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Risk of readmission for infection after surgical intervention for intracerebral hemorrhage

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ABSTRACT

Background: Several operative interventions are performed to reduce the mortality and morbidity of Intracerebral hemorrhage (ICH) in the acute setting, including: craniotomy or craniectomy, placement of an external ventricular drain (EVD), placement of a ventriculo-peritoneal shunt (VPS) and stereotactic craniotomy. Infections are a major source of readmissions following ICH. We explored the association between operative interventions for ICH and 30-day readmissions for infection-related causes.
Methods: The Nationwide Readmissions Database contains > 14 million discharges for all payers and uninsured in 2013. International Classification of Disease, Ninth Revision, Clinical Modification codes were used to identify index cases of ICH, intracranial procedures, and comorbidities. We summarized demographics and comorbidities during index admission, stratified by receipt of operative interventions. We calculated differences in means (using *t*-tests) and frequencies (using chi-square) by group (any intervention versus none). Top 5 causes of 30-day readmission and top 5 causes for infectious readmissions were identified. Cox regression analysis was performed for time to readmission for infectious causes.
Results: There were 27,739 index admissions with ICH, 13% had operative interventions. In the operative group, 45.5% underwent craniotomy, 65.4% had EVD placement and 7.6% had VPS placement. Acute cerebrovascular disease was the top cause of readmission followed by infection in the entire cohort and those with interventions. Among infectious causes of readmissions, septicemia was the largest in the intervention group (65%). In both adjusted and unadjusted models, there was significant association between ICH intervention and risk of readmission for infectious causes. Among those with operative interventions for ICH, risk of readmission with infection is double the risk in the non-intervention group. Cumulative risk of readmission was higher for infection following ICH, starting after approximately 50 days, in the intervention group (log-rank *p*-value < .0001).
Conclusions: Infections and cerebrovascular complications contribute to most readmissions after ICH. There is a dose-response relationship between number of interventions and risk of infectious readmission, and this risk significantly increases after approximately 50-days.

1. Introduction

Intracranial hemorrhage (ICH) is a devastating disease with an estimated 1-year mortality of 50% [1]. Several procedures are performed to reduce the mortality and morbidity of ICH in the acute setting, including: craniotomy or craniectomy, placement of an external ventricular drain (EVD), placement of a ventriculo-peritoneal shunt (VPS) and stereotactic craniotomy. While all these procedures are individually deemed to be lifesaving in the critical period, little data is available on the severity-adjusted, nationally representative outcomes after such procedures.

Based on prior literature [2,3], we estimated that infections probably rank among the top causes of 30-day readmissions after ICH. Prior studies using the National Inpatient Sample found that the rates of urinary tract infection, pneumonia and sepsis during ICH admission were 14.8%, 7.8% and 4.1%, respectively [4]. However, this was a cross-sectional analysis, and longitudinal follow-up data are lacking.

We hypothesized that operative interventions for ICH including EVD

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placement, VPS, craniotomy or stereotactic aspiration were associated with higher rates of readmissions for infections after ICH compared to those with no interventions. This hypothesis was developed because not only are the operative interventions invasive, exposing patients to the risk of infection but also people with operative interventions tend to have longer hospital stays, increasing their changes of acquiring nosocomial infections. The primary aim of this study was to use the National Readmission Database to examine 30-day readmissions (infectious and non-infectious) for all ICH patients and stratify by receipt of operative intervention. We also explored whether the risk of infectious readmission changed with increase in the number of interventions in both unadjusted models as well as models adjusted for comorbidities and functional outcomes.

2. Methods

2.1. National readmission database

The Nationwide Readmissions Database (NRD) is a national database of readmissions for all payers and the uninsured with data on > 14 million U.S. admissions during the year 2013. It comprises data from 49.1% of all U.S. hospitalizations, excluding rehabilitation and long-term acute-care hospitalizations. The NRD allows analysis of readmissions with the use of an anonymized, verified linkage identifier for each individual. The Mount Sinai IRB reviewed and approved this project. Since the data are made publicly available through HCUP, the data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure.

2.2. Patient selection

We used International Classification of Disease, Ninth Revision, Clinical Modification (ICD9-CM) codes to identify index admissions for intracranial hemorrhage (ICH) using the ICD9-CM code 431. This code has been validated for identification of ICH patients from administrative datasets and has high sensitivity and specificity with a positive predictive value of 89% [5]. These cases were divided into 2 groups: 1) patients with ICH who were managed non-operatively, 2) patients who had some operative intervention for ICH, identified using ICD9-CM procedure codes. ICH interventions included placement of external ventricular drain (EVD, ICD9-CM codes 02.2, 02.21, 02.22), ventriculoperitoneal shunt (VPS, 02.3×), craniotomy or craniectomy (01.2, 01.23, 01.24, 01.25, 01.26, 01.27, 01.28, 01.39), stereotactic aspiration of blood products (92.3, 92.39). Admissions for infection were identified using ICD9-CM codes as detailed in Supplementary Table 1.

2.3. Comorbidity indices

Using standard ICD9-CM codes, we identified comorbidities including atrial fibrillation or atrial flutter, diabetes, hypertension, alcohol, smoking history, and ischemic stroke. 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), income quartile of patient's zip code, 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 (population 10,000-49,999), and not metropolitan or micropolitan counties]. The All Patient Refined Diagnosis Related Groups (APR-DRGs) are designated using 3 M Health Information Systems software. APR-DRGs classify patients into 25 major diagnostic categories, and then further subdivide patients into 4 severity of illness subclasses in terms of degree of loss of function (minor, moderate, major, extreme) and 4 risk of mortality subclasses (minor, moderate, major, extreme). These 2 scores are calculated separately and may be different from one another. Analysis of the APR-DRG has demonstrated that mortality rate correlates with increasing APR-DRG risk of mortality scores [6] and the APR-DRG has been adapted to the VA health system [6,7].

Since patients with comorbidities tend to have poorer outcomes, several models were made to adjust for these comorbidities. The Charlson Comorbidity Index (CCI) summarizes comorbidities of patients based on ICD-9 diagnosis codes found in administrative data. Each comorbidity category has an associated weight (from 1 to 6), based on the adjusted risk of mortality or resource use, and the sum of all the weights results in a single comorbidity score for a patient. A score of zero indicates that no comorbidities were found. The higher the score, the more likely the predicted outcome will result in mortality or higher resource use.

We also used the Elixhauser Comorbidity Index (ECI), which summarizes comorbidity based on ICD-9 codes. ECI includes 31 different conditions and is believed to be a better predictor of mortality in patients with cardiac, gastrointestinal, hepatobiliary, and oncologic conditions. Each comorbidity category is dichotomous. Weights are assigned to each comorbidity to develop a comprehensive comorbidity index. Recent evidence suggests that comorbidity indices can be valid substitutes for the full set of measures under a wide set of conditions and can provide a way to condense comorbidity information into an easy-to-use metric [8]. Previous research has shown that the composite comorbidity index can be used to predict in-hospital mortality and hence the ECI is used to estimate a 'Mortality score' [9,10]. Additionally, just as with predictions of mortality, patients' burden of illness needs to be considered when assessing readmission rates, hence a 'Readmission score' can be calculated using the ECI [11]. Prior studies have shown that ECI has better overall predictive value for comorbidity than the CCI, based on its inclusion of more variables, especially in the setting of stroke and MI [12,13].

2.4. Outcome measures

The National Inpatient Sample Subarachnoid Hemorrhage Outcome measure (NIS-SOM) was used to dichotomize outcome into good or poor. Good outcome was defined as discharge to home or a rehabilitation facility or hospital. Poor outcome was defined as in-hospital mortality; discharge to a nursing facility, extended care facility, or hospice; placement of a tracheostomy tube (ICD9-CM procedure codes: 31.1, 31.2. 31.21, 31.29), or placement of a gastrostomy tube (ICD9-CM procedure codes: 43.1, 43.11, 43.19, 44.32, 44.38, 44.39). Prior studies have validated the NIS-SOM against a dichotomized modified Rankin scale (mRS), which is a conventionally used scale for stroke outcomes, with substantial agreement (85.2% agreement and k = 0.63) [14].

2.5. Statistical analysis

We calculated baseline characteristics of those with ICH index admission, stratified by receipt of operative interventions (EVD, VPS, craniotomy or craniectomy, stereotactic aspiration of blood products) versus no intervention. We calculated means and standard deviations for continuous variables and frequencies and percentages for categorical variables; we calculated differences in means (using *t*-tests) and frequencies (using chi-square) by group (any intervention versus none).

We summarized the top 5 reasons for 30-day readmissions in the entire cohort as well as both the groups individually using Clinical Classifications Software (CCS) to group hospitalizations into clinically coherent, mutually exclusive condition categories according to their principal diagnosis. We also summarized the top 5 infection-related reasons for 30-day readmission in the entire cohort and stratified by intervention group.

We created a Kaplan-Meier curve of cumulative risk of readmission for infection after intracerebral hemorrhage, stratified by receipt of intervention, using the log-rank test to test for significance. For this analysis, we used all available follow-up data, and measured time from discharge from the index hospitalization to admission for infectious causes. Since only the month of admission and not the exact date is available in the NRD, for those without the event of interest, we calculated the maximum observed follow-up period as the number of days from the midpoint of the month of index admission to December 31, 2013.

We performed Cox regression analysis, reporting hazard ratio (HR) and 95% confidence intervals (CI) for time to readmission for infectious causes. The main predictor was receipt of intervention (0 = none, 1 = any intervention). We ran an unadjusted model, and then adjusted for risk of mortality, based on the subclass assigned by the APRDRG software, based on likelihood of dying, with 1 = minor, 2 = moderate, 3 = major, 4 = extreme. In a separate model, we adjusted for severity of illness, based on the subclass assigned by APRDRG software and classified similarly as the APRDRG risk of mortality. In another model, we adjusted for vascular risk factors during the index admission, including age, diabetes mellitus (DM), and smoking. In other models, we additionally adjusted for length of stay and infection during index hospitalization. Additional models were built to adjust for the ECI readmission score and ECI mortality score. Adjustment was also made for NIS-SOM measured during the index hospitalization. We assumed full capturing of mortality and no loss to follow-up. In secondary analysis, we repeated the above Cox models, with the main predictor of number of ICH procedures performed during the index hospitalization (0, 1, 2, or 3, with 0 as reference). Analyses were performed in SAS version 9.4.

3. Results

3.1. Demographics

In 2013, there were 27,739 index admissions with ICH of which 48.2% were females and 3680 had an operative intervention for ICH. Table 1 lists baseline characteristics of the study population at the time of index event, stratified by receipt of intervention during the index admission. Patients with operative interventions for ICH were older, had lower prevalence of atrial fibrillation and alcohol use, higher prevalence of ischemic stroke, and higher disease severity and risk of mortality, estimated with several scales including the APRDRG scores, CCI and ECI. The operative intervention group also had higher prevalence of hydrocephalus and edema, longer length of stay, and a higher chance of tracheostomy and PEG tube placement.

In the operative intervention group, 45.5% underwent craniotomy, 65.4% had EVD placement and 7.6% had VPS placement. Among the interventions for ICH, > 75% had a single intervention. In this group, 6.8% of cases had at least 1 readmission for an infection-related cause and 1.4% had multiple admissions for infectious causes, compared to 4.1% and 0.7% respectively among those with no intervention.

3.2. Causes of readmission

Acute cerebrovascular disease was the most common cause of readmission in the entire cohort (20.8%), among those with no intervention (16.4%), and those with any intervention (32.8%) (Table 2A). Infectious causes were the second most common cause of readmission (8.2% in the entire cohort). Among infectious causes of readmissions (Table 2B), septicemia was the largest contributor in the intervention group (65%) and in the no intervention group (59%). Pneumonia and device-related complications closely followed.

There was a greater cumulative risk of readmission for infection following ICH, starting after approximately 50 days, among those with operative interventions compared to those without intervention (Fig. 1;

Table 1
Baseline characteristics of study population at index intracerebral hemorrhage admission.

Characteristics	No intervention	Intervention	p-Value
Number of participants	24,059	3680	
Age, mean (SD)	70.0 (14.8)	61.65 (14.1)	< 0.0001
Female, No. (%)	11,725 (48.73)	1641 (44.59)	< 0.0001
Median income for zip code, No. (%)			0.052
$0–25,000	630 (26.8)	1037 (28.78)	
$25,001–30,000	6126 (25.94)	921 (25.56)	
$30,001–35,000	5836 (24.71)	885 (24.56)	
$35,001 +	5328 (22.56)	760 (21.09)	
APRDRG[a] mortality risk, No. (%)			< 0.0001
Minor likelihood	37 (0.15)	17(0.46)	
Moderate likelihood	11,288 (49.92)	124 (3.37)	
Major likelihood	5825 (24.21)	1251 (33.99)	
Extreme likelihood	6909 (28.72)	2288 (62.17)	
APRDRG[a] illness severity subclass, No. (%)			< 0.0001
No or minor loss of function	1671 (6.95)	50 (1.36)	
Moderate loss of function	7830 (32.54)	232 (6.3)	
Major loss of function	9133 (37.96)	910 (24.73)	
Extreme loss of function	5425 (22.55)	2488 (67.61)	
Atrial fibrillation or atrial flutter, No. (%)	4901 (20.37)	612 (16.63)	< 0.0001
Diabetes, No. (%)	6737 (28.0)	997 (27.09)	0.26
Alcohol (%)	9576 (39.8)	1008 (27.39)	< 0.0001
Hypertension, No. (%)	16,765 (69.68)	2603 (70.73)	0.19
Smoking history, No. (%)	5614 (23.33)	842 (22.88)	0.54
Ischemic stroke, No. (%)	749 (3.11)	206 (5.6)	< 0.0001
Discharge Destination:			< 0.0001
Routine (home)	6083 (25.29)	465 (12.64)	
Transfer to short-term hospital	493 (2.05)	148 (4.02)	
Transfer Other: Includes Skilled Nursing Facility, Intermediate Care Facility, Another Type of Facility	8250 (34.3)	1534 (41.7)	
Home Health Care	3308 (13.75)	307 (8.34)	
Against Medical Advice	104 (0.43)	< 10	
Died	5742 (23.87)	1204 (32.73)	
Discharged alive, destination unknown	75 (0.31)	15 (0.41)	
Length of stay, day, mean (SD)	8.65 (12.5)	21.13 (22.0)	< 0.0001
Total charges (SD)	75,186 (105692)	253,238 (255861)	< 0.0001
Charlson comorbidity index, mean (SD)	3.47 (2.23)	3.58 (2.12)	0.011
Readmission score, ECI,[b] mean (SD)	13.5 (13.9)	20.3 (14.56)	< 0.0001
Mortality score, ECI,[b] mean (SD)	5.3 (9.0)	10.9 (10.2)	< 0.0001
Deep venous thrombosis/ pulmonary embolism	177 (0.74)	72 (1.96)	< 0.0001
Hemodialysis	473 (1.97)	98 (2.66)	0.0055
Hydrocephalus	1603 (6.66)	1980 (53.8)	< 0.0001
Edema	7571 (31.47)	1803 (48.99)	< 0.0001
Tracheostomy	569 (2.37)	779 (21.17)	< 0.0001
PEG	1491 (6.2)	1011 (27.47)	< 0.0001
Bed size of hospital, No. (%)			< 0.0001
Small	1385 (5.76)	122 (3.32)	
Medium	4912 (20.42)	601 (16.33)	
Large	17,762 (73.83)	2957 (80.35)	
Hospital urban-rural designation, No. (%)			< 0.0001
Large metropolitan areas with at least 1 million residents	13,880 (57.69)	2392 (65)	
Small metropolitan areas with < 1 million residents	9190 (38.2)	1232 (33.48)	
Micropolitan areas	757 (3.15)	55 (1.49)	
Not metropolitan or micropolitan (non-urban residual)	232 (0.96)	1 (0.03)	

(continued on next page)

Table 1 (*continued*)

Characteristics	No intervention	Intervention	p-Value
Hospital teaching status, No. (%)			< 0.0001
Metropolitan non-teaching	8366 (34.77)	967 (26.28)	
Metropolitan teaching	14,704 (61.12)	2657 (72.2)	
Non-metropolitan hospital	989 (4.11)	56 (1.52)	

[a] APRDRG = All Patient Refined Diagnosis Related Group.
[b] ECI = Elixhauser Comorbidity Index.

log-rank *p*-value < .0001). In unadjusted Cox models (Table 3), operative intervention (versus no intervention) was associated with almost double the risk of readmission for infection (HR 1.90, 95% CI 1.60–2.26). In multiple models, adjusting for severity measures, vascular risk factors, infection during the index admission, and length of stay during the index admission, there continued to be a significant association between ICH intervention and risk of readmission for infectious causes. We also tested number of ICH interventions (versus none) as the primary predictor, in unadjusted and adjusted Cox models (Table 4). We found a dose-response relationship in most models, such that a greater number of ICH interventions were associated with progressively greater risk of readmission for infection.

4. Discussion

Using nationally representative data, we found increased readmissions for infections up to 1 year after index admission for ICH among those with operative interventions for ICH. Nearly 13% of subjects with ICH had some operative intervention for ICH during the index admission. Infections and acute cerebrovascular disease were the most common causes of readmission after ICH with or without some operative intervention for ICH. Among infectious causes of readmission, septicemia and pneumonia were the most common. The risk for readmission for infection was elevated in those with an operative intervention to almost double at the 50-day mark. The risk remained elevated at 22–117% in the operative intervention group after confounder adjustment, using different summary measures of comorbidity, both cerebrovascular-specific and not. With increasing numbers of operative interventions for ICH during the index admission, we observed a dose-response relationship with increasing number of infections in both adjusted and unadjusted models.

In a study examining > 24,000 index admissions with ICH between 2006 and 2010 using the California Statewide Inpatient Database, the primary outcome was 30-day unplanned readmission with primary infection-related ICD-9CM code. Infection related primary diagnosis codes represented 22% of readmissions and nearly 51% of readmissions had infections when evaluating primary and all secondary diagnosis codes. Stroke related readmissions accounted for about 24%. These findings are similar to our data, in that we found that the top causes of readmission were infection and cerebrovascular illnesses and the most common infectious causes of readmission was septicemia (11.8% versus 8.3% in our study population) [3]. However, we additionally examined the relationship between operative intervention and risk of infection readmission.

In a multicenter, Ethnic/Racial Variations of Intracerebral Hemorrhage (ERICH) study involving 800 patients, univariate and multivariate analyses were performed to determine the association of infection with admission characteristics and hospital complications. Infections occurred in 31% of admissions and were associated with higher discharge mortality and worse 3-month outcome using the modified Rankin Scale. Additionally, infection was found to be an independent predictor of poor 3-month outcome [2]. However, the relationship between operative intervention for ICH and outcomes was not examined.

Using the National Inpatient Sample (NIS) from 2004 to 2013, temporal trends in medical complications after ICH (total 575,211) were identified. While mortality was reduced, ARF and DVT risk after ICH have increased over the 10-year period, whereas odds of sepsis and pneumonia have declined over the last decade. This study reported the rates of medical complications in patients with EVD/ VPS and craniotomy, which were comparable to our study; however, these operative interventions were not used in multivariate analysis to adjust for ICH severity, and the NIS allows only cross-sectional analyses and not longitudinal analysis of outcomes within individuals, as in our study. The rates of DVT/ PE, diabetes, hemodialysis, atrial fibrillation and other comorbidities were comparable to our findings [4].

In a prospective, single-center, observational cohort registry from 2006 to 2012, 30-day readmissions and functional outcomes were tracked for almost 250 patients. It was again demonstrated that the most common indication for readmission was infection (4%) after discharge, closely followed by vascular events (2.4%), and readmission was associated with worse functional outcomes at three months. While this study had lower overall rates of readmission as well as lower rages of infectious readmissions, it is difficult to generalize the data based on the single center experience, and operative interventions were not tested separately [15].

In a Norwegian retrospective cohort study including all ICH patients, from 2007 to 2013, 226 patients were enrolled and Cox regression analysis was performed to identify predictors of 30-day readmission. While there was a 70% survival rate, 72% of readmissions were due to infectious causes and there were no cerebrovascular readmissions. Pneumonia and enteral feeding during the index hospitalization were associated with readmission for infections [16].

In a retrospective case–control study evaluating 1544 patients admitted for stroke (hemorrhagic, ischemic, or TIA) from January 2013 to December 2014, the 30-day readmission rate was 8.7%. The most common etiologies for readmission were infection (30%), recurrent stroke and TIA (20%), and cardiac complications (14%) [17].

Given that Joint Commission Primary Stroke Center (JC-PSC)-certified hospitals have better outcomes of ischemic stroke, a study examined the impact of JC-PSC status on outcomes after hemorrhagic strokes for all fee-for-service Medicare beneficiaries aged 65 years or older with a primary discharge diagnosis of subarachnoid hemorrhage (SAH) or intracerebral hemorrhage (ICH) in 2006. In 8708 ICH admissions, while the in-hospital mortality was lower in JC-PSCs, there was no difference in readmission rates which were around 16% for ICH [18].

A meta-analysis involving 81 studies and 137,817 patients with any

Table 2A
Reasons for 30-day readmission after index admission for intracerebral hemorrhage.

Entire Cohort	ICH with no intervention	ICH with intervention
N = 27,739	*N* = 24,059	*N* = 3680
Acute cerebrovascular disease (20.8%)	Acute cerebrovascular disease (16.4%)	Acute cerebrovascular disease (32.7%)
Septicemia (except labor) (8.3%)	Septicemia (except labor) (9.9%)	Other hereditary and degenerative nervous system conditions (13.6%)
Acute and unspecified renal failure (3.9%)	UTI (3.6%)	Complication of device; implant or graft (7.3%)
UTI (3.6%)	Acute and unspecified renal failure (3.3%)	Septicemia (except in labor) (6.4%)
Other nervous system disorders (3.2%)	Rehabilitation and fitting of prosthesis (3.2%)	Secondary malignancies (6.4%)

Table 2B
Infection-related reasons for 30-day readmission, among those with readmission for infections after index admission for ICH.[a]

Entire Cohort	ICH with no intervention	ICH with intervention
N = 27,739	*N* = 24,059	*N* = 3680
Septicemia (except in labor) (60.0%)	Septicemia (except in labor) (58.8%)	Septicemia (except in labor) (64.8%)
Pneumonia (except that caused by tuberculosis or sexually transmitted disease) (14.4%)	Pneumonia (except that caused by tuberculosis or sexually transmitted disease) (15.2%)	Pneumonia (except that caused by tuberculosis or sexually transmitted disease) (11.1%)
Complication of device; implant or graft (7.6%)	Complication of device; implant or graft (8.1%)	Complications of surgical procedures or medical care (8.0%)
Intestinal infection (3.9%)	Intestinal infection (4.0%)	Complication of device; implant or graft (5.6%)
Complications of surgical procedures or medical care (3.7%)	Skin and subcutaneous tissue infection (3.7%)	Intestinal infection (3.7%)

[a] This table includes only infection related reasons for readmission.

type of stroke (hemorrhagic and ischemic) quantified the associations between population- and study characteristics and infection rates. The overall pooled infection rate was 30% (24–36%) and the rates of pneumonia and urinary tract infection were 10% each [19].

These studies corroborate our findings of infections and cerebrovascular causes being the top reasons for readmission in patients with ICH. While the literature has reports of varying infection rates associated with EVDs and VPSs, no study, to our knowledge, has tested the relationship between operative interventions and infectious readmissions in patients with ICH.

A possible mechanism of increased readmissions for infections in the operative intervention group may be related to the introduction of infectious organisms during the actual procedure, or the increased access of infectious organisms through persistent catheters or incisions. This would also explain the dose-response relation of the number of interventions and the risk of readmission for infection.

VPS and indwelling catheters may also be a source of late infection. We hypothesize that this may be a potential reason for the surge in readmission after 50-days for infections in the operative intervention group. While several models were created to adjust for comorbidities, it is possible that there was residual neurological severity that was not adjusted for, which may have contributed to this increased infectious risk in the operative intervention group.

There are several limitations to this study. First, there may be misclassification of variables based on ICD9 codes, and comorbidities may be incompletely accounted for. We could not adjust for stroke severity, pre-procedural risk, or medications. Furthermore, we could not capture out-of-hospital mortality or morbidity. There are several strengths of this study. We used data from a large, nationally representative, and contemporary data set. Patients were not selected by enrollment in a device registry or from a single center. The current study is unique because no previous study has examined operative interventions and their influence on infectious readmissions. Additionally, no prior administrative datasets have used multiple approaches to adjust for various comorbidities using ECI, CCI as well as the NIS-SOM to adjust for functional outcomes.

In summary, we demonstrated that infections and cerebrovascular complications contributed to most readmissions after ICH. Among those with operative interventions for ICH, the unadjusted as well as adjusted risk of readmission with infection was almost double the risk in the non-intervention group. There was a dose-response relationship between the number of interventions and the risk of infectious readmission, and this risk significantly increased after approximately 50 days. This data may be used to help with decision-making and prognostication in patients undergoing these operative interventions. Further studies are required to better understand how each individual procedure may add to the overall morbidity, irrespective of the neurological severity of illness.

Supplementary data to this article can be found online at https://

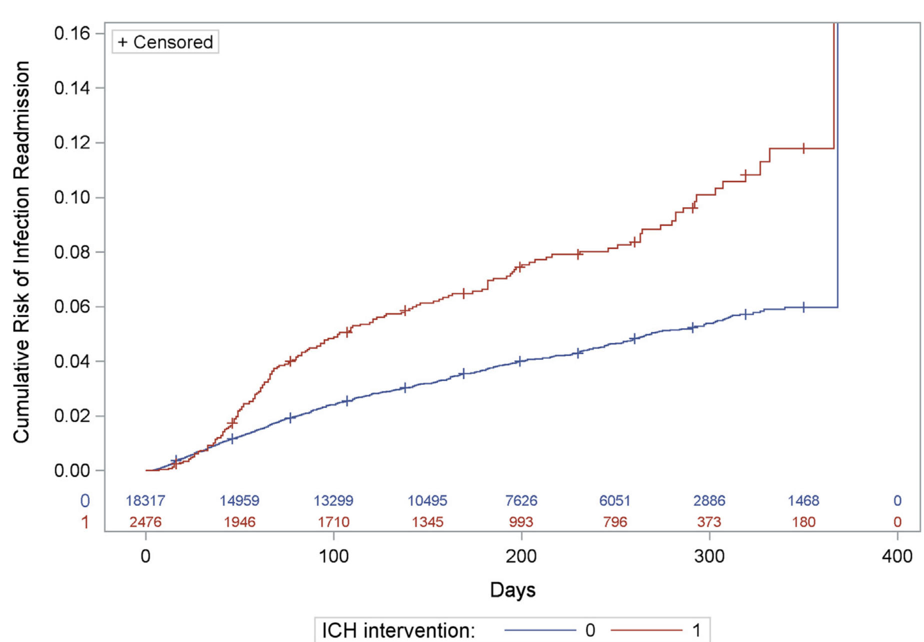

Fig. 1. Kaplan-Meier curve of cumulative risk of readmission for infection after intracerebral hemorrhage, stratified by receipt of intervention. Log-rank *p*-value < .0001.

Table 3
Cox models of the relationship between intracerebral hemorrhage intervention and readmission for infection.

Main predictor: Any ICH intervention vs. none:	Outcome = readmission for infection		
	HR	95% CI	p-Value
Unadjusted model	1.90	1.60–2.26	< 0.0001
Adjusted for APRDRG Risk of Mortality	1.30	1.08–1.56	0.0058
Adjusted for APRDRG Severity	1.22	1.01–1.47	0.039
Adjusted for vascular risk factors[a]	2.17	1.82–2.59	< 0.0001
Adjusted for vascular risk factors[a] and infection during index hospitalization	1.75	1.45–2.10	< 0.0001
Adjusted for vascular risk factors[a] and infection and length of stay during index hospitalization	1.61	1.33–1.95	< 0.0001
Adjusted for Elixhauser comorbidity index, readmission score	1.58	1.33–1.88	< 0.0001
Adjusted for Elixhauser comorbidity index, mortality score	1.52	1.25–1.82	< 0.0001
Adjusted for NIS-SOM[b]	1.65	1.39–1.96	< 0.0001

[a] Adjusted for: age, DM, smoking.
[b] NIS-SOM = NIS-SAH Outcome Measure.

Table 4
Cox models of the relationship between number of intracerebral hemorrhage interventions and readmission for infection.

Main predictor: # of ICH interventions vs. none	Outcome = readmission for infection			
	# of interventions	HR	95% CI	p-Value
Unadjusted model	1	1.79	1.46–2.18	< 0.0001
	2	2.07	1.51–2.84	< 0.0001
	3	3.58	1.78–7.18	< 0.0001
Adjusted for APRDRG Risk of Mortality	1	1.23	1.00–1.52	0.05
	2	1.38	0.99–1.91	0.053
	3	2.39	1.19–4.87	0.015
Adjusted for APRDRG Severity	1	1.82	0.96–1.46	0.123
	2	1.24	0.89–1.72	0.19
	3	2.04	1.01–4.13	0.05
Adjusted for vascular risk factors[a]	1	2.02	1.65–2.48	< 0.0001
	2	2.44	1.77–3.37	< 0.0001
	3	2.06	2.02–8.17	< 0.0001
Adjusted for vascular risk factors[a] and infection during index hospitalization	1	1.66	1.35–2.05	< 0.0001
	2	1.86	1.35–2.58	0.0002
	3	3.03	1.49–6.10	0.002
Adjusted for vascular risk factors[a] and infection and length of stay during index hospitalization	1	1.56	1.26–1.93	< 0.0001
	2	1.67	1.19–2.33	0.0025
	3	2.6	1.28–5.28	0.0081
Adjusted for Elixhauser comorbidity index, readmission score[b]	1	1.49	1.22–1.83	< 0.0001
	2	1.69	1.23–2.32	0.0012
	3	2.79	1.39–5.62	0.0039
Adjusted for Elixhauser comorbidity index, mortality score[b]	1	1.45	1.45–1.18	0.0004
	2	1.61	1.61–1.17	0.0035
	3	2.79	1.39–5.61	0.0039
Adjusted for NIS-SOM[c]	1	1.56	1.28-1.91	< 0.0001
	2	1.78	1.29–2.44	0.0004
	3	2.84	1.42–5.71	0.003

[a] Adjusted for: age, DM, smoking.
[b] Using the Elixhauser Comorbidity index.
[c] NIS-SOM = NIS-SAH Outcome Measure.

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