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Treatment at safety-net hospitals is associated with delays in coil embolization in patients with subarachnoid hemorrhage.

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Abstract

Introduction—Successful endovascular management of aneurysmal subarachnoid hemorrhage (aSAH) requires timely access to significant resources. Prior studies suggest an association between time to treatment and patient outcome. Patients treated at safety-net hospitals are thought to be particularly vulnerable to disparities in access to interventions that require substantial technological resources. We hypothesize that patients treated at safety-net hospitals are at greater risk for delayed access to endovascular treatment.

Materials and Methods—Adults undergoing endovascular coiling procedures between 2002–2011 in the Nationwide Inpatient Sample were included. Hospitals in the quartile with the highest proportion of Medicaid or uninsured patients were defined as safety-net hospitals. A multivariable model including patient and hospital-level factors was constructed to permit analysis of delays in endovascular treatment (defined as time to treatment greater than 3 days).

Results—Analysis included 7,109 discharges of patients with aSAH undergoing endovascular coil embolization procedures from 2002–2011. The median time to coil embolization in all patients was 1 day; 10.1% of patients waited more than three days until treatment. In multivariable analysis, patients treated at safety-net hospitals were more likely to have a prolonged time to coil embolization (OR 1.32, $p < 0.01$) when compared to patients treated at the lowest burden hospitals.

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Conclusions—After controlling for patient and hospital factors, individuals with aSAH treated at safety-net hospitals from 2002–2011 were more likely to have a delay to endovascular coil embolization than those treated at non-safety-net hospitals. This disparity could affect patient outcomes.

Keywords

coil; aneurysm; hemorrhage; subarachnoid

INTRODUCTION:

Aneurysmal subarachnoid hemorrhage (aSAH) is associated with an average mortality rate of 51 % [1]. If untreated, greater than 50% of patients suffer re-rupture with permanent neurologic disability or death; the rate of which is highest in the first two weeks post-ictus [2–4]. Re-rupture rates have been quoted as 4% during the first post-bleed day and 1–2% per day thereafter for the first two weeks [5] with 23.5% of re-ruptures occurring in the first three days [4]. Successful exclusion of ruptured brain aneurysms at timepoints within the first 72h after rupture or hospital admission (“early treatment”) [6, 7] [8] significantly reduces re-rupture rates [9] and overall mortality [10], particularly in patients in poor clinical condition [11]. In addition to reducing the rate of re-rupture, early treatment of a ruptured aneurysm secures the aneurysm before the onset of vasospasm, which typically occurs between post-bleed day 4 to 14 [12]. Patients whose aneurysms are treated during day 4–14 may have increased rates of periprocedural stroke and death [13, 14]. Although some authors recommend “ultra- early” treatment within 24 hours of rupture [15], the European Stroke Organization guidelines [16] advocate a three day treatment window following initial aneurysmal rupture. These guidelines are based upon the International Cooperative Study on the timing of Aneurysm Surgery and systematic literature reviews [17–19] [20]. The time to aneurysm treatment is a quantifiable indicator of care delivery in aSAH, and a three-day threshold represents a reasonable outcome metric for assessment.

Recent studies have focused on hospital safety-net status as a factor associated with adverse outcomes in surgical patients. [21, 22] Safety-net hospitals are defined as facilities that care for the greatest number of uninsured, Medicaid, or otherwise vulnerable patients. Although these centers play a critical role in healthcare delivery, they are often limited by their susceptibility to economic challenges and resource availability. Werner et al. examined quality performance measures with respect to myocardial infarction, heart failure, and pneumonia at safety net hospitals over a three- year period. The authors demonstrated smaller gains in performance improvement at safety-net, when compared to non-safety net, hospitals and concluded that the safety net hospitals were less likely to be high-performing over time. [22]

Due to the levels of technology, expertise, and institutional support required to sustain endovascular treatment programs, their presence and efficiencies vary among hospital facilities throughout the country. Endovascular treatment of ruptured brain aneurysms may be particularly affected by disparities in provision of care. The role of care delivery by safety-net hospitals has been examined in other neurologic disease states including

thrombolysis for stroke and radiosurgery for metastatic brain cancer.[23, 24] However, impact of hospital safety-net burden on endovascular treatment of ruptured brain aneurysms remains unstudied. This investigation aims to determine the impact of hospital safety net status on time to endovascular treatment of ruptured brain aneurysms. We hypothesize that safety-net status is associated with delayed time to endovascular treatment in the setting of aSAH.

METHODS

Data Source

We utilized the 2002–2011 datasets of the NIS. The National Inpatient Sample (NIS) of the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project included over 8,000,000 annual discharges from over 1,000 hospitals across 46 states in 2011 [25]. The NIS includes a standard set of patient and hospital variables; analytic methods have been described in prior papers[19]. Patient level variables include race (categorized as African-American, Asian Pacific Islander, Hispanic, Native American, White, other), insurance payer (categorized as charity/no charge, Medicare, Medicaid, private insurance, self-pay), and gender. We broke down age into clinically relevant categories (age <44 years, 45–64 years, 65–74 years, >75 years) as previously reported[19]. Hospital-level variables included hospital size, hospital teaching status, and hospital region according to 4-region census breakdown (Northeast, Midwest, South, West). Hospital size is reported as small (defined as <200 beds), medium (201–400 beds), or large (>400 beds). Time to procedure is reported in the dataset. The All Patient Refined Diagnosis Related Group (APR DRG) risk of mortality score is reported in the dataset, according to a proprietary algorithm (3M, St. Paul MN).

Study Population

We utilized International Classification of Diseases, Ninth Edition Clinical Modification (ICD-9CM) codes provided in the NIS to define inclusion and exclusion criteria. We included admissions containing both a diagnosis code of subarachnoid hemorrhage (430.xx) and a procedure code of endovascular embolization (39.79, 39.72, 39.52). The NIS provides a time-to-procedure variable measured in days which we dichotomized into two categories: patients with a time to endovascular procedure of 3 or fewer days and patients with a time to endovascular procedure of more than 3 days.

Hospital safety-net burden was defined as described in prior investigations[26] [22] [27], based upon the proportion of each hospital's patients who had Medicaid or were uninsured. Similar to a prior investigation[26], we stratified hospitals into three groups based upon safety-net burden. High-burden hospitals (safety-net hospitals) were those in the highest quartile of safety net burden. Medium-burden hospitals were defined as those in the middle 2 quartiles and low-burden hospitals (non-safety-net hospitals) were in the lowest quartile of safety net burden.

Statistical analysis

Descriptive statistics were calculated. Comparisons were made using ANOVA for continuous normally distributed variables, and frequency, percentage and Chi square test were used for categorical variables. Multivariable analysis was performed using a generalized linear mixed model with modified Poisson regression (Poisson regression with a robust error variance)[28]. Patient characteristics and hospital-level factors were included in the model. The primary outcome variable was the likelihood of delayed coil embolization, defined as a time to procedure for coil embolization > 3 days. Statistical significance was defined as a 2 sided $p < 0.05$. Analysis was conducted using SAS V 9.4 (Cary, North Carolina, USA).

RESULTS

Of the 7,946 discharges of patients with a SAH who underwent endovascular coil embolization between 2002–2011, 837 (11.2%) did not have a documented time to procedure and were excluded from analysis. The remaining 7,109 discharges were included our analysis. The majority of patients treated were white, privately insured patients who received care at large teaching hospitals.

In our analysis, high-burden hospitals (“safety-net” hospitals) were defined as hospitals with >28.0% of uninsured and Medicaid patients. Medium-burden hospitals were defined as those with 11.6%- 28.0% uninsured and Medicaid patients in our analysis. Low- burden hospitals had 11.6% uninsured and Medicaid patients in our data. 34.9% of patients were treated at high burden hospitals, 46.6% of patients were treated at medium burden hospitals, and 18.5% of patients were treated at low burden hospitals. The demographic characteristics of patients categorized by hospital safety- net burden are presented in Table 1.

The median time to coil embolization procedure was 1 day after admission with an interquartile range of 0–2 days; 720 patients (10.1%) had a delayed coil embolization by greater than three days after admission. The distribution of all patients with delayed time to procedure is shown in Figure 1. In univariate analysis, age, race, payer and risk of mortality were all significant predictors of having a delay (>3 days) to coil embolization (all $p < 0.05$).

Main Outcomes

We performed multivariate analysis to evaluate whether patient and hospital factors were associated with an increased likelihood of a delay in treatment > 3 days (Table 2). Hospital safety-net burden was also associated with delays in coil embolization: compared to hospitals in the lowest quartile of safety-net burden, patients treated at safety-net hospitals were more likely to have delayed treatment (RR 1.32, $p < 0.01$). Several patient factors were associated with increased delays in care. We found that Hispanic (RR 1.39, $p < 0.01$) and Asian/Pacific Islander (RR 1.53, $p < 0.01$) patients were more likely to have a delay in treatment. Medicaid patients were also more likely to have delayed treatment (RR 1.22, $p < 0.01$). Other hospital factors were also associated with delays in coil embolization. Patients treated at a large (RR 1.50, $p < 0.01$) or medium (RR 1.38, $p < 0.01$) size hospital were

more likely to have delayed treatment. However, patients treated at teaching hospitals were less likely to have delayed treatment (RR 0.87, $p=0.0155$).

DISCUSSION

This study examined 7,109 discharges of aneurysmal subarachnoid hemorrhage patients who underwent endovascular coil embolization procedures from 2002 to 2011. When compared to patients treated at hospitals with the lowest safety-net burden, patients treated at high burden hospitals (caring for the greatest proportion of Medicaid and uninsured patients) were more likely to have delays in time to coil embolization in the time period analyzed, even after controlling for multiple patient and hospital factors. This disparity is likely multifactorial. Safety-net hospitals serve disadvantaged populations and therefore may not be afforded the economic benefits of other facilities. Although some receive federal and state subsidized funding, others do not have official status as county or state designated centers but rather achieve de facto safety-net status by virtue of the patient populations or geographic catchment areas to which they provide care [29]. As evident in our analysis, hospitals with high safety-net burden vary in size, geographic location, and teaching status. Likewise, they serve patients of diverse age ranges and ethnic backgrounds. These potentially confounding patient and hospital level factors were controlled for in multivariable analyses.

Prior studies have documented disparities in the quality of care at safety-net hospitals during the time period analyzed [22]. This disparity is particularly evident in the setting of complex and/ or emergent surgical procedures. Wakeam et al. demonstrated increased failure to rescue rates following high-risk inpatient surgeries in safety-net hospitals.[21] Likewise, a study by Shahan et al. found that safety-net hospitals register higher complication rates following emergency general surgery procedures[30].

aSAH provides an ideal model through which to explore disparities in acute health care delivery systems. Patients' with aSAH have an emergent need for relatively complex multidisciplinary care and specialized procedures, revealing stresses on infrastructure that may not be apparent during day-to-day operations. Effective administration of an endovascular aneurysm treatment program requires planning and foresight. These programs require multidisciplinary physician collaboration along with dedicated nursing staff, experienced technologists, and readily available equipment and devices. Successful delivery of neuroendovascular services is resource and cost dependent [31]. Safety-net hospitals often have limited revenue streams due to disadvantaged payer mixes and may, therefore, lack critical resources or be incapable of mobilizing them in an efficient manner[21]. Accordingly, hospitals with a higher burden of uninsured or under-insured patients may decide not develop the infrastructure necessary to provide neuroendovascular services on a consistent basis.

Moreover, as the onset of aSAH is unpredictable, patients who might otherwise self-select a specific treatment facility are often transported to the nearest hospital with appropriate emergency services rather than a center of excellence. These safety-net hospitals may not have endovascular capabilities to treat aSAH. Aneurysmal SAH patients often complain of

headache or present with loss of consciousness, rendering prehospital diagnosis and triage challenging. By contrast, acute stroke systems of care have algorithms and protocols developed to direct ischemic stroke patients to centers specifically equipped to manage stroke in an efficient manner [32]. Lack of similar triage and routing protocols presents a challenge for aSAH patients and their care providers. Upon hospital arrival, aSAH patients often require emergent ventriculostomy or other stabilizing measures, impeding rapid transfer to centers with more advanced endovascular capabilities and causing delays in definitive aneurysm treatment.

Using the same administrative database analyzed in the current study (HCUP NIS), Attenello et al. showed that longer time to procedure (> 3 days) was associated with increased likelihood of moderate to severe neurologic disability in patients with aSAH[19]. They also demonstrated that Medicaid-insured aSAH patients experienced longer wait times to endovascular therapy than privately insured patients. However, that study did not investigate whether hospital safety-net burden mediated this effect. Our current study suggests that these previously reported associations may be at least partially due to hospital safety-net status rather than individual insurance status.

Our multivariable analysis demonstrated that Hispanic and Asian-Pacific Islanders were independently at risk for delays in coil embolization compared to white patients, even after controlling for hospital type, safety-net status and other factors. This is consistent with findings from Attenello et al. (despite a different analysis model), which demonstrate that Hispanic patients had prolonged wait time to endovascular coiling procedures[33]. We are not able to evaluate the causes of this racial disparity in timely access to care using the current administrative dataset.

Due to inherent limitations of administrative data, we are not able to determine whether a particular safety-net hospital factor drives delays in the endovascular care of aSAH patients. It is not clear whether an unmeasured variable, such as delayed initial presentation, could render treatment during the vasospasm risk period challenging. However, safety-net hospital disparities persist despite controlling for APR-DRG Risk of Mortality, a proprietary score that reflects the overall probability of death during a hospitalization. This suggests that the observed disparity is not solely attributable to patient-level clinical factors.[34] The present report leverages administrative data from the NIS, a well-known and validated dataset with clearly defined limitations. Coding mistakes may influence large administrative databases. [35] Of note, the time frame analyzed in this study is from 2002–2011 and generalization of the results to any other time frame cannot be assumed. NIS data is limited to the years available in the dataset at the time of analysis. Endovascular therapy has become more accessible in the years after the time block analyzed and it is possible that any discrepancy in endovascular treatment based on hospital safety-net status observed here may have been amplified in the period cited. Future studies examining trends in endovascular therapy usage after 2011 would be interesting; however safety-net hospitals have structural constraints that have persisted after 2011 and may continue to limit the use of endovascular therapy at safety-net hospitals for the reasons outlined here. The lack of patient-specific clinical information limits ability to adjust for confounding variables. Assessment of disease severity is based on previously validated scoring systems, which only indirectly estimate actual

illness. Missing data affected 11.2% of patients in this study, which may introduce a source of bias into our estimates.

Conclusion

After controlling for patient and hospital factors, our data suggests that patients treated at safety net hospitals with the highest burden of uninsured and Medicaid patients were more likely to experience delays in endovascular coil embolization for ruptured cerebral aneurysms. Hospital factors may affect timely access to urgent neuroendovascular procedures at facilities treating the most economically disadvantaged patients.

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Abbreviations:

aSAH	aneurysmal subarachnoid hemorrhage
NIS	Nationwide Inpatient Sample
APR DRG	All Patient Refined Diagnosis Related Group

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Highlights

- Endovascular management of aSAH requires timely access to significant resources.
- Safety-net hospitals have the highest proportion of Medicaid or uninsured patients.
- Patients with aSAH have delays in coil embolization at safety-net hospitals.
- This disparity could affect patient outcomes.

Figure 1:
Time to Treatment in Patients with Delayed Treatment. 20 patients had time to coil embolization greater than 30 days (not shown).

Table 1:

Demographics of variables categorized by degree of hospital safety-net burden (weighted).

Variable	Hospital by Safety -Net Burden			p-value
	LBH (%) ^{a,b}	MBH (%)	HBH (%)	
Total Number	1444	3266	2399	
Mean Age (SEM) ^{c,d}	54.9 (14.2)	55.6 (14.2)	54.9 (14.5)	ns
Female Gender	991 (68.6)	2216 (67.9)	1561 (65.1)	0.02
Race				<0.0001
White	628 (43.5)	1826 (55.9)	1111 (46.3)	
Black	121 (8.4)	351 (10.8)	374 (15.6)	
Hispanic	147 (10.2)	257 (7.9)	286 (11.9)	
Asian or Pacific Island	80 (5.5)	100 (3.1)	55 (2.3)	
Native American	DS	DS	DS	
Other	47 (3.3)	79 (2.4)	77 (3.2)	
Missing	419 (29.0)	648 (19.8)	487 (20.3)	
Payer				<0.0001
Medicare	373 (25.8)	870 (26.6)	597 (24.9)	
Medicaid	114 (7.9)	395 (12.1)	476 (19.8)	
Private Insurance	748 (51.8)	1578 (48.3)	856 (35.7)	
Self-Pay	146 (10.1)	253 (7.8)	269 (11.2)	
No Charge	17 (1.2)	33 (1.0)	44 (1.8)	
Other	44 (3.1)	122 (3.7)	148 (6.2)	
Missing	DS ^f	15 (0.5)	DS	
APRDRG Risk Mortality ^e				ns
Extreme	412 (28.5)	972 (30.1)	788 (32.9)	
Major	501 (34.7)	1136 (35.2)	807 (33.7)	
Moderate	189 (13.1)	417 (12.9)	286 (11.9)	
Minor	342 (23.7)	706 (21.9)	515 (21.5)	
Hospital Bedsize				<0.0001
Large	1119 (77.5)	2783 (85.2)	2141 (89.3)	
Medium	166 (11.5)	373 (11.4)	220 (9.2)	
Small	159 (11.0)	76 (2.3)	DS	
Missing	DS	34 (1.0)	33 (1.4)	
Hospital Region				<0.0001
Northeast	325 (22.5)	894 (27.4)	250 (10.4)	

Variable	Hospital by Safety -Net Burden			p-value
	LBH (%) ^{a,b}	MBH (%)	HBH (%)	
Midwest	94 (6.5)	862 (26.4)	192 (8.0)	
South	578 (40.0)	950 (29.1)	1344 (56.0)	
West	447 (31.0)	560 (17.2)	613 (25.6)	
Teaching Hospital				<0.0001
Teaching	1290 (89.3)	2746 (84.1)	2264 (94.4)	
Non-teaching	154 (10.7)	486 (14.9)	102 (4.3)	
Missing	DS	34 (1.0)	33 (1.4)	

^a LBH, low-burden hospital; MBH, medium-burden hospital, HBH, high-burden hospital

^b Percentage calculated from total number within safety-net burden group

^c Age in years

^d SEM= Standard Error of Mean

^e APDRG= All Patient Refined Diagnosis Related Groups

^f DS= Data suppressed per HCUP Data User Agreement

Table 2:

Patient- and hospital-level factors associated with an increased likelihood of delay in treatment (>3days).

Variable		Relative Risk	95% CI	P value
Gender	Female	0.72	0.67, 0.77	<0.01
	Male	Reference		
Race	Black	0.97	0.87, 1.08	ns
	Hispanic	1.39	1.25, 1.54	<0.01
	Asian Pacific	1.53	1.31, 1.79	<0.01
	Islander			
	Native American	1.1	0.59, 2.04	ns
	Other	0.92	0.75, 1.12	ns
	White	Reference		
Health Insurance	Medicare	1.06	0.94, 1.2	ns
	Medicaid	1.22	1.1, 1.34	<0.01
	Self-pay	1.11	0.98, 1.25	0.092
	No Charge	0.88	0.65, 1.2	ns
	Other	0.95	0.81, 1.12	ns
	Private Insurance	Reference		
Age ^a	0–44	1.31	1.11, 1.54	<0.01
	45–64	1.12	0.96, 1.3	ns
	65–74	1.2	1.05, 1.38	<0.01
	≥75	Reference		
Hospital bedsize	Medium	1.5	1.17, 1.92	<0.01
	Large	1.38	1.1, 1.74	<0.01
	Small	Reference		
Hospital Region	Midwest	0.95	0.85, 1.07	ns
	South	0.84	0.76, 0.93	<0.01
	West	1.07	0.97, 1.19	ns
	Northeast	Reference		
Teaching Hospital	Teaching	0.87	0.77, 0.97	0.0155
	Nonteaching	Reference		
APRDRG Risk of Mortality ^b	Moderate	1.49	1.33, 1.68	<0.01
	Major	1.38	1.26, 1.53	<0.01
	Extreme	1.35	1.22, 1.5	<0.01
	Minor	Reference		
Hospital by Safety - Net Burden	LBH	Reference		
	MBH	0.78	0.71, 0.86	<0.01
	HBH	1.32	1.2, 1.46	<0.01

^aAge in years

^bAPDRG= All Patient Refined Diagnosis Related Groups

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