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Cost of hospitalization for aneurysmal subarachnoid hemorrhage in the United States*

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ABSTRACT

Objective: Recent large-scale studies describing hospitalization cost trends secondary to aneurysmal subarachnoid hemorrhage (aSAH) in the United States are lacking. We sought to discover the impact of aSAH-related factors upon its hospitalization cost.

Patients and methods: Patients with a primary diagnosis of aSAH were selected utilizing the National Inpatient Sample. Regression analyses were used to evaluate the impact of aSAH-related factors on hospitalization costs.

Results: From 2002–2014, 22,831 cases of aSAH were identified. The inflation-adjusted mean cost of hospitalization was $82,514 (standard deviation ± $54,983). The proportion of males was lower (31%), but a higher cost of $3385 (± $685; $p < .001$) remained compared to females. Median length of hospitalization was 16 days (interquartile range 11–23) and each day increase in hospitalization was associated with a cost increase of $3228 (± $19; $p < .001$). There was no difference in cost between patients undergoing aneurysmal coiling or clipping. When compared to patients < 40 years old, the increase in cost for patients 40–59 years old was $3829 (± $914; $p < .001$), and $4573 (± $1033; $p < .001$) for patients 60–79 years old; however, for patients ≥ 80 years old, there was a decrease in cost of $8124 (± $1722; $p < .001$). Several central nervous system complications were also associated with increased cost.

Conclusion: aSAH is a significant financial burden on the United States healthcare system. We were able to identify many important factors associated with higher costs, and these results may help us understand resource utilization and develop future cost-reduction strategies.

1. Introduction

The reported incidence of aneurysmal subarachnoid hemorrhage (aSAH) in the United States has varied greatly [1] but is estimated to be around 10–15 cases per 100,000 per year [2,3]. However, due to a significant number of cases with prehospital mortality, the actual number of cases may be even higher. Management of aSAH invariably requires admission to an intensive care unit, for at least 2 weeks in most cases. Furthermore, it carries high rates of inpatient complications such as respiratory failure, vasospasm, hydrocephalus, and seizures. Patients require multiple imaging studies and surgical or endovascular interventions. Taken together, all of these factors lead to high admission-related costs. In the United States, the mean hospital cost for subarachnoid hemorrhage was estimated to be $65,900 in the year 2000–2001, which was a significant increase from $37,400 in the year 1990–1991 [4]. The cost of hospitalization in the United States has not been studied in recent years, despite significant advancements in the management of these patients and a shift from surgical to endovascular treatment. In the setting of rising national hospitalization costs, especially in critical care [5], we sought to obtain estimates regarding the hospitalization costs of aSAH in the United States using a nationally representative administrative database. We also sought to determine which factors were associated with higher costs.

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2. Patients and methods

2.1. Data

We obtained data from the National Inpatient Sample (NIS) of the Healthcare Cost and Utilization Project (HCUP) from January 2002 to December 2014. NIS is sponsored by the Agency for Healthcare Research and Quality of the US Department of Health and Human Services. It is the largest, publicly available inpatient health care database and contains an approximately 20% sample of all hospital admissions to non-federal US hospitals. The information in NIS is based on hospital charges for single admissions/encounters. More details regarding design, content and use of NIS can be found at the HCUP website [6].

Regarding informed consent, NIS - being publicly available - does not contain any unique patient identifying information, and therefore, the database meets the criteria for exemption from review by any institutional review board as per the US Department of Health and Human Services under exemption 45 CFR 46.101(b)(4).

2.2. Patient selection

International Classification of Diseases, Ninth Revision, Clinical Modification (*ICD-9-CM*) codes were used to identify particular diagnoses and inpatient procedures. NIS was searched to isolate adult (age ≥ 18 years) patients with the primary discharge diagnosis of subarachnoid hemorrhage *(430)* who underwent an aneurysm clipping *(39.51)* or coiling *(39.52, 39.72, 39.75, 39.76)* procedure. Those who carried diagnoses of traumatic intracranial injury/hemorrhage, arteriovenous malformation, discharge to another hospital and any missing variables were excluded. Such strict selection criteria were used to ensure that the sample contained only aSAH cases. Several in-hospital procedures and complications relevant to aSAH were identified using *ICD-9* codes.

2.3. Statistical analysis

Hospitalization cost was calculated using the method provided by HCUP [7]. Inflation adjustment was done for the year 2017 using the Consumer Price Index Calculator of the Bureau of Labor Statistics [8].

Categorical and ordinal variables were described by percentages and the numeric variables were described using mean, median and interquartile range (IQR). Gamma regression analyses were used to identify predictors of higher hospitalization cost. This method was used to accommodate the non-normal distribution of cost data. Standard deviations were given for all cost estimates, except where otherwise noted. The regression model was adjusted for Charlson Comorbidity Index [9], hospital characteristics (bed size and location/teaching status) and the source of payment. All statistical analyses were conducted in SAS version 9.4 (SAS Institute Inc., Cary, NC).

3. Results

During this period, a total of 22,831 adult patients with aSAH who underwent coiling or clipping were identified. Inflation-adjusted mean cost of hospitalization was $82,514 (standard deviation ± $54,983), while the median cost was $67,544 (IQR $45,533-$103,206). The mean cost of hospitalization increased almost every year during the study period (Fig. 1).

The median age of our study population was 54 years (IQR 45–63) and its association with cost was not linear. When compared to the patients < 40 years, the increase in cost was $3829 (± $914; P < .001) for patients 40–59 years old, and $4573 (± $1033; P < .001) for patients 60–79 years old; however, for patients ≥ 80 years old there was a decrease in cost of $8124 (± $1722; P < .001). The proportion of males was lower (31%), but there was a $3385 (± $685; P < .001) higher cost compared to females. Median length of hospitalization was 16 days (IQR 11–23), and in the regression analysis, per day increase of hospitalization was associated with a cost increase of $3228 (± $19; P < .001).

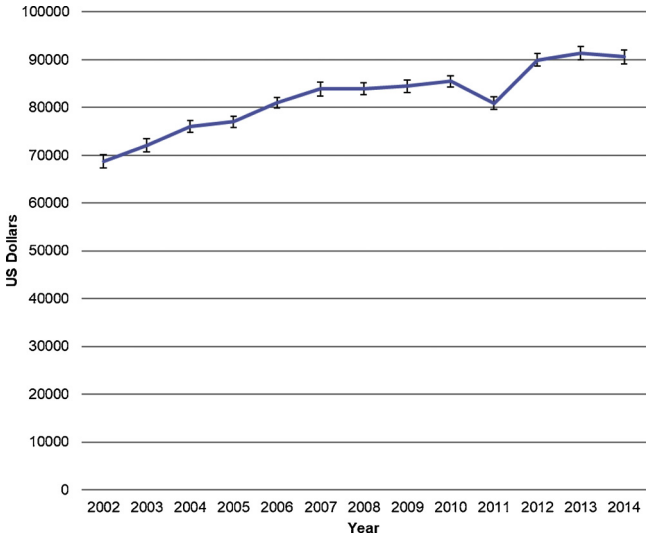

Fig. 1. Line graph demonstrating the gradual increase in mean cost of hospitalization for aSAH admissions.

Endovascular coiling was performed in 51% of patients and surgical clipping in 47%, while both procedures were performed in 2.6%. The difference in cost between patients undergoing coiling only or clipping only was not significant after adjustments in the regression model (P = .28). But increased costs were associated with cases in whom both coiling and clipping were performed ($121,164 ± 3093), compared to coiling only ($82,219 ± 507; P < .001) or clipping only ($80,667 ± $517; P < .001).

In-hospital mortality was 13%, which had a declining trend over time, until 2011, whereby a slight increase was observed (Fig. 2). A variety of inpatient complications could potentially affect the overall cost; however, analysis of all of these complications would have been outside the scope of this study. Thus, we focused only on the central nervous system complications (including respiratory failure, which is commonly the consequence of altered mentation with poor oral

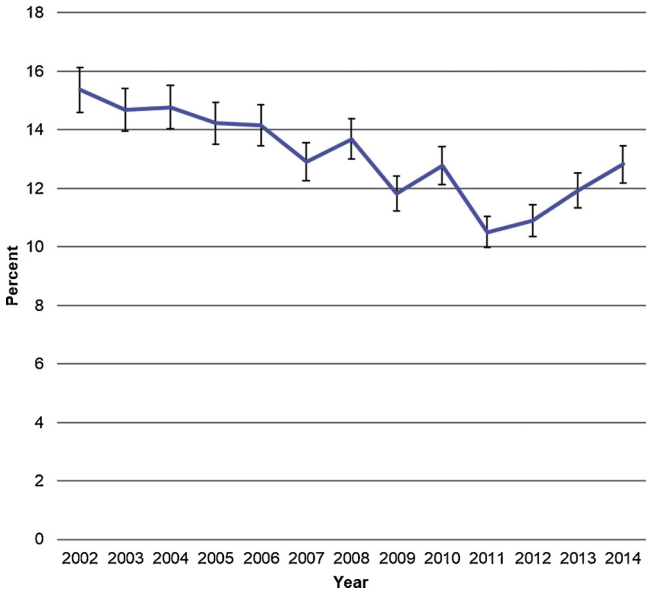

Fig. 2. Line graph demonstrating improved in-hospital mortality rates.

Table 1
Central nervous system complications associated with higher hospitalization cost.*

	Patients with Complication (%)	Associated Mean Increase in Cost (± SE)
Respiratory failure	45%	$41,897 (± 641)
Ventriculostomy	37%	$31,797 (± 704)
Ischemic stroke	11%	$31,441 (± 1307)
Seizures	11%	$22,240 (± 1206)
Central nervous system infection	3.8%	$51,399 (± 5583)

SE, standard error.
* Cost is adjusted for inflation for the year 2017; all P-values are < 0.001.

secretion handling) as listed in Table 1.

4. Discussion

Our study analyzed data from a large, nationally representative administrative database to estimate hospitalization cost of aSAH in the United States. The overall cost of healthcare in the United States has increased over time [10–13], which is also reflected in our study; the mean cost of aSAH hospitalization has increased from $68,783 in 2002 to $90,585 in 2014. A number of studies have revealed endovascular coiling to be costlier than surgical clipping [14–18]; however, our study revealed no difference in cost between the 2 procedures. The aforementioned rise in cost could be secondary to increasing resource utilization, including imaging studies, laboratory tests, intensity of care, nursing care and aneurysm treatment procedures. These proposed suggestions appear to be supported by the literature, as there has been an increase in service price and intensity in the healthcare field overall [19]. Given technological advancements in ICU monitoring and care, along with aneurysm securing devices, these could be the driving force for increased cost in this specific population.

Among the demographic variables, the cost of hospitalization increased with aging before the age of 80 years, after which the cost was lower. This trend was seen even when adjusted for mortality. No clear explanation was found in the analysis, but the authors hypothesize that less interventions were possibly performed for patients of 80 years and older. Male gender, while less commonly affected by the disease, was associated with a higher cost for reasons that are unclear to the authors.

4.1. Medical and central nervous system complications

Acute respiratory failure is often an indicator of poor neurological status, which often correlates with the severity of the hemorrhage or the presence of complications like hydrocephalus, rebleeding, and vasospasm. Mechanical ventilation and related complications from ventilation contribute to an overall increase in total cost [20]. Persistent ventilator dependence may require tracheostomy and gastric/jejunal feeding tube placement with the direct and indirect costs associated with these procedures.

A number of central nervous system complications also significantly raise the cost. Hydrocephalus is one of the most common complications [21], leading to temporary or permanent cerebrospinal fluid diversion through ventriculostomy or shunt placement. Therefore, the presence of this condition adds to the cost with its related surgical procedures, intracranial pressure monitoring or additional imaging and laboratory studies [22,23]. Moreover, these interventions increase the risk of nosocomial central nervous system infections [24–27], thus further increasing the length of stay and overall cost. Ischemic stroke as a complication of cerebral vasospasm is a relatively frequent occurrence [26], which was observed in 11% of our patients. According to 1 study, symptomatic vasospasm results in 27% higher costs and 4 days longer length of stay compared to patients without symptomatic vasospasm [28]. Vasospasm may require invasive treatment with cerebral angiography and angioplasty [29–31], further adding to the cost [18]. One also needs to take into account the iatrogenic strokes secondary to cerebral angiography or aneurysmal clipping procedures, which, if present, will contribute heavily to the overall cost of hospitalization. Clinical and subclinical seizures are frequent in aSAH, may lead to poor neurological recovery [32–35] and may be a cause of coma and respiratory failure [33]. Their detection and treatment requires additional resource utilization, especially electroencephalographic monitoring for nonconvulsive seizures, and administration of antiepileptic drugs.

As one can derive, the vast majority of these complications lead to an increase in the cost of hospitalization independently, as well as by lengthening the hospital stay. Other medical comorbidities not described in this study, such as systemic infections, venous thromboembolism, acute kidney injury, central fever, and hyponatremia, have also been reported to increase the length of stay, and hence, the cost [36–43].

4.2. Study limitations

A major limitation of our study was the unavailability of admission severity of aSAH (Hunt and Hess, Fisher or Glasgow Coma Scale scores). Other major limitations include unknown location and size of the aneurysm and the unavailability of follow-up data after hospital discharge. Additionally, there are inherent limitations to the NIS. As noted above, this database utilizes a random 20% sample of all hospital admissions to non-federal US hospitals, which can potentially introduce selection bias and limit its generalizability. Furthermore, as per HCUP, professional fees and non-covered charges are not included in the cost calculation. This underestimates the calculations in our study, and we are unable to determine how significant an impact these fees and charges have upon total costs. Additionally, while the rise in cost of aSAH has risen, so has the cost of healthcare. Based on our data, we are unable to determine the specific factors that lead to the increased cost in this cohort, apart from proposing several possible causes as noted above. Despite these setbacks, our study has major advantages secondary to the large number of identified cases and the systematic method of data collection in the NIS across all types of demographic and hospital settings.

5. Conclusions

aSAH not only has high morbidity and mortality, but it also carries significant financial burden. The cost of hospitalization for aSAH in the United States continues to rise gradually almost every year. We were able to identify many important factors associated with higher costs; however, further prospective clinical data should be collected to determine causative associations, which may help us develop future cost reduction strategies.

Author contributions

Sumul Modi: study design, study concept, data collection, as well as drafting and revision of the manuscript. No conflict of interest.

Kavit Shah: study concept, data collection, drafting and revising the manuscript. No conflict of interest.

Lonni Schultz: data analysis. No conflict of interest

Rizwan Tahir: data collection and drafting the manuscript. No conflict of interest.

Muhammad Affan: data collection and drafting the manuscript. No conflict of interest.

Panayiotis Varelas: study design and revision of the manuscript. No conflict of interest.

All aforementioned authors reviewed the final, submitted manuscript.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Competing interests

The authors have no competing interests to declare.

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