Original research

Higher Hospital Frailty Risk Score is associated with increased complications and healthcare resource utilization after endovascular treatment of ruptured intracranial aneurysms

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ABSTRACT

Aim To use the Hospital Frailty Risk Score (HFRS) to investigate the impact of frailty on complication rates and healthcare resource utilization in patients who underwent endovascular treatment of ruptured intracranial aneurysms (IAs).

Methods A retrospective cohort study was performed using the 2016–2019 National Inpatient Sample database. All adult patients (≥18 years) undergoing endovascular treatment for IAs after subarachnoid hemorrhage were identified using ICD-10-CM codes. Patients were categorized into frailty cohorts: low (HFRS <5), intermediate (HFRS 5–15) and high (HFRS >15). Patient demographics, adverse events, length of stay (LOS), discharge disposition, and total cost of admission were assessed. Multivariate logistic regression analysis was used to identify independent predictors of prolonged LOS, increased cost, and non-routine discharge.

Results Of the 33 840 patients identified, 7940 (23.5%) were found to be low, 20 075 (59.3%) intermediate and 5825 (17.2%) high frailty by HFRS criteria. The rate of encountering any adverse event was significantly greater in the higher frailty cohorts (low: 59.9%; intermediate: 92.4%; high: 99.2%, p<0.001). There was a stepwise increase in mean LOS (low: 11.7±8.2 days; intermediate: 18.7±14.1 days; high: 26.6±20.1 days, p<0.001), mean total hospital cost (low: $62 888±37 757; intermediate: $99 670±63 446; high: $134 937±80 331, p<0.001), and non-routine discharge (low: 17.3%; intermediate: 44.4%; high: 69.4%, p<0.001) with increasing frailty. On multivariate regression analysis, a similar stepwise impact was found in prolonged LOS (intermediate: OR 2.38, p<0.001; high: OR 4.49, p<0.001)], total hospital cost (intermediate: OR 2.15, p<0.001; high: OR 3.62, p<0.001), and non-routine discharge (intermediate: OR 2.13, p<0.001; high: OR 4.17, p<0.001).

Conclusions Our study found that greater frailty as defined by the HFRS was associated with increased complications, LOS, total costs, and non-routine discharge.

INTRODUCTION

Ruptured intracranial aneurysms (IAs) account for a majority of non-traumatic subarachnoid hemorrhage (SAH).[1] In recent years the majority of ruptured IAs have been treated using an endovascular approach. Despite continued advancements in this technology and neurocritical care, aneurysmal SAH remains a devastating disease with a mortality rate in excess of 50% and only 20–33% of survivors making a full recovery.[2–10] Given these variable outcomes and the high resource utilization associated with inpatient care, the identification of those most at risk for poor outcomes is desirable.

Frailty is an evolving concept that reflects an individual's increased vulnerability to poor health outcomes. Its utility as a predictive tool is increasingly recognized in general medicine and surgery. Its relevance to neurovascular disease remains poorly studied but of great potential interest. For example, it has been reported that 25–45% of patients with aneurysmal SAH are frail and may be at increased risk for poor outcomes.[11–14] Operationally, there are various ways to define frailty without widespread consensus on a 'best' methodology. Two commonly used tools are the modified 5-item Frailty Index (mFI-5) and modified 11-item Frailty Index (mFI-11).[15 16]

More recently there have been efforts to systematically identify frailty using variables that are routinely collected in national databases.[17 18] One example is the Hospital Frailty Risk Score (HFRS), which is based on a broad set of ICD-10 diagnostic codes over-represented in frailty including codes for volume depletion, chronic pulmonary disease and heart failure.[17] An increasing number of studies have shown the utility of the HFRS to predict mortality and poor health outcomes across a range of medical conditions and surgical procedures including pneumonia, acute myocardial infarction, COVID-19 hospitalizations, and revision total hip and knee arthroplasty.[15 19–22] Other recent studies have explored the HFRS as a predictive tool in stroke.[23] To date, the HFRS has not been explored in aneurysmal SAH.

The aim of this study was to use the HFRS to investigate the impact of frailty on complication rates and healthcare resource utilization in patients who underwent endovascular treatment of ruptured IAs.

METHODS
Data source and patient population
The Healthcare Cost and Utilization Project's National Inpatient Sample (NIS) database is a

stratified discharge database representing 20% of all inpatient admissions from community hospitals in the USA. It is the largest all-payer healthcare database in the USA, containing over 7 million hospital admissions (approximately 35 million hospitalizations, weighted) per year. A retrospective study was performed using years 2016–2019 of the NIS for all adult (≥18 years old) patients undergoing endovascular treatment for a ruptured IA. Institutional Review Board (IRB) exemption was obtained prior to initiation of the study.

Within the NIS, the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) diagnosis and procedural coding system (PCS) was used to identify patients with ruptured aneurysm, as well as their previously diagnosed comorbidities and the surgical interventions they underwent. The ICD-10-CM codes I60.X, I61.X were used (see online supplemental table 1). These identified patients were then cross-matched using ICD-10-PCS codes for endovascular treatment (see online supplemental table 2).

Hospital Frailty Risk Score (HFRS)

Frailty was defined using the HFRS, a validated ICD-10 coding algorithm developed by Gilbert et al[17] and used in multiple studies.[19–25] The coding algorithm is derived from a cluster of frail individuals with 109 over-represented ICD-10 codes assigned a number of points ranging from 0.1 to 7.1 reflecting the strength of association to the frail cluster.[17] These points are added together for a final frailty risk score.[17] All ICD-10 codes for the admission were entered into the calculation. In addition to presenting frailty as a continuous variable, we then stratified the frailty score into low (HFRS <5), intermediate (HFRS 5–15), and high (HFRS >15), as previously described.[17] A flow chart demonstrating the criteria used to identify the cohorts is shown in online supplemental figure 1.

Data collection

Patient demographics such as age, sex, race, median household income quartile, and insurance provider were all collected from the NIS database. Additional hospital characteristics such as bed size volume, region (Northeast, South, Midwest, and West), and type (rural, urban teaching, and urban non-teaching) were also collected. Elixhauser comorbidities were used to evaluate the incidence of congestive heart failure (CHF), cardiac arrhythmia, valvular disease, hypertension, pulmonary circulation disorders, peripheral vascular disorders, paralysis, other neurological disorders, chronic pulmonary disease, diabetes, hypothyroidism, renal failure, liver disease, peptic ulcer disease excluding bleeding, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, anemia (blood loss or deficiency), and alcohol abuse. In addition, patient admission comorbidities, affective disorders, smoking, and long-term aspirin or anticoagulant use were assessed (online supplemental table 1). Data on aneurysm location were collected including anterior (carotid siphon bifurcation, middle cerebral aneurysm, anterior communication) and posterior (posterior communicating, basilar, vertebral artery) location. Procedural data collected included ventriculoperitoneal shunt, central venous catheter, arterial monitoring, fluoroscopy of cerebral arteries with contrast, vasospasm treatment, video-electroencephalogram monitoring, and unspecified procedures such as external ventricular drain (online supplemental table 2).

Data regarding postoperative adverse events for each patient were collected by indexing additional diagnoses from the NIS database. Complications included in the analysis were urinary tract infection, post-procedural fever, pressure ulcer, sepsis, cardiogenic shock, cerebral infarction, syndrome of inappropriate antidiuretic hormone secretion, hypo-osmolar hyponatremia, pulmonary embolism, phlebitis, acute deep vein thrombosis, periprocedural stroke, acute myocardial infarction, acute respiratory failure, acute kidney injury, mechanical ventilation, tracheostomy, and gastrostomy (see online supplemental tables 1 and 2). In addition, postoperative outcome measures such as hospital length of stay (LOS), total cost of hospital admission, and discharge disposition were also assessed between the two cohorts. Discharge disposition was classified as routine (home, self-care, home healthcare), non-routine (patient sent to short-term hospital, skilled nursing facility, intermediate care facility), and other (leaving against medical advice, died in hospital, unknown destination). All-payer inpatient cost-to-charge ratios were used to convert total hospital charge to total cost of hospital services.

Statistical analysis

Discharge-level weights provided by the Agency for Healthcare Research and Quality were used to calculate national estimates. Parametric data were expressed as mean±SD and compared using a two-way independent t-test. Non-parametric data were expressed as median (IQR) and compared using the Mann–Whitney U test. Nominal data were compared with the χ^2 test. For our primary hypothesis, weighted univariate and multivariate logistic regressions were fitted with extended postoperative hospital LOS (as defined by LOS greater than the 75th percentile for the entire cohort), increased hospital costs (as defined by total costs greater than the 75th percentile for the entire cohort), and non-routine discharge as the dependent variables. There were no patients with missing information on LOS. Patients with missing total cost variable (n=64) were excluded from this portion of the analysis. Patients with 'other' discharge were also excluded from this portion of the analysis in order to dichotomize routine versus non-routine discharge. Backward stepwise multivariate logistic regression analysis was used to select variables in the final model, using 0.1 as entry and stay criteria. Based on our primary aim and in view of the plausibility for confounding, age and female sex were forced into the models. A p value of <0.05 was deemed to be statistically significant. Statistical analysis was performed using R Studio Version 3.6.2 (RStudio Inc, Boston, Massachusetts, USA).

RESULTS

Patient demographics and hospital characteristics

A total of 33 840 patients were included, of which 7940 (23.5%) were classified as low frailty, 20 075 (59.3%) as intermediate frailty, and 5825 (17.2%) as high frailty (table 1). Age increased significantly with increasing HFRS score (low: 54.1 years; intermediate: 57.5 years; high: 58.6 years, p<0.001) (table 1). Healthcare coverage also varied significantly between the frailty cohorts, with the low frailty cohort having a higher percentage of privately insured patients (low: 45.8%; intermediate: 36.7%; high: 35.5%) and patients in the high frailty cohort having a higher percentage of Medicare patients (low: 21.3%; intermediate: 32.8%; high: 35.7%, p<0.001) (table 1). While treating hospital region varied significantly between cohorts (p<0.001), race, household income quartile, weekend admission rate, and hospital bed size and type were all similar among the frailty cohorts (table 1).

Patient comorbidities, aneurysm locations and other surgical/intensive care procedures

The average HFRS score for each cohort was 2.7±1.6, 9.7±2.8, 18.7±3.0 for the low, intermediate, and high frailty cohorts, respectively (table 2). On comparison of the admission comorbidities and clinical presentation between frailty cohorts, seizure

Table 1 Patient demographics and hospital characteristics

Variables	Low (n=7940)	Intermediate (n=20 075)	High (n=5825)	P value
Age (years)				
Mean±SD	54.1±13.6	57.5±14.2	58.6±13.7	<0.001
Female (%)	63.0	67.2	69.9	<0.001
Race (%)				0.386
White	56.8	57.9	55.1	
Black	18.9	17.4	17.6	
Hispanic	13.7	13.8	16.1	
Other	10.5	10.9	11.2	
Income quartile (%)				0.158
0–25th	30.5	29.7	30.8	
26–50th	26.7	24.1	23.7	
51–75th	22.3	25.7	25.2	
76–100th	20.4	20.5	20.3	
Admitted during weekend (%)	24.2	28.3	28.7	0.005
Healthcare coverage (%)				<0.001
Medicare	21.3	32.8	35.7	
Medicaid	18.8	20.0	19.6	
Private insurance	45.8	36.7	35.5	
Other	14.1	10.5	9.2	
Hospital demographics				
Hospital region (%)				<0.001
Northeast	17.8	19.4	15.1	
Midwest	17.5	18.3	22.9	
South	42.8	40.0	36.7	
West	21.9	22.3	25.3	
Hospital bed size (%)				0.626
Small	5.0	4.9	5.4	
Medium	18.1	16.7	18.3	
Large	77.0	78.4	76.3	
Hospital type (%)				0.618
Rural	0.3	0.1	0.3	
Urban non-teaching	6.4	6.3	5.9	
Urban teaching	93.3	93.5	93.8	

Table 2 Patient comorbidities, aneurysm location, and surgical/intensive care procedures

Variables	Low (n=7940)	Intermediate (n=20 075)	High (n=5825)	P value
Frailty risk score				
Mean±SD	2.7±1.6	9.7±2.8	18.7±3.0	<0.001
Comorbidities (%)				
Seizure	1.3	8.4	16.2	<0.001
Neurological deficit associated with subarachnoid hemorrhage	0.1	0.6	1.0	0.002
Coma	0.9	5.5	7.9	<0.001
Aphasia	1.8	9.4	21.8	<0.001
Dysphagia	2.6	15.7	34.9	<0.001
Cranial nerve palsy	3.6	4.0	4.5	0.527
Diplopia	2.1	2.3	1.8	0.581
Hypertensive chronic kidney disease	0.4	3.6	6.2	<0.001
Personal history of transient ischemic attack	3.4	3.9	3.4	0.633
Headache	4.8	3.2	3.7	0.010
Affective disorder	12.8	16.3	17.1	0.002
Smoking	24.8	23.5	20.3	0.018
Congestive heart failure	3.1	8.1	11.1	<0.001
Cardiac arrhythmias	12.7	23.0	30.9	<0.001
Valvular disease	1.3	3.4	3.9	<0.001
Pulmonary circulation disorders	1.1	3.3	4.3	<0.001
Peripheral vascular disorders	4.7	5.9	6.1	0.156
Hypertension, combined	63.5	71.2	73.6	<0.001
Paralysis	0.9	15.6	53.6	<0.001
Other neurological disorders	14.2	43.9	64.0	<0.001
Chronic pulmonary disease	10.1	14.4	13.2	<0.001
Diabetes, uncomplicated	7.5	6.8	6.0	0.321
Renal failure	1.0	5.0	8.5	<0.001
Hypothyroidism	6.4	8.1	7.6	0.076
Liver disease	1.8	3.5	3.0	0.003
Peptic ulcer disease	0.2	0.3	1.4	0.017
Coagulopathy	4.3	7.6	8.3	<0.001
Obesity	12.5	14.6	12.6	0.074
Weight loss	2.7	9.4	16.3	<0.001

Continued

(p<0.001), neurological deficit associated with SAH (p=0.002), coma (p<0.001), aphasia (p<0.001), dysphagia (p<0.001), and hypertensive chronic kidney disease (p<0.001) were notably all significantly increased with increasing frailty score (table 2). IA location also varied across the frailty cohorts, with the greatest proportion of IAs located in the anterior communicating artery (low: 26.9%; intermediate: 27.4%; high: 27.8%, p<0.001) (table 2). In general, significantly more procedures were done as the frailty score increased across the cohorts (table 2). For example, the proportion of patients who underwent external ventricular drainage (low: 25.3%; intermediate: 51.8%; high: 60.3%, p<0.001) and subsequent ventriculoperitoneal shunt placement (low: 3.6%; intermediate: 10.6%; high: 15.8%, p<0.001) increased along with the HFRS score (table 2).

Adverse events and postoperative outcomes
Overall, the proportion of patients who experienced any adverse event (AE) significantly increased with increasing frailty (low:

Table 2 Continued

Variables	Low (n=7940)	Intermediate (n=20075)	High (n=5825)	P value
Fluid and electrolyte disorders	33.2	70.0	86.6	<0.001
Deficiency anemias	2.1	2.9	4.1	0.009
Alcohol abuse	4.1	6.9	8.3	<0.001
Current aspirin use	10.5	10.5	9.4	0.554
Current anticoagulant use	2.3	2.9	2.3	0.301
Aneurysm location (%)				<0.001
Anterior				
Carotid siphon bifurcation	4.1	3.0	3.3	
Middle cerebral artery	6.2	7.3	10.9	
Anterior communicating artery	26.9	27.4	27.8	
Posterior				
Posterior communicating artery	21.4	19.6	19.9	
Basilar artery	5.5	6.5	4.3	
Vertebral artery	0.8	1.9	2.3	
Unspecified	35.1	34.2	31.5	
Procedures (%)				
External ventricular drain	25.3	51.8	60.3	<0.001
Ventriculo-peritoneal shunt	3.6	10.6	15.8	<0.001
Central venous catheter placement	15.2	33.5	45.6	<0.001
Arterial monitoring	6.4	10.6	13.6	<0.001
Fluoroscopy of cerebral arteries with contrast	52.8	55.7	63.3	<0.001
Vasospasm treatment	2.5	6.3	10.7	<0.001
Video-EEG monitoring	1.4	6.0	10.0	<0.001

EEG, electroencephalogram

59.9%; intermediate: 92.4%; high: 99.2%, p<0.001) (table 3). With regard to specific AEs, the most common were vasospasm (low: 13.0%; intermediate: 37.9%; high: 55.3%, p<0.001), hydrocephalus (low: 34.1%; intermediate: 60.5%; high: 69.4%, p<0.001), cerebral infarction (low: 2.2%; intermediate: 11.5%; high: 22.4%, p<0.001), acute respiratory failure (low: 14.2%; intermediate: 47.3%; high: 66.4%, p<0.001), and mechanical ventilation (low: 16.2%; intermediate: 47.5%; high: 66.1%, p<0.001) (table 3). All adverse events increased in prevalence as the frailty score increased (table 3). Postoperative inpatient outcomes varied significantly among the frailty cohorts. Mean LOS (low: 11.7±8.2; intermediate: 18.7±14.1; high: 26.6±20.1, p<0.001), total cost of admission (low: $62 888±37 757; intermediate: $99 670±63 446; high: $134 937±80 331, p<0.001), and rate of non-routine discharge (low: 17.3%; intermediate: 44.4%; high: 69.4%, p<0.001) were all significantly increased with increasing frailty (table 3).

Logistic multivariate regression analyses

Increasing frailty was significantly associated with greater odds of experiencing a prolonged LOS (intermediate: OR 2.38 (95% CI 1.84 to 3.09), p<0.001; high: OR 4.49 (95% CI 3.36 to 6.00), p<0.001) (table 4). Similarly, increasing frailty was significantly associated with an increased cost of hospital admission (intermediate: OR 2.15 (95% CI 1.66 to 2.77), p<0.001; high: OR 3.62 (95% CI 2.71 to 4.83), p<0.001) (table 4). Finally, the odds of experiencing a non-routine discharge were found to increase with advancing HFRS (intermediate: OR 2.13 (95% CI 1.79 to 2.55), p<0.001; high: OR 4.17 (95% CI 3.26 to 5.33), p<0.001) (table 4). The complete univariate and multivariate data are available in online supplemental tables 3–5.

DISCUSSION

This retrospective national database study of 33 840 patients who underwent endovascular treatment of a ruptured IA shows that increasing frailty (as measured by HFRS) was associated with increased LOS, rates of hospital AEs, rates of non-routine discharges, and total costs. Further, on multivariate analysis, we found that intermediate and high frailty independently predicted prolonged LOS, increased cost, and non-routine discharge.

Frailty is increasingly recognized as a predisposing factor for adverse health outcomes and increased healthcare resource utilization.[26 27] Preliminary efforts have begun to assess the impact of frailty on patients with aneurysmal SAH. In a retrospective analysis of 217 patients who underwent surgical clipping of ruptured IAs, McIntyre et al found that ~26% of patients were frail, defined as mFI score ≥2.[11] Similarly, in a single-institution study of 173 elderly patients (≥60 years) who underwent surgical clipping of a ruptured IA, Yue et al found frailty, as defined by the presence of severe anemia, hypoalbuminemia, or low body mass index, to be common affecting ~45% of their patient cohort.[14] In our study, nearly 75% of patients undergoing endovascular treatment for a ruptured IA were considered to have intermediate (59.3%) or high (17.2%) frailty, as defined by the HFRS.

While there is a paucity of studies directly assessing frailty and outcomes, prior studies have attempted to identify the relationship between frailty and complications after management of ruptured IAs. In the retrospective study of 217 patients with aSAH by McIntyre et al, the authors found on multivariate regression analysis that frail patients were significantly more likely to experience a complication during their hospital stay (OR 2.6).[11] In a retrospective NIS database study of 5353 patients undergoing treatment for ruptured aneurysms between 2012 and 2015, Chotai et al found on multivariate analysis that the odds of experiencing any inpatient complication significantly increased as the neurovascular comorbidity index (NCI) score, a value closely related to frailty, progressed from 1 (OR 1.13) to 4 (OR 1.58) and to 7 (OR 2.05).[28] Similarly, our study of patients undergoing endovascular treatment of ruptured IAs found that, as the severity of frailty increased, the rate of perioperative AEs increased by more than fivefold from the low to the high frailty cohort. Further studies assessing frailty in ruptured IAs are needed to aid in patient risk stratification and patient-centered management strategies.

Table 3 Adverse events and postoperative outcomes

Variables	Low (n=7940)	Intermediate (n=20 075)	High (n=5825)	P value
Adverse events (%)				
Vasospasm	13.0	37.9	55.3	<0.001
Hydrocephalus	34.1	60.5	69.4	<0.001
Urinary tract infection	1.3	16.4	46.5	<0.001
Post-procedural fever	0.5	0.2	0.5	0.108
Pressure ulcer	0.0	1.4	4.0	<0.001
Sepsis	0.4	6.6	13.8	<0.001
Cardiogenic shock	0.3	1.4	1.5	0.002
Cerebral infarction	2.2	11.5	22.4	<0.001
Syndrome of inappropriate antidiuretic hormone secretion	3.5	4.2	4.1	0.421
Hypo-osmolar hyponatremia	15.9	30.5	33.4	<0.001
Pulmonary embolism	0.4	1.8	2.6	<0.001
Phlebitis	0.3	0.8	1.1	0.045
Acute deep vein thrombosis	2.0	7.8	13.6	<0.001
Periprocedural stroke	0.4	1.6	1.7	0.001
Acute myocardial infarction	1.3	3.2	3.8	<0.001
Acute respiratory failure	14.2	47.3	66.4	<0.001
Acute kidney injury	1.5	10.2	17.9	<0.001
Mechanical ventilation	16.2	47.5	66.1	<0.001
Tracheostomy	2.1	11.4	22.3	<0.001
Gastrostomy	3.0	14.1	31.0	<0.001
Any adverse event	59.9	92.4	99.2	<0.001
Number of adverse events				<0.001
0	48.7	14.4	3.3	
1	27.5	18.0	9.2	
>1	23.8	67.6	87.6	
Mortality (%)	6.4	15.3	10.8	<0.001
Length of stay (days)				
Mean±SD	11.7±8.2	18.7±14.1	26.6±20.1	<0.001
Median (IQR)	11 (7–15)	16 (11–23)	22 (16–31)	<0.001
Total cost of admission ($)				
Mean±SD	62 888±37 757	99 670±63 446	134 937±80 331	<0.001
Median (IQR)	55 247 (39 050–75 934)	83 358 (56 981–122 835)	112 881 (82 426–164 897)	<0.001
Disposition (%)				<0.001
Routine	75.1	39.8	19.6	
Non-routine	17.3	44.4	69.4	
Other	7.6	15.7	11.1	

While there is a paucity of studies directly assessing the impact of frailty with hospital LOS and non-routine discharges in patients with ruptured IA, there have been a few that evaluated the impact of comorbidities and other factors closely associated with frailty. In a retrospective NIS database study of 19 034 patients who underwent clipping or coiling of a ruptured or unruptured IA between 2002 and 2006, Hoh et al demonstrated that older age as well as diabetes, coagulopathy, CHF, renal failure, peripheral vascular disorders, and neurological or electrolyte disorders were each independently associated with longer hospitalizations.[29] Of these identified comorbidities, four are included in the commonly used 11-item mFI,[30] three

are included in the 5-item mFI,[31] and five are included in the HFRS.[17]

However, not all studies have reported results similar to the findings outlined above. For example, in a retrospective observational database study of 203 patients treated for a ruptured IA between 2012 and 2017, Hammer et al found that all analyzed comorbidities including hypertension, diabetes, hypothyroidism, cholesterinemia, and smoking did not have a significant impact on LOS in the intensive care unit.[32] Analogous to the aforementioned studies, our study found that mean hospital LOS more than doubled when comparing low to high HFRS cohorts. Furthermore, on multivariate analysis, we also found

Table 4 Logistic multivariate regression analyses on prolonged LOS, increased cost, and non-routine discharge disposition

Variables	Prolonged LOS		Increased cost		Non-routine discharge	
Frailty risk category	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Low	Reference					
Intermediate	2.38 (1.84 to 3.09)	<0.001	2.15 (1.66 to 2.77)	<0.001	2.13 (1.79 to 2.55)	<0.001
High	4.49 (3.36 to 6.00)	<0.001	3.62 (2.71 to 4.83)	<0.001	4.17 (3.26 to 5.33)	<0.001
Age	0.99 (0.99 to 0.99)	0.038	0.99 (0.98 to 0.99)	0.003	1.04 (1.03 to 1.05)	<0.001
Female sex	0.91 (0.79 to 1.04)	0.172	0.86 (0.74 to 0.99)	0.035	0.76 (0.65 to 0.88)	<0.001
Aphasia	1.63 (1.32 to 2.01)	<0.001	1.35 (1.09 to 1.66)	0.005	1.68 (1.35 to 2.11)	<0.001
Dysphagia	3.00 (2.55 to 3.52)	<0.001	2.04 (1.72 to 2.41)	<0.001	3.95 (3.20 to 4.87)	<0.001
Headache	0.72 (0.49 to 1.07)	0.101	0.51 (0.32 to 0.83)	0.006	0.50 (0.34 to 0.73)	<0.001
Aneurysm location						
Anterior	Reference					
Posterior	1.02 (0.87 to 1.20)	0.824	1.05 (0.89 to 1.23)	0.587	0.85 (0.72 to 0.99)	0.041
Unspecified	1.00 (0.85 to 1.17)	0.954	1.10 (0.93 to 1.30)	0.254	1.30 (1.11 to 1.53)	<0.001
Number of adverse events						
0	Reference					
1	4.20 (2.61 to 6.76)	<0.001	2.81 (1.87 to 4.24)	<0.001	1.89 (1.52 to 2.36)	<0.001
>1	19.75 (12.73 to 30.65)	<0.001	14.40 (9.99 to 20.73)	<0.001	6.74 (5.55 to 8.18)	<0.001

LOS, length of stay.

that both intermediate and high frailty were significant independent predictors of prolonged LOS when compared with patients with low baseline frailty. With respect to discharge disposition, in the study by McIntyre et al the authors showed on multivariate analysis that frail patients were significantly less likely to be discharged to home (OR 0.32).[11] Our study also found that rates of non-routine discharge were nearly four times higher in patients with high frailty than in those with low frailty. As prolonged LOS and non-routine discharges have repeatedly been shown to increase healthcare resource utilization and be associated with inferior outcomes in patients undergoing various neurosurgical procedures, further studies should be done to better define the relationship between frailty and LOS following treatment of ruptured IAs.

While few studies have examined the impact of frailty on the cost of hospital admission in patients undergoing treatment for IAs, there have been efforts to characterize the effect of frailty-associated factors on hospital admission cost within this patient population. In the NIS database study of patients treated for a ruptured IA by Chotai et al, the authors found on regression analysis that higher NCI scores were associated with a greater cost of hospital admission.[28] Consistent with these findings, the NIS database study of patients with ruptured or unruptured IA by Hoh et al demonstrated that frailty-associated comorbidities (eg, diabetes, CHF, coagulopathy, electrolyte disorders, neurological disorders, renal failure, and peripheral vascular disorders) and older age were each independently associated with greater hospital costs.[29] Similarly, our study found that the mean cost of hospital admission more than doubled between the low frailty and the high frailty cohort. These data, although limited, demonstrate how frailty may be contributing to the soaring healthcare costs in the USA.

This study has a number of limitations inherent to all administrative databases, including the NIS. First, the analysis is retrospective, potentially limiting the interpretation of our results. The data are also available only by ICD-10-CM codes, which may contain coding and reporting biases. Second, data may be misclassified or incomplete. Third, information regarding preoperative factors such as the size of the IA prior to rupture is unavailable, which may have an unrecognized effect on our results. Also, there may be additional confounding variables present which are unavailable or have not been measured. Finally, given the NIS has information specific to a single inpatient admission, we cannot comment on long-term functional outcomes or the durability of treatment. Despite these limitations, this study uses one of the largest inpatient databases in the USA to provide unique insights into the impact of frailty on postoperative outcomes and healthcare resource utilization for patients undergoing endovascular treatment of ruptured IAs.

CONCLUSION
Our study is the first to use the HFRS to assess the impact of frailty on patients who underwent endovascular treatment for ruptured IAs. We found that greater frailty was associated with increased complications, prolonged hospital LOS, higher total costs, and non-routine discharge. These results highlight the need for further studies that examine the impact of frailty on outcomes following endovascular treatment for a ruptured IA, as it may improve patient care and reduce healthcare resource utilization.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplemental information. Not applicable.

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