neurocritical care society Neurocrit Care (2011) 14:334–340
DOI 10.1007/s12028-011-9505-z

ORIGINAL ARTICLE

Impact of a Dedicated Neurocritical Care Team in Treating Patients with Aneurysmal Subarachnoid Hemorrhage

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Published online: 22 March 2011

Abstract
Background Intensivist staffing of intensive care units (ICUs) has been associated with a reduction in in-hospital mortality. These improvements in patient outcomes have been extended to neurointensivist staffing of neuroscience ICUs for patients with intracranial hemorrhage and traumatic brain injury.
Objective The primary objective of this study is to determine if hospital outcomes (measured by discharge status) for patients admitted with aneurysmal subarachnoid hemorrhage changed after the introduction of a neurointensivist-led multidisciplinary neurocritical care team.
Methods The authors retrospectively identified 703 patients admitted to the neuroscience ICU with a diagnosis of aneurysmal subarachnoid hemorrhage at a single academic tertiary care hospital between January 1, 1995 and December 31, 2002. It was compared with discharge outcomes for those patients treated prior to and following the development of a multidisciplinary neurocritical care team.
Results Patients treated after the introduction of a neurocritical care team were significantly more likely to be discharged to home (25.2% vs. 36.5%) and less likely to be discharged to a rehab facility (25.2% vs. 36.5%). Patients treated after introduction of a neurocritical care team were also more likely to receive definitive aneurysm treatment (10.9% vs. 18%).
Conclusion The implementation of a neurointensivist-led neurocritical care team is associated with improved hospital discharge disposition for patients with aneurysmal subarachnoid hemorrhage.

Keywords Subarachnoid hemorrhage · Neurocritical care · Discharge outcomes · Cerebral aneurysm · Neurointensivist

Introduction

Pronovost et al. [1] identified 17 published studies that examined the relationship between the level of physician staffing in the intensive care unit (ICU) and hospital mortality rates. Overall, 16 of the 17 studies reported significantly lower risk-adjusted, in-hospital mortality rates in ICUs with high intensity (mandatory intensivist consultation) staffing compared to ICUs with low intensity (no intensivist or elective intensivist consultation) staffing [2–10]. In addition, none of these studies found that high intensity staffing was significantly associated with higher in-hospital mortality rates. As a result, both the Society of Critical Care Medicine [11] and the Leapfrog Group [12, 13] have implemented guidelines calling for dedicated "intensivist" staffing of ICUs.

As of now only a few studies have specifically examined the impact of specialized neurologic intensivists (neurointensivist) staffing of neuroscience intensive care units (NICU) outcomes. Mirski [14] found that patients treated for a non-traumatic intracranial hemorrhage (ICH) in a NICU had significantly better outcomes (lower mortality

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and increased probability of being discharged home or to a rehabilitation facility) compared to a similar cohort of patients treated in the hospital's general ICU. Diringer [15] reported that patients with acute ICH admitted to a NICU had lower risk-adjusted mortality rates than similar patients admitted to general ICUs. Suarez [16] found that the introduction of a neurointensivist led neurocritical care team in the NICU significantly reduced in-hospital mortality compared with a similar group of patients treated in the NICU without a neurointensivist-led care team. Varelas [17], in a study of head trauma patients, found that patients admitted to a NICU after the appointment of a neurointensivist had significantly lower mortality rates and significantly greater odds of being discharged to home or rehabilitation than patients admitted in the period prior to the appointment of a neurointensivist.

The primary objective of this study is to examine if there has been any improvement in the discharge outcomes of aneurysmal subarachnoid hemorrhage (SAH) patients treated by a neurointensivist-led multidisciplinary neurocritical care team compared with similar risk-adjusted patients treated in the same NICU prior to the implementation of a multidisciplinary neurocritical care team. This study examines four possible hospital discharge outcomes; discharged to (1) home, (2) rehabilitation facility, (3) a nursing home or skilled nursing facility, or (4) in-hospital death. In addition, this study examines if aneurysmal SAH patients treated by a multidisciplinary neurocritical care team were more likely to receive some type of treatment (clip ligation or endovascular coiling) than patients treated in the NICU prior to the implementation of a neurocritical care team.

Methods

Study Population and Study Group

This retrospective study included all patients admitted to Emory University Hospital's NICU for their initial treatment of an aneurysmal SAH between January 1, 1995 and December 31, 2002. Potential study patients were identified by searching the annual hospital discharge abstract files for patients with any ICD-9-CM diagnosis code of 430 (SAH). Patients were included in the study only if their medical record indicated that they were admitted to the NICU for treatment of SAH. Sixty patients admitted with an SAH were excluded from the study because their medical record indicated that no source for the hemorrhage was identified on angiography, while four patients were excluded because the patient was admitted twice for a SAH during the study period. The final study population consists of 703 patients undergoing their initial treatment for an aneurysmal subarachnoid hemorrhage in the Emory University Hospital NICU during the study period. Data was extracted after IRB study approval.

Patients were classified into one of two study periods depending on their admission date as follows: Group A: pre-multidisciplinary neurocritical care group—317 patients admitted between January 1, 1995 and August 31, 1998; Group B: post-multidisciplinary neurocritical care group—386 patients admitted between September 1, 1998 and December 31, 2002. Table 1 describes the key differences in the staffing and treatment of patients admitted to the NICU at Emory University Hospital over the study period. The key difference in the NICU, for the purpose of this study, was the development of the multidisciplinary critical care team that started treating patients on September 1, 1998. This team was led by a neurointensivist and included acute care nurse practitioners and a critical care pharmacist in addition to nutritional and respiratory therapy support.

Outcome Measures and Control Variables

The patient's hospital discharge status was the primary outcome measure of interest. Each patient's discharge status, obtained from an administrative database, was classified into one of four categories: Home, if the patient was discharged home; Rehabilitation facility, if the patient was discharged to some type of rehabilitation facility; Nursing home, if the patient was discharged to any type of nursing facility, including skilled nursing faculty; and Death, if the patient died during the hospitalization.

Information on ten control variables was obtained from a review of each patient's medical record. The ten control variables included three demographic characteristics: the patients age, gender, and race; five co-morbid risk factors: history of smoking, history of coronary artery disease, and the presence of hypertension, diabetes mellitus, and hypercholesterolemia; the patient's initial Hunt and Hess grade (patients were classified into three groups—grades I and II, grade III, and grades IV and V); and the patient's primary treatment procedure (clip ligation, endovascular coiling, or no treatment) [18]. Complete information for the control variables was available for all patients except for patient's race (missing on approximately 20.5% of the patients) and all co-morbid risk factors (missing for 68 (9.7%) patients).

Statistical Methods

Descriptive data are expressed as proportions for discrete variables and means ± standard deviations for continuous variables. Statistical differences in categorical variables were assessed using χ^2 or Fisher's exact tests for binary variables, χ^2 tests for categorical variables, and two-sample *t*-test for continuous variables. Multivariate logistic regression analysis was estimated to determine if a

Table 1 Key differences in neurocritical care at Emory University Hospital between the two study groups

Group A: pre-neurointensive care group January 1, 1995 to August 31, 1998	Group B: post-neurointensive care group September 1, 1998 to December 31, 2002
7 bed neurointensive care unit	Up to 23 bed neurointensive care unit
	5 bed intermediate care unit
Primary neurointensive care by the neurology/ neurosurgery physician staff	Creation of a neurointensivist-led critical care service team
Routine medical and critical care services provided by the primary neurology/neurosurgery staff	Multidiciplinary team
	Critical care nurse practitioners
	Neuro-pharmacist
	Respiratory Therapy
	Nutrition support
Elective pulmonary critical care consultation for ventilation management	

multidisciplinary neurocritical care team was significantly associated with selected discharge outcomes after controlling for patient characteristics, initial Hunt and Hess grade, and type of treatment. In all analyses, differences were considered statistically significant if the calculated *P*-value was less than 0.05. All statistical analyses were performed using SAS statistical software version 9.1.

Results

Characteristics of Study Population

Table 2 provides the demographic characteristics, co-morbid risk factors and initial Hunt and Hess grade of all patients in the study and for patients in each of the two study groups. Overall, Table 2 indicates that approximately 70% of the patients in the study were females and the average age of patients was 52 ± 13 years old. In addition, 44% of the study patients were assigned a Hunt and Hess grade of I or II, 30% were assigned a Hunt and Hess grade III, and the remaining 26% were assigned a grade of IV or V.

A comparison of demographic, co-morbid risk factors and initial Hunt and Hess grade between the two study groups indicates only one consistently significant difference between group A and B. The average age of patients in group A (50.6 years) was significantly younger than the average age of patients in group B (53.2 years). There are three points worth noting when examining the variation in patient demographics and severity of illness between the two study periods. First, there was only one significant difference in the co-morbid risk factors between groups: group B had fewer smokers (26% compared with 37%). Second, there was no significant difference in the proportion of patients in each of the three Hunt and Hess categories groups. Third, the racial differences observed in Table 1 between study groups is most likely the result of better identification of race in the medical record among group B patients (patients whose race was unknown drop from approximately 37% in the group A to below 15.6% in group B).

Treatments Received

Table 3 compares the primary treatment patients received in the two study groups for all patients and then by the three Hunt and Hess categories. There has been a significant change in the overall treatment of aneurysmal SAH patients between group A and B. Patients in group B are significantly more likely to receive some definitive treatment (surgical clip ligation or endovascular coiling). Overall, less than 11% of patients did not receive any definitive treatment in group B compared with 18.0% of the patients in group A. In addition, patients in group B were significantly more likely to undergo endovascular coiling than group A patients.

Table 3 also reports the treatment patients received by their initial Hunt and Hess grade. An examination of treatment choice by Hunt and Hess grade indicates that the overall observed trends in treatment choice hold in each of the three Hunt and Hess grade categories. First, the general trend toward greater use of endovascular coiling as opposed to surgical clip ligation during the study period remained significant for patients treated in each of the three Hunt and Hess grade categories. Second, patients in group B were more likely to receive definitive treatment; this held for all three Hunt and Hess grade categories.

Hospital Discharge Status

Table 4 reports the hospital discharge status for all aneurysmal SAH patients in both study periods. Overall, patients in group B were significantly more likely to be discharged to home (25.2% vs. 36.5%) and significantly less likely to be discharged to a rehabilitation facility (42.5% vs. 32.4%).

Table 2 Baseline demographic characteristics and co-morbid risk factors of aneurysmal subarachnoid hemorrhage patients by study groups

Variables	All patients	Group A	Group B	*P*-Value
Number of patients	703	317	386	
Age (years)	52.1 ± 13.4	50.6 ± 13.1	53.2 ± 13.7	0.02
Male %	30.3	29.8	30.8	0.76
Race (%)				<0.001
White	49.5	41.3	56.2	
Black	25.0	19.6	29.5	
Other race	1.7	0.9	2.3	
Race unknown	23.8	38.2	12.0	
Co-morbidities	($n = 678$)	($n = 307$)	($n = 371$)	
Hypertension %	41.6	42.7	40.7	0.60
Diabetes mellitus %	7.9	7.2	8.6	0.49
Smoker %	30.9	36.8	26.1	0.003
Coronary artery disease	5.0	6.5	3.8	0.10
Hypercholesterolemia %	3.7	3.9	3.5	0.78
Hunt and Hess (%)				0.55
I and II	43.9	43.5	44.2	
III	29.8	27.4	31.7	
Iv and V	26.2	29.0	23.9	

Table 3 Comparison of treatment procedure for selected groups of aneurysmal subarachnoid hemorrhage patients by study groups

Procedure	All Patients	Group A	Group B	*P*-Value
All patients (%)	($n = 703$)	($n = 317$)	($n = 386$)	
Clip ligation	59.1	66.9	52.8	<0.001
Endovascular	26.7	15.1	36.3	<0.001
No treatment procedure	14.1	18.0	10.9	0.01
Grade I and II (%)	($n = 288$)	($n = 138$)	($n = 150$)	
Clip ligation	68.9	78.3	60.3	<0.001
Endovascular	22.7	13.8	39.7	<0.001
No treatment procedure	3.8	8.0	0.0	<0.001
Grade III (%)	($n = 207$)	($n = 87$)	($n = 120$)	
Clip ligation	68.6	80.5	60.0	0.002
Endovascular	22.7	10.3	31.7	<0.001
No treatment procedure	8.7	9.2	8.3	0.83
Grade IV and V (%)	($n = 202$)	($n = 92$)	($n = 110$)	
Clip Ligation	35.6	37.0	34.5	0.72
Endovascular	29.7	21.7	36.4	0.02
No treatment procedure	34.6	41.3	29.0	0.07

Table 4 Comparison of unadjusted hospital discharge status for aneurysmal subarachnoid hemorrhage patients by study groups

Outcome	All patients	Group A	Group B	*P*-value
All patients (%)	($n = 703$)	($n = 317$)	($n = 386$)	
Home	31.4	25.2	36.5	<0.001
Rehabilitation	36.9	42.5	32.4	0.01
Nursing home	5.6	5.4	5.7	0.85
Dead at discharge	26.0	26.8	25.4	0.67
Grade I and II (%)	($n = 294$)	($n = 138$)	($n = 156$)	
Home	49.0	40.6	56.4	0.01
Rehabilitation	35.0	39.1	31.4	0.17
Nursing home	3.4	4.3	2.6	0.40
Dead at discharge	12.6	15.9	9.6	0.10
Grade III (%)	($n = 207$)	($n = 87$)	($n = 120$)	
Home	28.5	20.7	34.2	0.03
Rehabilitation	44.5	55.2	36.7	0.01
Nursing home	6.3	4.6	7.5	0.40
Dead at discharge	20.8	19.5	21.7	0.71
Grade IV and V (%)	($n = 202$)	($n = 92$)	($n = 110$)	
Home	8.9	6.5	10.9	0.28
Rehabilitation	32.2	35.9	29.1	0.30
Nursing home	7.9	7.6	8.2	0.88
Dead at discharge	51.0	50.0	51.8	0.80

Table 4 also reports hospital discharge status for each study period by the Hunt and Hess grades. Three general conclusions are worth noting. First, patients admitted with Hunt and Hess grade I or II had the most favorable discharge outcomes (most likely to be discharged to home and least likely to experience in-hospital mortality) and the discharge status for patients admitted in the other two Hunt and Hess grade categories progressively deteriorated (less

likely to be discharged home and more likely to die). Second, the introduction of the neurocritical care team had the most significant impact on discharge status among patients admitted with Hunt and Hess grades of I, II, or III and the least impact of patients admitted with Hunt and Hess grades of IV and V. For example, group B patients with Hunt and Hess grades I, II, or III were significantly more likely to be discharged to home (40.6 vs. 56.4% and 20.7 vs. 34.2%) and less likely to be discharged to a rehabilitation facility (39.1 vs. 31.4% and 55.2 vs. 36.7%). Hunt and Hess grade I–II patients in Group B showed a favorable difference in mortality during hospitalization (15.9 vs. 9.6%) though this did not reach statistical significance. Among patients admitted with an initial Hunt and Hess grade of IV or V there was no difference in discharge status or in hospital mortality.

Estimated Odds Ratio for Treatment Period

Table 5 reports the estimated odds ratios for being in group B (group A is the reference group) calculated from the logistic regression equation estimated separately for the four discharge status of interest. The four models estimated using all 703 patients controlled for a patient's age, gender, and race, treatment received, and the patient's Hunt and Hess grade on admission. Patients treated in group B were significantly more likely to be discharged home (odds ratio 2.35) and less likely to be discharged to rehabilitation (odds ratio 0.54).

The remainder of Table 5 reports the estimated odds ratio for being treated in group B by patients' Hunt and Hess grade. Among patients with a Hunt and Hess grade III, those patients treated in group B were significantly more likely to be discharged home (odds ratio 2.37) and less likely to be discharged to a rehabilitation facility (odds ratio 0.45). Finally, Table 5 indicates that patients with a Hunt and Hess grade IV or V treated in group B were also less likely to be discharged to a rehabilitation facility.

Discussion

This retrospective study examines the difference among hospital discharge outcomes of patients being treated for an aneurysmal SAH in a NICU at EUH from January 1, 1995 to December 31, 2002. The intervention of interest was the creation of a multidisciplinary neurocritical care team in 1998 to treat all patients admitted to the NICU at Emory University Hospital.

Because of the retrospective study design and the relatively long study period, it is impossible to determine all of the clinical and operational factors that might influence the observed results in this article. However, this study provides preliminary evidence that the implementation of a multidisciplinary neurocritical care team corresponded with improved hospital discharge disposition for patients with aneurysmal SAH. Both univariate and multivariate (controlling for patient's age, gender, race, initial Hunt and Hess grade, and treatment received) analyses indicate that a multidisciplinary neurocritical care team in an NICU had an independent and positive impact on the discharge disposition among aneurysmal SAH patients. In particular, patients treated after the implementation of a multidisciplinary neurocritical care team were significantly more likely to be discharged home and significantly less likely to be discharged to a rehabilitation facility than patients

Table 5 Estimated odds ratio on the variable indication the study period for each hospital discharge statuses for all patients and by initial Hunt and Hess grade: controlling for age, male, white and treatment (clip or coil versus no treatment)

	Home Odds ratio *P*-Value	Rehabilitation Odds ratio *P*-Value	Nursing Odds ratio *P*-Value	Dead Odds ratio *P*-Value
All patients $n = 703$				
Group B	2.35	0.54	0.82	1.00
Post-NICU Period	$P < 0.001$	$P < 0.001$	$P = 0.57$	$P = 0.97$
All patients admitted with Hunt and Hess grade of I or II, $n = 294$				
Group B	2.35	0.61	0.38	0.56
Post-NICU Period	$P = 0.001$	$P = 0.06$	$P = 0.17$	$P = 0.16$
All patients admitted with Hunt and Hess grade of III, $n = 207$				
Group B	2.37	0.45	1.52	1.04
Post-NICU Period	$P = 0.01$	$P = 0.01$	$P = 0.51$	$P = 0.91$
All patients admitted with Hunt and Hess grade of IV or V, $n = 202$				
Group B	2.02	0.54	0.79	1.51
Post-NICU Period	$P = 0.20$	$P = 0.08$	$P = 0.67$	$P = 0.22$

treated in the same NICU prior to the intervention. In addition, patients with an initial Hunt and Hess grade I–II treated after the intervention showed a favorable difference in mortality during hospitalization though this difference did not reach statistical significance.

The retrospective design of this study also limits the possible outcome measurements. Discharge disposition serves as a surrogate marker for the short-term functional outcome of this population of aneurysmal subarachnoid hemorrhage patients. Ideally, a prospective analysis would combine this with more direct functional outcome measurements. While there are other factors that might influence an individual patient's discharge disposition such as availability of rehabilitation resources and patient's financial resources, there were no significant changes in the approach to the determination of rehabilitation needs or availability of resources over the study period. All patients received a comprehensive evaluation prior to discharge by speech therapy, occupational therapy, and physical therapy to determine the discharge disposition that would offer the greatest benefit (home with outpatient rehabilitation, acute inpatient rehabilitation, sub-acute rehabilitation in a skilled nursing facility).

This study is similar to most of the previous research cited in that the authors conducted a retrospective single site study. This study is different from most of the previous studies in that it was examine the impact of a multidisciplinary neurocritical care team on outcome of patients who were all treated in a NICU, while most of the previous studies have compared the outcomes of selected patients with neurological problems treated in a general ICU to similar patients treated in a dedicated NICU. Nevertheless, the major finding in this study (association of improved discharge disposition with implementation of a multidisciplinary neurocritical care team) is consistent with a recent study showing that such a model had an independent and positive impact on patients outcomes among patients treated for traumatic brain injury in a NICU [19].

There are a number of other possible explanations or contributing factors for the improved outcomes observed among patients being treated for an aneurysmal SAH, in addition to the primary intervention. The authors cannot exclude the possibility that overall improvements in critical care or improvements in the surgical and interventional management of aneurysms played some role. However, no clear changes in the infrastructure or personnel at this center other than the neurocritical care team changed during the study period. The same number of neurosurgeons and interventional neuroradiologists, the same nursing leadership and bedside nursing staffing, and same physical plant existed during both periods. It was also cannot absolutely exclude the possibility that changes in the patient population had an impact. For example, despite the fact that there were no differences in initial severity of illness (as measured by Hunt and Hess grade) between study groups, there was a significant reduction in the proportion of patients who were smokers between the two study groups (36.8% to 26.2%). Though smoking has been associated with the development of delayed ischemic deficits, it has not been shown to impact overall outcome following aneurysmal SAH [20]. In order to test the sensitivity of smoking and other risk factors on the finding in this study, it was re-estimated both univariate and multivariate regression models including only the risk factors (individually and as a group). These regression results indicated that none of the risk factors were significantly associated ($P < 0.10$) with any of the discharge outcomes.

This study has other limitations. First, the study period is 7 years long and any number of changes in technology, procedures, or NICU experience might contribute the improved outcomes in the post-intervention group. There has been an increasing trend toward the use of endovascular coiling instead of surgical clip ligation to treat aneurysmal subarachnoid hemorrhage patients (see Table 2). This is reflective of a national trend over that same time period [21]. Based upon the International Subarachnoid Aneurysm Trial (ISAT), it is suggested that in patients with ruptured aneurysms equally suitable for either surgical clipping or endovascular coiling, coiling is more likely to result in independent survival at 1 year [22]. A separate subgroup analysis of the data revealed that patients treated by surgical clipping were more likely than those treated by endovascular coiling to be discharged to home or rehabilitation. In addition, patients treated with endovascular coiling were more likely to be discharged to a nursing home or die during hospitalization than those treated by surgical clipping. Given this, an increase in the use of endovascular coiling during the study period would not be sufficient to explain the outcome differences seen. In fact, given these findings one might expect increased endovascular coiling to contribute to worsening outcomes over the study period in this cohort. The authors suggest as an explanation that endovascular coiling was likely a preferred treatment option for patients with significant medical co-morbidities and a disproportionate number of Hunt and Hess grade VI and V patients with higher expected morbidity and mortality.

The addition of a multidisciplinary neurocritical care team represents a system-based change in the treatment of patients with aneurysmal subarachnoid hemorrhage. While it is not the single addition of any type of personnel, it is the overall impact of a consistent and organized approach to patient management that contributed to improved outcomes. This includes the development of protocols for management of hyperglycemia, intracranial pressure, temperature modulation, and sepsis as well as standardized

disease-specific order sets and clinical pathways, early recognition of medical complications and quality improvement bundles designed to reduce the incidence of catheter associated blood stream infections and ventilator associated pneumonia. These system-based interventions led to a consistent and predictable approach to the management of patients with subarachnoid hemorrhage.

Conclusion

This study provides additional evidence that a multidisciplinary neurocritical care team in the NICU is independently associated with improved hospital discharge disposition for patients with aneurysmal SAH. In this study the impact of the neurocritical care team had its largest positive impact on the likelihood that patients will be discharged to home.

The results of this study also suggest that the introduction of a multidisciplinary neurocritical care team may have financial implications. From a health care system perspective, increasing the number of aneurysmal SAH patients being discharged home will most likely reduce the total cost of treating these patients. One can also speculate that patients being discharged home have a higher functional status and less neurological impairment than patients being discharged to rehabilitation or skilled nursing facilities.

Disclosure No funding to disclose.

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