opposite effect of discharging patients too soon before they are fully medically optimized.

The conditions identified are chronic medical conditions which, with or without SAH, are notably difficult to manage. CHF, diabetes, and renal impairment were the sole independent predictors of readmissions, and most preventable readmissions were for issues tied to these chronic illnesses (dehydration, bacterial pneumonia, urinary tract infections, hypertension and heart failure). In subgroup analysis, increasing age and medical comorbidities, but not discharge disposition, were identified as predictors of PQI ("preventable") readmissions. However, CHF and diabetes were no longer significantly associated with non-PQI ("unpreventable") readmissions. Taken together, this suggests that these patients are chronically ill, and readmissions after SAH may be coincidental with no reflection on the quality of care rendered during

Table 4 Univariate Poisson model testing factors associated with readmission

Variable	Estimate	95% CI	Relative ratio	95% CI	*p* value
Age, per year	0.002	0.0005–0.003			0.007
Female	0.02	− 0.02, 0.06	1.02	0.98–1.06	0.3
Private or medicare insurance	0.02	− 0.02, 0.07	1.02	0.98–1.07	0.29
Median income					
26th–50th percentile	− 0.02	− 0.08, 0.03	0.98	0.93–1.03	0.41
51st–75th percentile	− 0.02	− 0.08, 0.03	0.98	0.93–1.03	0.38
76th–100th percentile	− 0.05	− 0.1, 0.01	0.95	0.9–1	0.09
Hospital type					
Metropolitan teaching	− 0.005	− 0.05, 0.04	0.99	0.95–1.05	0.85
Non-metropolitan	− 0.08	− 0.24, 0.09	0.93	0.78–1.1	0.37
Medical history					
Atrial fibrillation or atrial flutter	0.10	0.03–0.16	1.1	1.03–1.17	0.004
Congestive heart failure	0.15	0.07–0.22	1.16	1.07–1.25	0.0002
Diabetes	0.11	0.06–0.16	1.12	1.06–1.17	< 0.0001
Hypertension	0.03	− 0.01, 0.07	1.03	0.99–1.07	0.17
Hyperlipidemia	0.03	− 0.02, 0.07	1.03	0.98–1.07	0.24
Renal impairment			1.4	1.18–1.66	< 0.0001
COPD	0.11	0.04–0.18	1.12	1.04–1.2	0.001
Smoking	− 0.01	− 0.05, 0.03	0.98	0.95–1.03	0.62
CCI, per point	0.04	0.03–0.05			< 0.0001
Tracheostomy	0.2	0.14–0.27	1.23	1.15–1.31	< 0.0001
PEG	0.19	0.13–0.25	1.2	1.13–1.28	< 0.0001
NIS-SSS, per point	0.004	0.002–0.005			< 0.0001
5–10	0.12	0.08–0.17	1.13	1.08–1.19	< 0.0001
> 10	0.15	0.06–0.23	1.16	1.07–1.26	0.0006
NIS–SOM good outcome	− 0.14	− 0.18, − 0.1	0.87	0.84–0.9	< 0.0001
Discharge home	− 0.16	− 0.2, − 0.12	0.85	0.82–0.88	< 0.0001
Length of stay, per day	0.003	0.002–0.004			< 0.0001

CCI charlson comorbidity index; *CI* Confidence Interval; *COPD* chronic obstructive pulmonary disease; *NIS-SSS* Nationwide Inpatient Sample-Subarachnoid Severity Scale; *NIS-SOM* Nationwide Inpatient Sample-Subarachnoid Outcome Measure; *PEG* percutaneous endoscopic gastrostomy

Table 5 Multivariate Poisson model of variables significant at *p* = 0.1 in univariate analysis

Variable	Estimate	95% CI	Rate ratio	95% CI	*p* value
Age, per year	− 0.0004	− 0.002, 0.001	–	–	0.6
Medical history					
Atrial fibrillation or atrial flutter	0.03	− 0.04, 0.1	1.03	0.96–1.11	0.38
Congestive heart failure	0.08	0.003, 0.17	1.09	1.003–1.18	0.04
Diabetes	0.08	0.03, 0.14	1.09	1.03–1.15	0.001
Renal impairment	0.3	0.12, 0.48	1.35	1.13–1.61	0.0009
COPD	0.07	− 0.002, 0.14	1.07	0.99–1.15	0.056
NIS–SSS					
5–10	0.02	− 0.03, 0.08	1.02	0.97–1.08	0.4
> 10	0.02	− 0.07, 0.12	1.02	0.93–1.13	0.66
Tracheostomy	0.06	− 0.04, 0.15	1.06	0.96–1.16	0.23
PEG	0.05	− 0.03, 0.13	1.05	0.97–1.14	0.24
Discharge home	− 0.12	− 0.16, − 0.07	0.89	0.85–0.93	< 0.0001
Length of stay, per day	0.001	− 0.0006, 0.003	–	–	0.2

CI Confidence Interval; *COPD* chronic obstructive pulmonary disease; *NIS-SSS* Nationwide Inpatient Sample-Subarachnoid Severity Scale; *NIS-SOM* Nationwide Inpatient Sample-Subarachnoid Outcome Measure; *PEG* percutaneous endoscopic gastrostomy

the initial SAH hospitalization. Furthermore, these findings question the appropriateness of using readmission as a quality metric in SAH. It is interesting to note that renal impairment was not a significant predictor for preventable readmission but was associated with a 28% increase risk of unpreventable readmission (Supplemental Tables 2, 4).

Preventable readmissions account for 1 out of every 10 readmissions which is similar to that seen in other cerebrovascular diseases such as ischemic stroke [15, 27]. A preventable readmission suggests that hospitalization can be avoided with improved discharge planning, effective inpatient to outpatient transition handoff, and timely follow-up care. We must also bear in mind that the validated PQI criterion is geared toward common ambulatory conditions and may under-represent the true number of preventable readmissions. It would be premature to assume that all readmissions not fulfilling the PQI criteria were unpreventable. Readmissions to a hospital are dependent on the emergency department's evaluation and diagnosis rather than by that of the original treatment team during the index event. The threshold for a primary care physician to send to the emergency department and for the emergency department to admit vague post-SAH neurological symptoms such as dizziness, headache, numbness and tingling is understandably lower than if the patient was evaluated by a neuroscience team. Therefore, development of neurocritical care follow-up clinics is logical and will hopefully reduce readmissions after SAH.

Our findings have some significant differences from a recent NRD analysis by Dasenbrock et al. which identified ≥ 3 comorbidities, increased severity of SAH (based on NIS–SSS), and disposition other than to home as independent predictors of readmission [14]. Our analysis did not find any association between SAH severity and readmission which is in agreement with prior studies [10, 11]. The discrepancy is likely due to the way our cohorts were identified. In our analysis, as well as the original derivation paper for the NIS–SSS [18], SAH patients were identified with ICD-9 code 430 in the primary position. This has been previously validated with sensitivity and specificity up to 98% [21, 22]. Dasenbrock et al. restricted their analysis to patients with ICD-9 codes for SAH (430) or intracerebral hemorrhage (431 and 432.9) and procedure codes for microsurgical clipping or endovascular embolization. The additional restrictions resulted in a sample of 3806 patients, about half of our total sample size, and the coding accuracy of this method is unclear. For consistency, we suggest future NRD analysis utilizing NIS-SSS should identify SAH patients using the same validated method as the derivation.

Aside from the NRD, prior studies quantifying SAH readmission rates and predictors have been limited by small samples from single centers and data restricted to elderly patients. In a study of 255 SAH survivors discharged from a single neuro-ICU over a 6-year period, there were 21 (8%) patients readmitted within 30 days [10]. Another single-center study looked at 778 SAH patients over a 10-year period and reported 97 readmission events (11.4%) within 30 days [12]. Lastly, a 2006 population-based study using administrative data for Medicare beneficiaries aged 65 years or older reported a 30-day readmission rate of 17% [13]. The mechanism behind this the higher readmission rate is unclear. It may potentially be related to the higher age in the Medicare cohort; however, our study did not find a significant association between increasing age and readmission rate. Compared to this current study, the Medicare cohort had both the higher in-hospital mortality (33.2 vs. 20.4%) and 30-day readmissions (17 vs. 7.8%). It is also possible that improvements in SAH management and general ICU care over the last 2 decades have attenuated the impact of age on outcomes in SAH.

There are limitations associated with the usage of administrative data which may be prone to misclassifications and inaccuracy. However, the sensitivity and specificity of ICD-9-CM codes for SAH have been previously validated and found to be excellent. Commonly accepted measurements of SAH severity, such as the Hunt and Hess Score, are not available in this database; therefore, the validated NIS–SSS was used as a proxy. Data on clinical variables (e.g., intracranial pressure, location of aneurysm, laboratory values) or medication administration are unavailable. This study extracted a limited list of common medical comorbidities, and while we were able to identify factors such as diabetes, renal impairment, and CHF as risk factors, we are unable to determine the degree or severity of these comorbidities. Readmissions derived from this administrative dataset represent encounters and not individual patients. Despite these limitations, our study represents the largest sample of data available to date on SAH all-cause and preventable readmissions rates up to 90 days and can serve as a foundation to help providers recognize high-risk subgroups requiring extra attention to curb readmission rates.

Conclusion

In summary, we demonstrated that readmissions after SAH are prevalent. The debate on appropriateness of using all-cause readmission rates as a quality metric continues; however, we show that at least 10–14% of all-readmissions are considered as potentially preventable and thus serves as a good starting target for improvement. Additionally, we have identified several factors associated with readmissions after SAH, but further research is needed to clarify causal relationships.

Author details
[1] Divisions of Cerebrovascular Disease, Critical Care, and Neurotrauma, Thomas Jefferson University, Philadelphia, PA, USA. [2] Department of Neurology, Thomas Jefferson University, Philadelphia, PA, USA. [3] Department of Neurology, Mount Sinai Downtown, New York, NY, USA. [4] Department of Neurology, Icahn School of Medicine at Mount Sinai, New York, NY, USA.

Author's Contributions
JWL and SOS were involved in study concept and design. JWL and LC drafted the manuscript. JWL, LC, LVO and MD helped in acquisition, analysis, or interpretation of data. MD performed statistical analysis. SOS and MD contributed to critical revision of the manuscript.

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Compliance with Ethical Standards

Conflict of interest
The authors declare that they have no conflict of interest.

Ethical Approval
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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