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Impact of case volume on aneurysmal subarachnoid hemorrhage outcomes☆,☆☆,★

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ABSTRACT

Purpose: To compare aneurysmal subarachnoid hemorrhage (aSAH) outcomes between high- and low-volume referral centers with dedicated neurosciences critical care units (NCCUs) and shared neurosurgical, endovascular, and neurocritical care practitioners.

Materials and Methods: Prospectively collected data of aSAH patients admitted to 2 institutional NCCUs were reviewed. NCCU A is a 22-bed unit staffed 24/7 with overnight in-house NCCU fellow and resident coverage. NCCU B is a 14-bed unit with home call by NCCU attending/fellow and in-house residents.

Results: A total of 161 aSAH patients (27%) were admitted to NCCU B compared with 447 at NCCU A (73%). Among factors that independently impacted hospital mortality, there were no differences in baseline characteristics: mean age (A: 53.5 ± 14.1 years, B: 53.1 ± 13.6 years), poor grade Hunt and Hess (A: 28.2%, B: 26.7%), presence of multiple medical comorbidities (A: 28%, B: 31.1%), and associated cocaine use (A: 11.6%, B: 14.3%). There was no significant difference in hospital mortality (A: 17.9%, B: 18%), poor functional outcome (A: 30%, B: 25.4%), aneurysm rerupture (A: 2.8%, B: 2.4%), or delayed cerebral ischemia (A: 14.1%, B: 16.1%).

Conclusions: The noninferior outcomes at the lower SAH volume center suggests that provider expertise, not patient volume, is critical to providing high-quality specialized care.

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1. Introduction

Aneurysmal subarachnoid hemorrhage (aSAH) is a relatively uncommon type of stroke that occurs in about 30000 patients per year in the United States [1]. The management of SAH is complex and distinct from the care of the general critically ill population. A multidisciplinary team of neurointensivists, neurosurgeons, nurses, and therapists may be involved to provide high-quality care. Specialized neurosciences critical care units (NCCUs) have been shown to improve outcomes, decrease length of stay, and reduce hospital mortality in critically ill neurologic patients [2–4]. In patients with aSAH, NCCU care has been reported to result in improved functional outcomes and a greater likelihood of discharge to home [5,6]. This is possibly attributed to more aggressive medical management, invasive monitoring, and advanced neurosurgical procedures [7].

Hospital case volume has also been suggested to impact outcomes. High-volume centers have been reported to have superior outcomes and lower mortality rates following aSAH [8–11]. Multiple components of specialized patient care besides case load may contribute to these findings, and conflicting findings of similar outcomes in high- and low-volume centers have been reported [12,13]. In the present study, we will further examine the effect of case volume on institutional aSAH outcomes by comparing 2 academic NCCUs with shared neurocritical care, neurosurgery, and endovascular providers. We hope to identify variables that may play a key role in providing high-quality specialized care and should be considered when making the decision to transfer a patient with SAH.

2. Materials and methods

Patients admitted to the Johns Hopkins Medical Institutions with a diagnosis of aSAH between 2001 and 2009 were reviewed. We excluded patients with traumatic SAH, SAH secondary to an underlying lesion (eg, arteriovenous malformation, dural arteriovenous fistula, and brain

Abbreviations: aSAH, aneurysmal subarachnoid hemorrhage; ICU, intensive care unit; IMC, intermediate care unit; NCCU, neurosciences critical care unit; GCS, Glasgow Coma Scale; H/H, Hunt and Hess grade; GOS, Glasgow Outcome Scale; DCI, delayed cerebral ischemia.

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tumor), or angiogram-negative SAH of uncertain etiology. NCCU A is a 22-bed combined intensive care unit (ICU)/intermediate care unit (IMC) staffed 24 hours/day with in-house neurocritical care fellow and resident coverage. NCCU B is a 14-bed unit (8-bed ICU/6-bed flex IMC/ICU) with a fellow on call from home with telemedicine access and in-house residents covering the general ward, emergency department consults, and the ICU/IMC. Both NCCUs are staffed overnight by attending neurointensivists who take call from home. Neurocritical care, neurosurgery, and endovascular practitioners (attendings, fellows, and residents) are shared between the 2 NCCUs. Nurses are specific to the individual hospital and do not rotate between the 2 institutions. However, both groups of nurses have received specialized training in neurosciences critical care. The 2 institutions also have similar access to diagnostic testing, radiology services, and invasive monitoring.

Protocols for SAH management are similar at both institutions. Patients are admitted to the NCCU with co-management by the neurocritical care and neurosurgical teams. All patients are started on nimodipine and empiric antiepileptic drug prophylaxis with either phenytoin or levetiracetam. Angiography is obtained as soon as possible, followed by surgical clipping or endovascular coiling based on neurosurgical and neurointerventional physician review of angiographic findings. Patients are monitored with daily transcranial Doppler studies; the duration of monitoring is determined by the treating physician. Management decisions such as blood pressure control, fluid management, and vasospasm therapy are at the discretion of the individual providers. Cardiac output monitoring, invasive neuromonitoring, and continuous EEG are not routinely employed but may be used in certain cases.

Baseline demographic and radiologic data were examined in patients admitted to NCCUs A and B. The impact of factors that could potentially affect outcomes such as age, admission Glasgow Coma Scale (GCS), Hunt and Hess grade (H/H), cocaine use, intraventricular hemorrhage, and medical comorbidities were analyzed. Our method of defining medical comorbidities using the Charlson index is described in detail in a prior publication [14]. Briefly, the Charlson index identifies major comorbidities including stroke, dementia, congestive heart failure, coronary and peripheral artery disease, chronic obstructive pulmonary disease, cirrhosis, peptic ulcer disease, renal failure, diabetes mellitus, human immunodeficiency virus, connective tissue disease, and cancer. This index has been validated in ischemic stroke and intracerebral hemorrhage (ICH) [15,16]. Outcome measures studied included (*a*) hospital mortality, (*b*) functional status using Glasgow Outcome Scale (GOS), and (*c*) complications related to aSAH including aneurysm rerupture and delayed cerebral ischemia (DCI). The detailed methodology for outcome variable review is as described in previous publications [17,18]. Poor functional outcome was defined as GOS scores 1 to 3. Glasgow Outcome Scale was measured both at discharge and at the first clinic appointment postdischarge. We determined aneurysm rerupture based on computed tomographic (CT) confirmation of new SAH, intraventricular hemorrhage, or ICH after a neurologic deterioration that prompted the CT in the first place or identified on institutional CT after interhospital transfer. ***Delayed cerebral ischemia*** was defined as (*a*) radiologic confirmation of cerebral infarction attributed to vasospasm or (*b*) symptomatic vasospasm [19]. At our institution, we defined symptomatic vasospasm as a new clinical deterioration greater than 48 hours post-SAH and greater than 24 hours after surgical clipping or endovascular coiling with either angiographic confirmation of vasospasm or clinical responsiveness (transient or sustained) to hemodynamic augmentation with transcranial Doppler corroboration. Other etiologies of neurologic deterioration, such as ventriculitis or hydrocephalus, were ruled out.

2.1. Statistical analysis

An unpaired *t* test was used when data were normally distributed, and nonparametric tests (Mann-Whitney *U* test, Kruskal-Wallis test) were used when data were not normally distributed. Dichotomous variables were compared with outcome using the χ^2 test; the Fisher exact test result was reported where appropriate. The SPSS (Statistical Package for the Social Sciences version 18.0: SPSS Statistics, Chicago, Ill) was used to assess the potential impact of each of the admission factors on hospital mortality. The impact of various factors on outcomes was initially studied using univariate analysis; individual medical comorbidities that impacted outcomes ($P < .10$ on univariate analysis) were grouped together as none, single, or multiple. Finally, all factors affecting hospital mortality and outcomes were analyzed using the multiple logistic regression model.

3. Results

A total of 608 patients with aSAH were included in the analysis. Four hundred forty-seven (73%) were admitted to NCCU A, for an average of 50 cases per year; 161 (27%) were admitted to NCCU B, for an average of 18 cases per year. Baseline patient characteristics which affected outcome on multivariate analysis are shown in Table 1. There were no significant differences in age based on comparison of mean age (A: 53.5 ± 14.1 years, B: 53.1 ± 13.6 years; $P = .691$) or advanced age >70 years (A: 13.4%, B: 13%; $P = .901$). There was no significant difference in clinical severity whether assessed by comparison of proportion of poor grade H/H (A: 28.2%, B: 26.7%; $P = .750$) or by admission GCS <8 (A: 21%, B: 21%; $P = .981$). Finally, the 2 populations did not differ significantly in terms of cocaine use at presentation (A: 11.6%, B: 14.3%; $P = .400$) or multiple medical comorbidities (A: 28%, B: 31.1%; $P = .470$). The severity of illness of the patient populations that presented to the 2 institutions with a diagnosis of aneurysmal SAH was overall similar. Annual admissions to the 2 ICUs between 2001 and 2009 are shown in Figure.

3.1. Outcome measures

Overall in-hospital mortality between 2001 and 2009 was 17.9%, with a mortality rate of 41% among high-grade (H/H 4-5) patients. During this period, endovascular coiling was used in 20.9% of patients. Poor functional outcome (GOS 1-3) was seen in 28.5% of patients. The mean time to functional outcome assessment post-SAH was 37 days. Approximately 19% of hospital survivors were lost to follow-up.

Outcomes from aSAH in the 2 NCCUs are shown in Table 2. No significant differences in outcome were detected between the 2 groups. Mortality rates were nearly identical between NCCU A (17.9%) and NCCU B (18%; $P = 1.000$). Poor functional outcome (GOS 1-3) was observed in 30% of patients in NCCU A and 25.4% of patients in NCCU B ($P = .300$). For survivors, this was assessed at the first clinic appointment postdischarge. While the timing of this was variable, there was no significant difference between the 2 centers when comparing mean days post-discharge for assessment. There were no differences in complications characteristically associated with aSAH including rates of aneurysm rerupture (A: 2.8%, B: 2.4%; $P = .998$) or DCI (A: 14.1%, B: 16.1%; $P = .520$) between the 2 centers.

4. Discussion

We found no significant differences in aSAH outcomes between low-volume (18 cases/y) and high-volume (50 cases/y) volume enters with

Table 1
Baseline patient characteristics affecting outcomes on multivariable analysis

	NCCU A (n = 447)	NCCU B (n = 161)	*P*
Age (y), mean ± SD	53.5 ± 14.1	53.1 ± 13.6	.691
Age >70 y	60 (13.4%)	21 (13%)	.901
Poor grade H/H (4, 5)	126 (28.2%)	43 (26.7%)	.750
GCS <8	94 (21%)	34 (21%)	.981
Cocaine use	52 (11.6%)	23 (14.3%)	.400
Comorbidities: ≥2	125 (28%)	50 (31.1%)	.470

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