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Research article

Annual incidences and predictors of 30-day readmissions following spontaneous intracerebral hemorrhage from 2010 to 2014 in the United States: A retrospective Nationwide analysis

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ABSTRACT

Objective: 30-day readmission rate is a quality metric often employed to represent hospital and provider performance. Currently, little is known regarding 30-day readmissions (30dRA) following spontaneous intracerebral hemorrhage (sICH). The purpose of this study was to use a national database to identify risk factors and trends in 30dRAs following sICH.

Patients and methods: 64,909 cases with a primary diagnosis of sICH were identified within the Nationwide Readmission Database (NRD) from 2010 through 2014. Charlson Comorbidity Index (CCI) was used to adjust for the severity of each patient's comorbidities. A binary logistic regression model was constructed to identify predictors of 30-day readmission. Cochran-Mantel-Haenszel test was used to generate a pooled odd ratio (OR) describing the likelihood of experiencing a 30dRA according to year.

Results: The 30dRA rate following sICH decreased from 13.9% in 2010 to 12.5% in 2014 (pooled OR = 0.90, 95% CI 0.87–0.94). Cerebrovascular and cardiovascular etiologies accounted for the greatest number of admissions (36.1%). Sodium abnormality, healthcare-associated infection, gastrostomy, venous thromboembolism, and ischemic stroke during the index admission were associated with 30-day readmission. Furthermore, patients who underwent ventriculostomy (OR = 1.20, 95% CI 1.03–1.38) and craniotomy (OR = 1.20, 95% CI 1.09–1.31) were more likely to be readmitted within 30 days. Hospital volume, hospital teaching status, mechanical ventilation, and tracheostomy did not affect 30dRAs. Median readmission costs increased from $9,875 in 2012 to $11,028 in 2014 ($p = 0.040$).

Conclusion: The overall U.S. 30dRA rate after sICH from 2010 to 2014 was 12.9% and decreased slightly during this time period, but associated costs increased. Prospective studies are required to confirm the risk factors described in this study and to identify methods for preventing readmissions.

1. Introduction

Rates of 30-day readmission (30dRA) have become an important metric used to represent hospital and provider performance [1, 2]. Unplanned readmissions pose a significant economic burden of more than $17 billion per year [3]. For this reason, the United States' Affordable Care Act (ACA) began penalizing hospitals of their reimbursements based on 30dRA rates [2]. Additionally, clinicians and researchers have begun to analyze 30dRA rates as quality measures, because data has shown that they correlate directly with hospital mortality rates [4]. Patients are often readmitted for exacerbations of their presenting problem, and many of these readmissions are preventable [1].

Stroke was recently added to the list of conditions in which 30dRAs are penalized by the ACA, which prompted numerous studies that analyzed readmission rates for various cerebrovascular insults [1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26]. Despite recent efforts, there remains limited knowledge regarding annual trends and risk factors for 30dRA among patients with spontaneous intracerebral hemorrhage (sICH). Published data regarding 30dRA rates and risk factors following sICH is largely limited to single institution studies and relatively small registries. The Nationwide Readmission Database (NRD) is currently the largest all-payer nationally accrued database in the United States developed specifically to capture readmissions data and has recently been used to study readmissions for

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several neurologic and neurosurgical conditions [1, 10, 21, 23, 26, 27, 28, 29, 30]. This study utilized the NRD to provide a large scale, national database analysis of 30dRA rates following sICH.

The goals of this study were to (a) identify trends in annual 30dRA rates following sICH, (b) identify risk factors for 30dRAs following sICH, (c) determine the most common indications for readmission after sICH, and (d) quantify the costs associated with readmissions after sICH. We hypothesized that increased age, greater comorbidity burden, presence of medical and neurologic complications during the index hospitalization, and more severe hemorrhage would be associated with greater odds of 30dRA.

2. Patients and methods

2.1. Data source

The NRD was used to identify patients for this study (https://www.hcup-us.ahrq.gov/nrdoverview.jsp). This is a publicly available dataset that includes inpatient data obtained from hospital discharges in 27 states participating in the Healthcare Cost and Utilization Project (HCUP). The database provides patient linkage numbers that allow users to track readmissions in the same state and calendar year for individual patients. Data includes over 100 clinical and nonclinical variables including demographics, payment sources, and up to 25 diagnoses and procedures per discharge provided as International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. All variables are provided for both index admissions and readmissions. The NRD includes data from approximately 17 million discharges annually.

2.2. Study population

The NRD was used to screen for adult index admissions between 2010 through 2014 with a primary diagnosis of non-traumatic ICH (431.0). This ICD-9-CM code has a sensitivity of 81–85% and a positive predictive value of 79–97% for ICH [5]. We did not include years 2015 or later due to the change from ICD-9-CM to ICD-10-CM. Patients who were discharged in December were excluded because it is not possible to track readmissions for individual patients across calendar years with the NRD. Elective admissions and those missing length of stay (LOS) information were excluded. Patients who were not residents of the same state that they were hospitalized in for their index admission were excluded because it is not possible to track readmissions for individual patients across different states. We also excluded patients with a structural cause of hemorrhage by identifying secondary diagnoses of a brain tumor (191.x, 198.3, 225.0, 225.9, 239.6) or a cerebral arteriovenous malformation (747.81) to select for only spontaneous ICH.

2.3. Comorbidity and severity adjustment

The Charlson Comorbidity Index (CCI) was used to adjust for the severity of each patient's comorbidities. This is a weighted score that accounts for several comorbidities and has been associated with functional outcomes after ICH [31]. Since typical measures of hemorrhage severity such as the ICH score are not available within the NRD, we included diagnoses that might have indicated more severe ICH as covariates, including hydrocephalus, cerebral edema, cerebral herniation, external ventricular drain (EVD) placement, and craniotomy or craniectomy.

2.4. Subgroup analysis

Since the NIS does not provide ICH scores for stratifying patients by the size and location of their hematomas, we performed a subgroup analysis of patients who underwent a craniotomy or craniectomy with or without hematoma evacuation. Given the indications for neurosurgical intervention for sICH are narrow, this analysis was done to partially account for patients' hematoma sizes and neurologic exams by comparing a group of patients with homogenous presentations (i.e. large, superficial hematomas with mass effect associated with poor neurologic status).

2.5. Outcome measures and statistical analysis

Our primary outcome was readmission within 30 days, which was calculated according to the method described by HCUP. Indications for readmission were classified according to the primary CCS code associated with the readmission. Planned readmissions were defined according to criteria published by the Center for Medicare and Medicaid Services [32]. Univariate analysis using Mann-Whitney U test for continuous variables and Fisher's exact test for categorical variables were performed to compare demographics, hospital characteristics, and comorbidities in patients with and without 30dRA. Binary logistic regression was performed to identify factors associated with 30dRA. Variables were included as covariates in the regression if they were associated with a p value <0.2 in the univariate analysis or if *a priori* they were suspected to influence the outcome. Cochran-Mantel-Haenszel test was used to generate pooled odds ratios. Costs of readmission were calculated using cost-to-charge ratios provided by HCUP that accounted for variations in actual expenses incurred between hospitals. Costs were inflation-adjusted to January 2019 $USD with the Bureau of Labor Statistics Consumer Price Index Calculator. Statistical analysis was performed with IBM SPSS Statistics 24.0 (IBM Corp., Armonk, NY). We followed STROBE guidelines when preparing this manuscript.

3. Results

A total of 108,578 index admissions with a primary diagnosis of non-traumatic ICH were screened for inclusion. After application of the exclusion criteria, a total of 64,909 patients were included in the study (Figure 1). Demographic data is provided in Table 1. Based on the univariate analysis, patients with 30dRAs were more likely to be >65 years old, male, insured by Medicare or Medicaid, treated at hospitals in large metropolitan regions, and have greater comorbidity burdens.

A total of 8,372 patients (12.9%) were readmitted within 30-days after an index admission for sICH between 2010 and 2014. Only 386 (4.6%) of these were planned readmissions. The Kaplan-Meier curve for the entire sample is shown in Figure 2. Among those who experienced 30dRA, the median time to readmission was 10 days (IQR 4–18). As seen in Figure 3, the annual 30dRA rate decreased slightly from 13.9% in 2010 to 12.0% in 2013 before increasing to 12.5% in 2014. Compared to the index year (2010), the annual odds of 30dRA for patients with sICH decreased over time (pooled OR = 0.90, 95% CI 0.87–0.94). To determine if this could be explained by a change in patients' overall health, we analyzed the change in comorbidity indices according to year. There was no difference in the proportion of patients with a CCI of 3 or more over time (pooled OR = 0.98, 95% CI 0.95–1.01). Likewise, the proportion of patients aged 65 years or more (pooled OR = 0.98, 95% CI 0.95–1.00) and the incidence of VTE (pooled OR = 0.98, 95% CI 0.93–1.02) did not change over time.

A binary logistic regression was performed to identify factors associated with increased odds of 30dRA (Table 2). The model was statistically significant ($X^2(33) = 1634.37$, $p < 0.001$) and correctly classified 87.1% of cases. Females had lower odds of 30dRA than males (OR = 0.93, 95% CI 0.89–0.98). Increasing CCI was associated with a stepwise increase in the odds of 30dRA. Hospital volume and teaching status were not associated with 30dRA. Venous thromboembolism (VTE) and healthcare-associated infection (HAI) increased patients' odds for 30dRA. Procedures performed during the index admission such as intubation and mechanical ventilation and tracheostomy were not associated with 30dRA, but gastrostomy was (OR = 1.84, 95% CI 1.70–1.98). Neurologic diagnoses that could have reflected a more severe hemorrhage including cerebral herniation, cerebral edema, and hydrocephalus

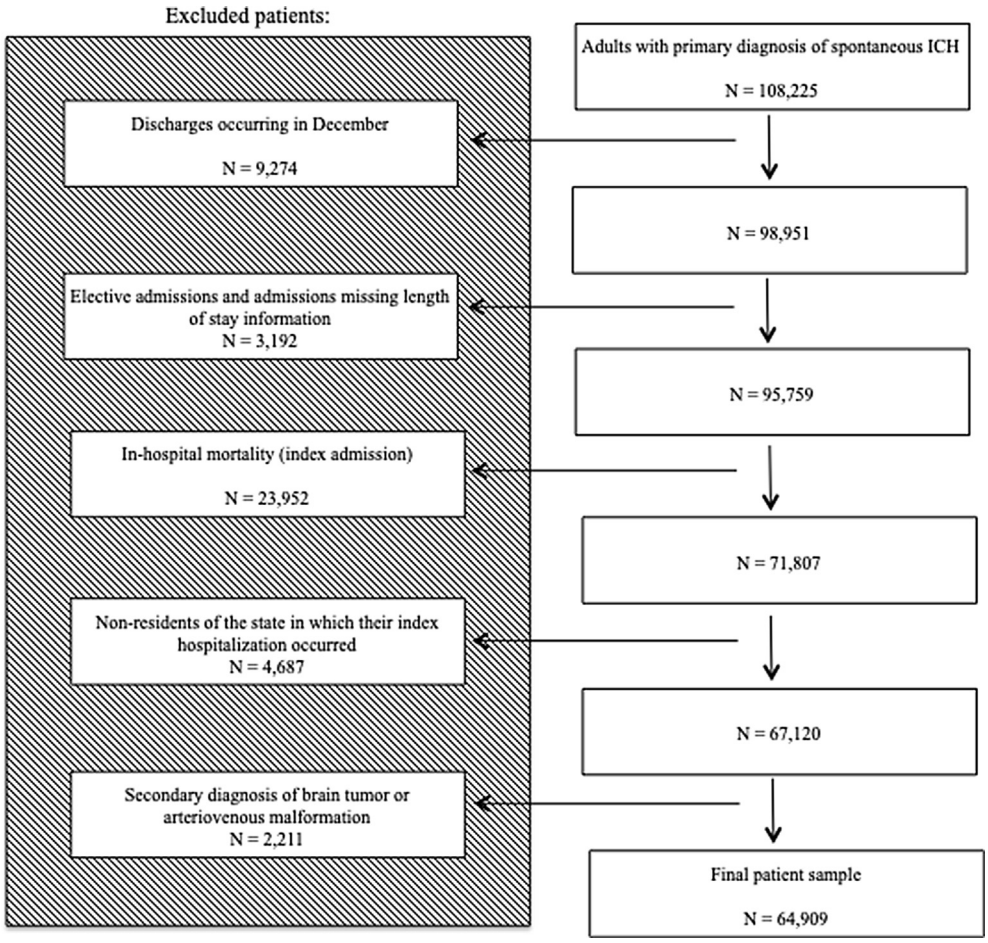

Figure 1. Development of the patient sample.

did not increase the likelihood of 30dRA, but ischemic stroke did (OR = 1.17, 95% CI 1.04–1.32). Surgical procedures performed during the index admission including EVD or ICP monitor placement (OR = 1.20, 95% CI 1.03–1.38) and craniotomy or craniectomy (OR = 1.20, 95% CI 1.09–1.31) were associated with greater odds of 30dRA.

We performed a subgroup analysis of the 4,216 patients who underwent a craniotomy or craniectomy during their index hospitalization (Table 3). Factors associated with 30dRA in this subgroup included gastrostomy (OR = 1.55, 95% CI 1.27–1.88), VTE (OR = 1.34, 95% CI 1.09–1.66), and greater LOS (Fourth quartile OR = 1.86, 95% CI 1.03–3.34). Patients in small metropolitan regions had slightly lower odds of readmission (OR = 0.83, 95% CI 0.70–0.99) than those treated in large metropolitan locations.

Table 4 lists the indications for 30dRAs stratified by CCS grouping of diagnoses. Cerebrovascular and cardiovascular etiologies were the most common (36.1%), followed by infectious (11.7%), and respiratory (8.5%). Neurologic and respiratory etiologies accounted for the shortest median times to readmission (Figure 4). The most common primary diagnoses associated with 30dRAs were nontraumatic intracerebral hemorrhage (10.4%), sepsis (8.2%), cerebral infarction due to cerebral artery occlusion (4.1%), urinary tract infection (3.7%), and aspiration pneumonitis (3.0%).

The 5-year inflation-adjusted total cost of 30dRAs was $160,320,059. The median cost of individual readmissions was $10,342 (IQR: $5,641 - $19,584) and is plotted against calendar year in Figure 5a. A Kruskal-Wallis H test demonstrated a significant difference in costs of individual readmissions between years ($p = 0.040$). Post-hoc analysis identified a significant difference only between 2012 and 2014, in which the median cost of readmission increased from $9,875 to $11,028. The annual costs of 30dRAs are shown in Figure 5b.

4. Discussion

Although the 30dRA rate has emerged as a marker for quality of health care and a monetary incentive for hospitals, relatively little data is available regarding trends, risk factors, and preventive strategies for readmission in numerous neurological and neurosurgical conditions. We found that sICH is associated with a 30dRA rate of 12.9%, and we identified several factors related to patients' demographics, medical history, and index hospital course that influenced readmission. Knowledge of risk factors for 30dRA could be used to focus post-discharge follow-up on those with the greatest risk of readmission. Furthermore, characterizing the most common causes of readmission could improve surveillance for complications after discharge that would most likely lead to readmission. A national perspective on 30dRAs after sICH in the United States is lacking, with current data primarily limited to relatively small single institution or single state cohorts [2, 7, 16, 18]. Although a prior study has used the NRD to evaluate 30dRAs among patients with ICH, they included all forms of stroke, did not exclude patients with underlying vascular or neoplastic lesions, and did not provide a detailed analysis of clinically relevant patient characteristics that influenced readmission [33]. National readmission rates following sICH have been described using the Taiwan National Health Insurance Research Database, but only one-year readmission rates were reported [34]. We feel that the 30-day time interval is most pertinent to patients with sICH given readmission during this time period is most likely to interrupt

Table 1. Comparison of demographic data, hospital characteristics, and comorbidities in patients with and without a 30-day readmission.

Variable	No 30-day readmission (%)	30-day readmission (%)	*p* value
No. of cases	56,537	8,372	-
Median age, years (IQR)	69 (57–81)	71 (59–81)	<0.001
Sex:			0.015
Male	29,599 (52.4)	4,502 (53.8)	
Female	26,938 (47.6)	3,870 (46.2)	
Primary payer:			<0.001
Medicare	32,367 (57.4)	5,273 (63.1)	
Medicaid	6,481 (11.5)	1,034 (12.4)	
Private	11,705 (20.7)	1,394 (16.7)	
Other	5,872 (10.4)	657 (7.9)	
Hospital bed size:			0.447
Small	3,059 (5.4)	425 (5.1)	
Medium	11,490 (20.3)	1,704 (20.4)	
Large	41,988 (74.3)	6,243 (74.6)	
Hospital location:			<0.001
Large metropolitan	34,684 (61.3)	5,379 (64.2)	
Small metropolitan	20,215 (35.8)	2,788 (33.3)	
Micropolitan	1,348 (2.4)	170 (2.0)	
Rural	290 (0.5)	35 (0.4)	
Hospital teaching status:			0.054
Metropolitan non-teaching	18,630 (33.0)	2,739 (32.7)	
Metropolitan teaching	36,269 (64.2)	5,428 (64.8)	
Non-metropolitan	1,638 (2.9)	205 (2.4)	
Hospital sICH volume:			0.435
Low	17,283 (30.6)	2,524 (30.1)	
High (top quartile)	39,254 (69.4)	5,848 (69.9)	
Median length of stay, days (IQR)	7 (3–17)	9 (5–20)	<0.001
Charlson Comorbidity Index:			<0.001
0	21,468 (38.0)	2,603 (31.1)	
1	13,578 (24.0)	1,872 (22.4)	
2	8,354 (14.8)	1,473 (17.6)	
≥3	13,137 (23.2)	2,424 (29.0)	
Hydrocephalus	5,228 (9.2%)	983 (11.7%)	<0.001
EVD or ICP monitor	1,149 (2.0%)	274 (3.3%)	<0.001
Craniotomy/craniectomy	3,435 (6.1%)	787 (9.4%)	<0.001

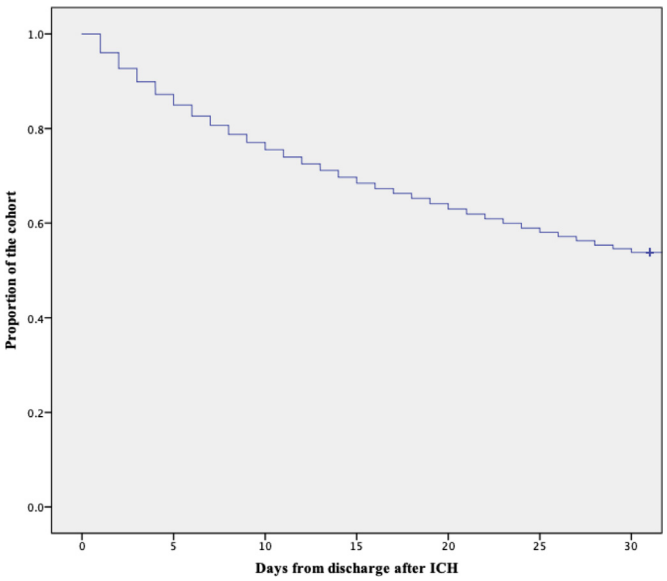

Figure 2. Kaplan-Meier curve indicating time to readmission after discharge from the index hospitalization.

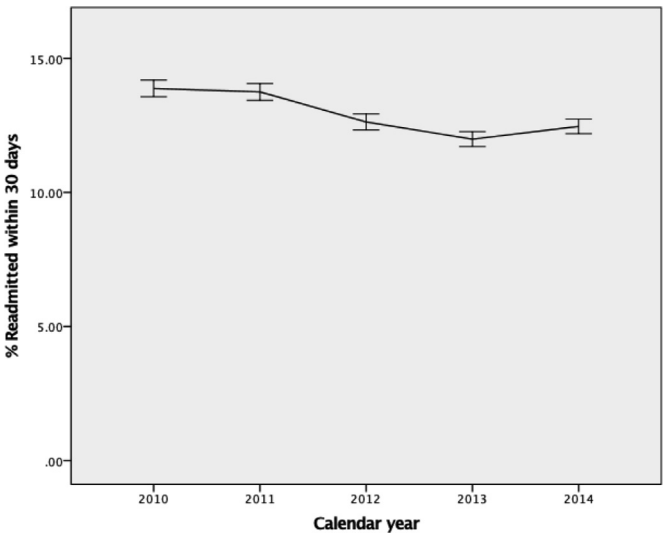

Figure 3. Annual rates of 30-day readmissions following spontaneous intracerebral hemorrhage from 2010 through 2014. Error bars indicate the standard error of the mean.

rehabilitation. To the best of our knowledge, we provide the largest analysis of 30dRAs after sICH and the only study to examine their associated costs.

We report a 12.9% 30dRA rate for sICH, which is comparable to figures that have been published previously. For example, in a cohort of 8,708 fee-for-service Medicare beneficiaries over the age of 65 years admitted to Joint Commission Primary Stroke Center certified hospitals with hemorrhagic stroke, 16% were readmitted within 30 days [15]. Our rate was likely lower because approximately 42% of our sample was younger than 65 years old. Bjerkreim et al. identified 226 sICH survivors from a single institution in Norway and noted a 30dRA rate of 18% [7]. Liotta et al. [2] examined 193 ICH patients from a single institution and found an 11% 30dRA rate. In one of the largest studies on readmissions after sICH to date, Lord et al. [16] reported that among approximately 24,500 patients admitted to California hospitals, there was a 30dRA of 14.5%. Given that the aforementioned readmission rates are similar to ours, the results of this study serve to confirm those in the literature with a larger, more generalizable sample. Likewise, our median time to readmission of 10 days is consistent with the previously published range (9–10) [2,7].

The binary logistic regression identified multiple demographic factors that increased patients' odds of 30dRA. Surprisingly, age >65 years was not associated with readmission, although a previous study also did not find an association between age and odds of readmission [2]. It is possible that a large number of these patients did not survive the index admission, given age is a known risk factor for mortality in sICH. Unsurprisingly, greater comorbidity burden increased patients' odds of readmission, a finding that has been reported previously in other stroke subtypes [18, 34]. Compared to hospitals in large metropolitan locations, those in smaller cities experienced lower readmission rates, although this finding may have been influenced by lower case severity in the latter.

We also identified several events occurring during the index hospitalization that were associated with 30dRA. For example, those who experienced VTE were more likely to be readmitted within 30 days, which could have been driven by the need for anticoagulation and its associated complications. This was also associated with readmission in the subgroup analysis of patients who underwent craniotomy or craniectomy. In Dasenbrock et al.'s study of readmission after SAH, they did not identify an association between VTE and readmission, however they

Table 2. Multivariate analysis of putative risk factors for 30-day readmission.

Variable	*p* value	Odds ratio	95% confidence interval	
			Lower	Upper
Age group, years:				
18–34	-	Ref	-	-
35–64	0.008	0.80	0.68	0.94
65–79	0.301	0.91	0.76	1.09
≥80	0.405	0.93	0.77	1.11
Sex:				
Male	-	Ref	-	-
Female	0.004	0.93	0.89	0.98
Primary payer:				
Medicare	-	Ref	-	-
Medicaid	0.091	0.92	0.84	1.01
Private	<0.001	0.77	0.71	0.84
Other	0.001	0.80	0.71	0.91
Hospital location:				
Large metropolitan	-	Ref	-	-
Small metropolitan	0.001	0.92	0.87	0.97
Micropolitan	0.039	0.83	0.70	0.99
Rural	0.411	0.86	0.60	1.23
Hospital teaching status:				
Metropolitan non-teaching	-	Ref	-	-
Metropolitan teaching	0.937	1.00	0.95	1.06
Charlson Comorbidity Index:				
0	-	Ref	-	-
1	0.071	1.06	1.00	1.13
2	<0.001	1.21	1.13	1.30
≥3	<0.001	1.27	1.19	1.36
Length of stay quartile:				
First	-	Ref	-	-
Second	<0.001	1.39	1.29	1.49
Third	<0.001	1.45	1.35	1.55
Fourth	0.028	1.10	1.01	1.20
Palliative care encounter	<0.001	0.28	0.24	0.33
High hospital sICH volume (top quartile)	0.115	0.96	0.90	1.01
Mechanical ventilation	0.522	1.03	0.95	1.11
Tracheostomy	0.377	0.95	0.85	1.06
Gastrostomy	<0.001	1.84	1.70	1.98
Sodium abnormality	0.001	1.11	1.05	1.19
Healthcare-associated infection	<0.001	1.17	1.10	1.23
Venous thromboembolism	<0.001	1.26	1.17	1.37
Cerebral herniation	0.533	0.97	0.88	1.07
Cerebral edema	0.148	1.04	0.99	1.10
Ischemic stroke	0.010	1.17	1.04	1.32
Hydrocephalus	0.256	1.05	0.97	1.14
EVD or ICP monitor	0.017	1.20	1.03	1.38
Craniotomy/craniectomy	<0.001	1.20	1.09	1.31

Table 3. Multivariate analysis of putative risk factors for 30-day readmission in patients who underwent craniotomy or craniectomy. The model was statistically significant ($X^2(31) = 119.42$, $p < 0.001$) and correctly classified 87.5% of cases.

Variable	*p* value	Odds ratio	95% confidence interval	
			Lower	Upper
Age group, years:				
18–34	-	Ref	-	-
35–64	0.253	1.33	0.82	2.17
65–79	0.134	1.50	0.88	2.56
≥80	0.203	1.46	0.82	2.61
Sex:				
Male	-	Ref	-	-
Female	0.452	0.94	0.80	1.10
Primary payer:				
Medicare	0.157	0.81	0.60	1.09
Medicaid	0.260	0.86	0.66	1.12
Private	0.326	0.81	0.53	1.24
Other	0.242	0.30	0.04	2.28
Hospital location:				
Large metropolitan	-	Ref	-	-
Small metropolitan	0.039	0.83	0.70	0.99
Micropolitan	0.099	0.51	0.22	1.14
Hospital teaching status:				
Metropolitan non-teaching	-	Ref	-	-
Metropolitan teaching	0.132	1.16	0.96	1.40
Charlson Comorbidity Index:				
0	-	Ref	-	-
1	0.233	0.84	0.63	1.12
2	0.336	1.12	0.89	1.43
≥3	0.375	1.11	0.88	1.39
Length of stay quartile:				
First	-	Ref	-	-
Second	0.135	1.62	0.86	3.06
Third	0.060	1.76	0.99	3.14
Fourth	0.039	1.86	1.03	3.34
Palliative care encounter	<0.001	0.35	0.21	0.60
High hospital sICH volume (top quartile)	0.498	0.93	0.77	1.14
Mechanical ventilation	0.551	1.06	0.87	1.29
Tracheostomy	0.228	0.88	0.71	1.09
Gastrostomy	<0.001	1.55	1.27	1.88
Sodium abnormality	0.862	0.99	0.83	1.17
Healthcare-associated infection	0.686	1.04	0.87	1.23
Venous thromboembolism	0.007	1.34	1.09	1.66
Cerebral herniation	0.360	0.91	0.76	1.11
Cerebral edema	0.532	1.06	0.89	1.25
Ischemic stroke	0.862	0.97	0.66	1.41
Hydrocephalus	0.142	1.15	0.95	1.40
EVD or ICP monitor	0.371	1.14	0.86	1.51

did note that VTE was one of the most frequent indications for readmission [1]. Since infectious etiologies were the second most common reason for readmission in our cohort, it was not surprising that those who developed a HAI during the index hospitalization were more likely to be readmitted. Indeed, similar results have been reported in ischemic stroke [35]. The development of a HAI could have reflected an underlying immunocompromised state or a longer index hospitalization. Limitations of the NRD prevented us from determining whether or not infections causing readmission occurred *de novo* or were manifestations of inadequately treated infections that began during the initial admission. Hospital volume was not associated with readmission, which is similar to results of NRD analyses in SAH [1] and all stroke types [33]. Joint Commission Comprehensive Stroke Center designation may be more important than raw volume, especially given the former's emphasis on post-acute care.

Many of the indicators of more severe sICH including cerebral herniation, cerebral edema, and hydrocephalus were not associated with higher risks of readmission, which is similar to the findings reported by Liotta et al [2]. However, patients who underwent neurosurgical procedures including EVD or craniotomy/craniectomy did have higher odds of readmission. The latter carries risks of complications that could have required patients to return to the hospital, including wound issues, seizures, and hydrocephalus. Furthermore, these patients were more likely to have had more severe hemorrhages to be deemed surgical candidates.

Table 4. Indications for 30-day readmissions after spontaneous intracerebral hemorrhage, categorized by Clinical Classifications Software's organization of diagnoses.

	Number of readmissions (%)	Median time to readmission (IQR)
Circulatory, cerebrovascular, and cardiovascular:	3,023 (36.1)	9.0 (3.0–17.0)
- Non-traumatic intracerebral hemorrhage	873	
- Cerebral infarction due to stenosis, unspecified artery	341	
- Pulmonary embolism	167	
Infectious:	977 (11.7)	9.0 (4.0–18.0)
- Sepsis, unspecified	688	
- Sepsis due to E. coli	58	
- Sepsis, other gram negative organism	35	
Respiratory	711 (8.5)	8.0 (4.0–17.0)
- Aspiration pneumonitis	255	
- Pneumonia, unspecified	177	
- Acute respiratory failure	82	
Genitourinary	639 (7.6)	10.0 (5.0–18.0)
Injury	613 (7.3)	10.0 (4.0–20.0)
Neurologic	563 (6.7)	8.0 (3.0–16.0)
- Seizures, other	74	
- Epilepsy, unspecified	57	
- Encephalopathy, unspecified	42	
Gastrointestinal	449 (5.4)	12.0 (5.0–20.0)
Endocrine	298 (3.6)	11.0 (6.0–18.0)
Neoplasm	225 (2.7)	13.0 (6.0–20.5)
Psychiatric	111 (1.3)	10.0 (5.0–17.0)
Hematologic	68 (0.8)	10.5 (7.0–21.0)
Musculoskeletal	67 (0.8)	15.0 (6.0–23.0)
Dermatologic	40 (0.5)	12.5 (6.0–20.5)

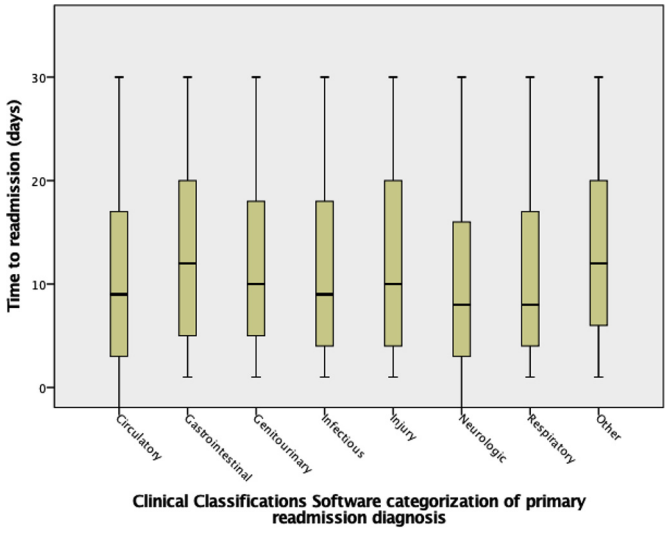

Figure 4. Medians, interquartile ranges, and 95% confidence intervals for times to readmission stratified by Clinical Classifications Software categorization of the primary readmission diagnosis.

The current study also found that intubation, mechanical ventilation and tracheostomy were not risk factors for readmission after sICH. This is in contrast to Lahiri et al [14] who reported that tracheostomy caused a slight increased risk of 30dRA following ischemic stroke. Gastrostomy had the strongest influence on 30dRA (OR = 1.84) and remained a significant factor in the subgroup analysis. This procedure has been implicated in readmissions after stroke before [21]. Of note, only some of the explanatory variables that are indicative of more severe hemorrhage were associated with readmission. We believe that survivorship bias may have accounted for this discordance, given patients who died during the index admission were not eligible for readmission analysis.

Cardiovascular and cerebrovascular etiologies accounted for the largest number of readmissions (36.1%), which is similar to prior NRD analyses of ischemic stroke [26] and all stroke subtypes [33]. Most readmissions within this category carried a primary diagnosis of ICH, however it is unclear if this referred to new hemorrhage or sequela of the initial event. Ischemic stroke was the second most common indication for readmission in this category, which could have been due to underlying cerebrovascular disease or interruption in anticoagulation or antiplatelet therapy due to concern for expansion of patients' pre-existing hemorrhages. Infection accounted for the second most number of readmissions. In prior studies, infection has been associated with the greatest number of readmissions after sICH [2, 15, 16], and among patients with ischemic stroke, infection has also been shown to be the leading reason for 30dRAs [19]. At least one study has shown that readmissions due to infection are associated with higher mortality than other causes of readmission [16]. The large number of infections in our cohort is likely related to the immunosuppression that is induced by the central nervous system after stroke [36]. Aspiration pneumonitis was the most frequent cause of respiratory readmissions, which could have resulted from dysphagia that was directly related to the initial hemorrhage or secondary to decreased mental status. Evaluation by a speech-language pathologist prior to discharge could help ensure that patients are appropriate for oral intake and determine if a modified diet is indicated. Identifying the most common causes of readmissions has important implications for preventing them and ensuring smooth transitions of care. For example, post-discharge follow-up in the form of a phone call or appointment with an ambulatory provider could be tailored toward the detection and prevention of factors known to drive 30dRAs. Furthermore, inpatient providers could take extra care to ensure that patients are optimized to avoid these complications prior to discharge.

Given the high morbidity associated with sICH, patients with this condition are prone to developing complications that could necessitate readmission. Previously described methods for reducing 30dRAs are multifaceted and implement a variety of personnel at different stages in the transition from the hospital to the community [37]. These include comprehensive discharge planning by a dedicated advanced practice nurse, educational interventions, telephone follow-up after discharge with assessments of patient and caregiver needs, telemonitoring with remote technology that transmits objective health information to providers, home visits, and close outpatient follow-up with a dedicated transition of care clinic [38]. Implementing all of these for each discharge would likely be prohibitively costly and time consuming. Furthermore, their use in low risk patients may be unnecessary. Therefore, identifying patients with or without risk factors for 30dRA could aid in the efficient use of these interventions.

The present study is strengthened by its large sample size and inclusion of patients across the United States with all forms of insurance, which affords our results strong generalizability. However, there are several limitations inherent to administrative databases that require our results to be interpreted with caution. For example, it was not possible to ascertain the ICH score from the NRD in order to adjust for hemorrhage severity. Likewise, validated measures of functional status in stroke patients such as the Modified Rankin Scale were not available, which would have been a useful factor to control for in our regression models. Coding errors could have led to inaccurate estimates of various index hospitalization diagnoses and procedures, and the lack of granularity associated with ICD-9-CM diagnosis codes left some uncertainty regarding the precise indications for a large portion of readmissions. Finally, it is not possible to follow patients across calendar years with the NRD, which required us to eliminate December admissions that would have otherwise been eligible for this study.

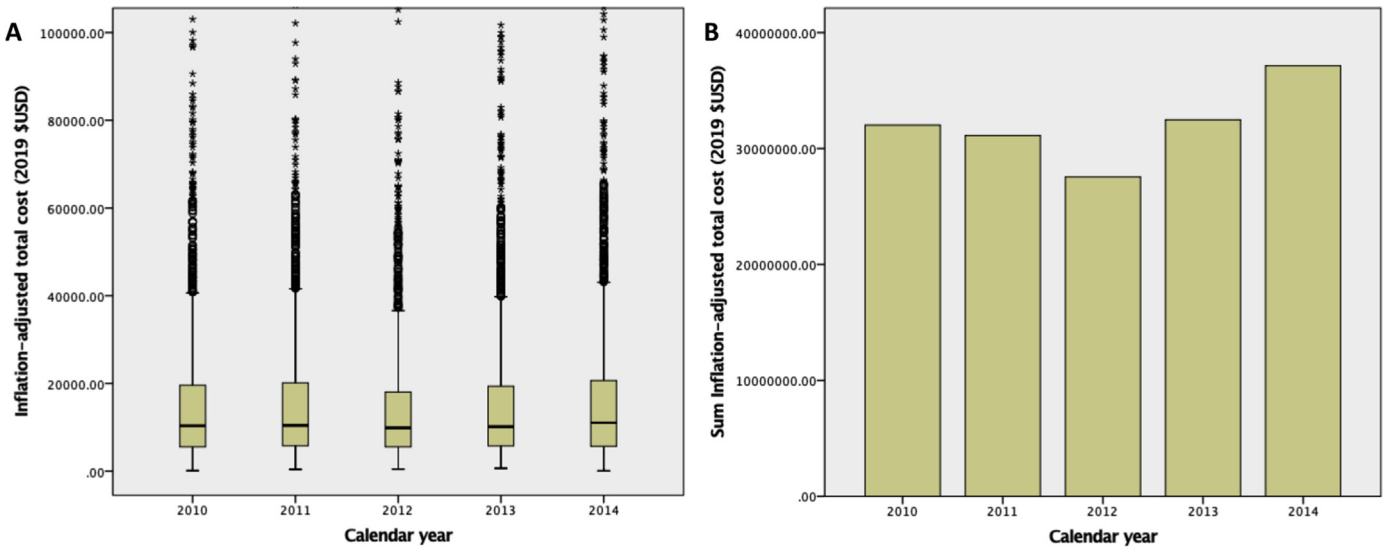

Figure 5. (a) Medians, interquartile ranges, and 95% confidence intervals for inflation-adjusted costs of individual readmissions stratified by calendar year. Asterisks indicate individual outliers. (b) Cumulative costs of 30-day readmissions stratified by calendar year.

5. Conclusion

The overall 30dRA rate following sICH decreased modestly between 2010 and 2014, but associated costs increased. Among the several variables associated with readmission in this study, gastrostomy placement, venous thromboembolism, and craniotomy or craniectomy increased patients' odds of readmission the most. Cerebrovascular and infectious indications were the leading causes of 30dRA. Large prospective studies are required to confirm our findings and identify strategies for preventing readmission after sICH.

Declarations

Author contribution statement

H. Hoffman: conceived and designed the experiments; performed the experiments analyzed and interpreted the data; wrote the paper.

T. Furst, M. Jalal: analyzed and interpreted the data; wrote the paper.

L. Chin: conceived and designed the experiments; analyzed and interpreted the data; contributed reagents, materials, analysis tools or data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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