Comparing Outcomes of Patients With Idiopathic Subarachnoid Hemorrhage by Stratifying Perimesencephalic Bleeding Patterns

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Background: To determine the clinical outcomes of perimesencephalic subarachnoid hemorrhages based on the computed tomography (CT) bleeding patterns. *Methods:* This retrospective cohort study included: (1) patients (≥18 years) admitted to a comprehensive stroke center (January 2015-May 2018), (2) with angiography-negative, nontraumatic subarachnoid hemorrhage in a perimesencephalic or diffuse bleeding pattern, and (3) had CT imaging performed in ≤ 72 hours of symptom onset. Patients were stratified by location of bleeding on CT: Peri-1: focal prepontine hemorrhage; Peri-2: prepontine with suprasellar cistern +/− intraventricular extension; and diffuse. *Results:* Of the 39 patients included, 13 were Peri-1, 11 were Peri-2, and 15 were diffuse. The majority were male (n = 26), with a mean (standard deviation) age of 55.3 (11.3) years, who often presented with headache (n = 37) and nausea (n = 28). Overall, patients in Peri-1 were significantly less likely to have hydrocephalus compared to Peri-2 and dSAH (*P*= .003), and 4 patients required an external ventricular drain. Five patients developed symptomatic vasospasm. Patients in Peri-1, compared to Peri-2 and diffuse, had a significantly shorter median neuro critical care unit length of stay (LOS) and hospital LOS. Most patients (n = 35) had a discharge modified Rankin Score between 0 and 2 with no significant differences found between groups. *Conclusion:* These data suggest that patients with the best clinical course were those in Peri-1, followed by Peri-2, and then diffuse. Because these patients often present with similar clinical signs, stratifying by hemorrhage pattern may help clinicians predict which patients with perimesencephalic subarachnoid hemorrhage develop complications.
Key Words: Nonaneurysmal subarachnoid hemorrhage—perimesencephalic subarachnoid hemorrhage—hydrocephalus—vasospasm—computed tomography angiography

Introduction

In what is often a diagnosis of exclusion, perimesencephalic subarachnoid hemorrhages (pmSAHs) frequently have a benign clinical course and excellent prognosis.[1] In contrast with pmSAHs, outcomes after aneurysmal subarachnoid hemorrhages (aSAHs) are poor as patients are more likely to encounter severe complications, including

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hydrocephalus, vasospasm, and delayed Cerebral ischemia (CI), present in nearly 14%-60% of all aSAH cases.[1-4] Interestingly, these groups typically present with similar initial clinical symptoms such as sudden headache, nausea, and vomiting, and additional work-up by computed tomography (CT) must be obtained to differentiate these patients from one another.[1] However, a small subset of pmSAHs closely mirrors those of aSAHs with a higher severity and incidence of complications.[5-7] Because no known risk factors have been identified for patients with pmSAHs, it can be challenging to assess prognosis in the short term.

Distribution of SAH on CT has been suggested by several studies as being predictive of clinical course.[5,6,8,9] These studies reported that more diffuse bleeding patterns on CT without aneurysm, frequently referred to as diffuse SAHs, have a significantly higher risk for complications compared to pmSAHs.[5,6,8,10-13] These data indicate that stratifying by bleeding pattern may be an important tool for treatment when no etiology has been identified. Therefore, the purpose of this study was to review cases of idiopathic pmSAHs to describe how incidence, symptoms, and patient outcomes differed based on hemorrhage patterns.

Materials and Methods

Patient Selection

This retrospective single-center cohort study at a large-volume comprehensive stroke center (CSC) included (1) consecutively admitted adult (≥18 years) patients with a nontraumatic, nonaneurysmal SAH, (2) who had an unenhanced CT within 72 hours of symptom onset, and (3) had a perimesencephalic or diffuse SAH bleeding pattern on CT. Angiography was used to rule out aneurysm. Patients initially treated at an outside facility with more than general emergency department care prior to arrival to the CSC (n = 2) and patients with convexity SAH (n = 27) were excluded. Data were retrospectively collected across 3 years (January 2015-May 2018) from the facility's retrospective stroke registry (NeuroBase, Evergreen, CO) and also abstracted from patient electronic medical records. This study was approved by the local Institutional Review Board (HCA IRB # 779117).

Radiography Imaging

A board-certified interventional neuro-radiologist (INR) (B.A.), was blinded to clinical data and evaluated all CT images of patients coded as nontraumatic SAH with negative angiography. A negative angiography was defined as having no identifiable source for hemorrhage demonstrated by more than equal to 1 catheter directed diagnostic angiogram. Diagnosis of pmSAH or dSAH was made if a patient had a negative angiography, and if the SAH was in a perimesencephalic or diffuse pattern. The criterion used for defining a perimesencephalic hemorrhage pattern was initially reported with strong agreement by Brinjikji, Kallmes, and White, et al. (interobserver = .79; intraobserver = .80).[14] These criteria, include: (1) the initial unenhanced CT was made within 72 hours after symptom onset; (2) the center of the hemorrhage was located immediately anterior to the midbrain or pons, with possible extension of blood to all perimesencephalic cisterns, the foramen magnum, the proximal part of the anterior interhemispheric fissure and to the basal part of the Sylvian fissure; (3) there was no complete filling of the anterior interhemispheric fissure and no extension to the lateral part of the Sylvian fissure, except for minute amounts of blood; and (4) frank intraventricular hemorrhage was absent. Some sedimentation of blood may be seen in the posterior horns of the lateral ventricles and the fourth ventricle. In addition, more diffuse SAH patients were also considered perimesencephalic if their hemorrhage pattern followed all but the third rule outlined by Brinjikji and colleagues.[14]

Patients were then stratified into 3 groups, 2 distinct pmSAHs, and 1 dSAH as the reference group. This stratification was based on clinical experience, where the INRs were observing worse complications in pmSAH as the hemorrhage spread. Groups were in the order of least to most diffuse bleeding patterns for analysis: Peri-1 included focal, mass-like, bleeding into the prepontine space (Fig 1); Peri-2 included a bleeding pattern not isolated to the prepontine space, but limited to the traditional perimesencephalic criteria outlined above (Figs 2 and 3), and dSAH (Fig 4) included bleeding into centered in the prepontine space, but with extension of hemorrhage through the interhemispheric fissure and Sylvian fissures over the cerebral convexities.

Figure 1. *Radiology imaging of Peri-1; focal bleeding isolated to the prepontine space.*

Figure 2. *Radiology imaging of Peri-2; bleeding to the traditional perimesencephalic criteria, including the pan-suprasellar cisterns.*

Figure 3. *Radiology imaging of Peri-2; bleeding to the traditional perimesencephalic criteria, including the pan-suprasellar cisterns and the left Sylvian fissure.*

Management

Following the institution's formalized SAH protocol, all patients diagnosed with SAH were initially admitted to the neurology critical care unit (NCCU), for continued work-up, stabilization, and treatment, and received 1 CT angiogram for diagnostic purposes. Because this method is not always sensitive enough to detect aneurysm, another angiogram or MRI was typically performed 7-10 days later. Asymptomatic patients thought to be low-risk based on clinical observation by a multidisciplinary team, including INRs, neurosurgeons, and neurologists, often did not receive a second angiogram. Prior to official negative angiography, all SAH patients initially received continuous hemodynamic monitoring, hourly neurologic evaluation, euvolemia, 60 mg of nimodipine every 4 hours, and daily transcranial Dopplers (TCDs). The duration for which patients with typical perimesencephalic hemorrhages were admitted to the NCCU was at the discretion of the multidisciplinary team and dependent on development of complications.

Figure 4. *Radiology imaging of dSAH; bleeding centered in the prepontine space, but with extension of hemorrhage through the interhemispheric fissure and Sylvian fissures over the cerebral convexities.*

Hydrocephalus was identified in patients experiencing elevated headache and lethargy and confirmed by findings on head CT. External ventricular drain (EVD) placement was used for patients with decreased consciousness and removed after intracranial pressure and clinical signs subsided. (Symptomatic) vasospasm confirmed by TCD was identified in patients with clinical symptoms that were similar to hydrocephalus, but also included signs of altered sensory-motor skills and personality changes. Vasospasm was managed with fluids and systolic blood pressure monitoring until symptoms subsided. Cerebral ischemia was diagnosed if new focal neurologic signs developed and CT or MRI showed ischemic regions unrelated to other causes. CI was managed with angioplasty or intra-arterial nimodipine, as needed.

Clinical Variables

The variables obtained from the stroke registry consisted of demographics (age, sex), comorbid medical history (hypertension [HTN]), diabetes mellitus, prior stroke, history of smoking, hyperlipidemia, history of migraines, coronary artery disease, presenting neurologic status and severity (admission Hunt and Hess Scores, baseline modified Rankin scores [mRS]), and discharge characteristics (discharge mRS, discharge destination).

The following variables were abstracted from the electronic medical record: clinical presenting symptoms from the patient's history and physical examination (photophobia, headache, lethargy, neck pain, any unilateral weakness, aphasia, ataxia, slurred speech, facial weakness/cranial nerve deficit, nausea/vomiting, diplopia, nuchal rigidity, numbness), modified fisher scale score,[1-4] NCCU length of stay (LOS), neurology floor LOS, hospital LOS, number of days on nimodipine, symptomatic vasospasm (defined as narrowing of large cerebral arteries by CT angiography or TCD, and requiring monitoring and treatment in interventional radiology), hydrocephalus (defined by enlarged ventricles on head CT), and severity (acute versus symptomatic [required an EVD]), CI (neurological worsening secondary to SAH and confirmed ischemic regions by CT or MRI), and cause of CI (procedural, vasospasm, unknown).

Statistical Analyses

The following variables were described: incidence, demographics, patient comorbidities, clinical features and severity on admission, clinical course, and short-term complications of patients, and compared them univariately between the 3 bleeding groups. Data were analyzed using Fishers exact tests for categorical variables. Student's t tests, 1-way ANOVAs, Wilcoxon 2-sample tests, or Kruskal-Wallis tests were used for continuous variables as appropriate. SAS 9.4 (Cary, NC) was used for all analyses. Two-tailed tests with an alpha of .05 were used for all tests.

Results

Presenting Demographic Characteristics

Of the 39 patients included in the study, 13 were Peri-1, 11 were Peri-2, and 15 were dSAH. The patients' demographics were similar between the 3 groups. A majority (n = 26) of patients were males with a mean (SD) age of 56.0 (11.3) years (Table 1). Overall, the following comorbid conditions did not differ among the groups: diabetes mellitus, history of migraines, hyperlipidemia, coronary artery disease, and history of smoking.

Clinical Characteristics on Admission

Presenting consciousness and neurological severity were similar between groups. Nearly all patients presented with Hunt and Hess Scores of 1-3 (n = 36) and baseline mRS scores between 0 and 2 (n = 38). Overall, the majority of patients presented with headache (n = 37), nausea/vomiting (n = 28), and neck pain (n = 25). There were significantly less patients with lethargy in Peri-1 and Peri-2 compared to dSAH (Table 1, p = .01). The following presenting symptoms did not differ among the groups: photophobia, headache, neck pain, weakness, aphasia, ataxia, slurred speech, cranial nerve deficit, nausea/vomiting, diplopia, nuchal rigidity, and numbness (Please see supplemental file #1 for statistical comparisons between Peri-1 and Peri-2).

Table 1. *Demographic and clinical characteristics between groups*

Characteristics, n (%)	Peri-1 N = 13 (33%)	Peri-2 N = 11 (28%)	dSAH N = 15 (38%)	*P* value
Sex				.53
Male	7 (54%)	8 (73%)	11 (73%)	
Age, mean (SD) y	52.9 (12.3)	54.2 (10.9)	58.2 (10.9)	.45
Comorbidities				
Hypertension	3 (23%)	2 (18%)	9 (60%)	**.05**
Hyperlipidemia	1 (8%)	2 (18%)	6 (40%)	.15
None	2 (15%)	4 (36%)	1 (7%)	.16
Presenting symptoms				
Headache	12 (92%)	11 (100%)	14 (93%)	>.99
Nausea/vomiting	9 (69%)	9 (82%)	10 (67%)	.74
Lethargy	1 (8%)	1 (9%)	10 (67%)	**.01**
Hunt and Hess (1-3)	12 (92%)	11 (100%)	13 (87%)	.77

Peri-1, bleeding located in the focal prepontine + foramen magnum (FM); Peri-2, pan-suprasellar cisterns + FM + intraventricular hemorrhage (IVH); (dSAH, diffuse): pan-suprasellar cisterns + FM + Sylvian fissures + IV

Abbreviation: SD, standard deviation.

Clinical Course and Short-term Complications

Of the 39 patients, 5 (2 in Peri-2; 3 in dSAH) developed (symptomatic) vasospasm, a mean (SD) of 7.2 (2.7) days after admittance to the hospital. Seven patients developed CI (3 Peri-2; 4 in dSAH), with no significant differences found between groups for either complication (Table 2). There were 10 patients diagnosed with hydrocephalus and of those, 4 were symptomatic (required EVD placement). There were significantly fewer patients diagnosed with hydrocephalus overall in Peri-1, compared to Peri-2 and dSAH (P= .003, Table 2). No patients in the Peri-1 group developed any short-term complications. Because of the small sample size, adjusting for covariates of developing short-term complications were unable to be performed.

Across Peri-1, Peri-2, and dSAH, patients had significantly different median (IQR) NCCU LOS days (7.0 (3.5-8.0) versus 8.0 (6.5-15.0) versus 11.0 (8.0-15.0), P= .02, Table 2); hospital LOS days (8.5 (6.5-10.5) versus 11.5 (8.5-18.0) versus 14.0 (12.0-22.0), P= .002, Table 2); and mean (SD) days on nimodipine treatment (8.2 (4.0) versus 11.5 (7.5) versus 15.1 (5.9), P= .01, Table 2) between groups. There were no significant differences found between groups for median neurology floor LOS days. (Please see supplemental file #2 for statistical comparisons between Peri-1 and Peri-2).

Discussion

Because no risk factors or predispositions have been confirmed for pmSAHs, it becomes challenging to predict which patients may develop short-term complications. This study observed that pmSAH patients with the best clinical course had minimal bleeding, and those with a more diffuse hemorrhage experienced complications. In patients that initially present with similar clinical signs, these data suggest that the distribution of bleeding may help predict complications. Larger studies examining this topic might have the ability to generate important data that can help guide triage management strategies in patients with pmSAHs.

Because the dSAH group in the current study is comparable to a traditional aSAH patients, it is important to examine the aSAH literature to understand the findings of the current study. A 2018 systematic review by Mensing et al pooled data from 5 studies comparing odds of established risk factors of diabetes, HTN, and smoking of pmSAHs to aSAHs.[15] When compared to patients with aSAHs, the review observed that the pooled odds ratios in patients with HTN and smoking for pmSAH were .5 (95% CI, .3-.9) and .4 (95% CI, .2-.8), respectively, indicating a reduced risk for pmSAH compared to aSAH. Although limited by small numbers, the dSAH group in this study was associated with a higher rate of HTN compared to Peri-1 and Peri-2. This finding is not surprising, since several studies have shown that patients with a similar bleeding distribution to aSAHs, translating to a similar clinical course.[5,6,8] It was also observed that 5 patients with pmSAH had a family history of diabetes mellitus, and no patients in the dSAH group had diabetes. Mensing et al confirmed these observations and noted the tendency towards an increased prevalence of diabetes mellitus in the classic pmSAH pattern, and a reduced risk for aSAHs.[15] While previous studies have suggested that a history of diabetes, HTN, and smoking may lead to an increased risk of acute hydrocephalus in aSAHs,[15] those findings were unable to be confirmed in this population.

Table 2. *Clinical course between groups*

Variable	Peri-1 N = 13 (33%)	Peri-2 N = 11 (28%)	dSAH N = 15 (38%)	*P* value
Vasospasm	0 (0%)	2 (18%)	3 (20%)	.24
*Mean (SD) days from admit to IR**	-	8.0 (1.4)	6.7 (3.5)	.72
Cerebral infarction	0 (0%)	3 (27%)	4 (27%)	.10
Hydrocephalus	0 (0%)	2 (18%)	8 (53%)	**.003**
NCCU LOS, median (IQR) days	7.0 (5.0-8.0)	8.0 (6.0-14.0)	11.0 (8.0-15.0)	**.02**
Neurology floor LOS, median (IQR) days	2.0 (1.0-3.0)	3.0 (1.0-5.0)	3.0 (2.0-8.0)	.10
Hospital LOS, median (IQR) days	8.0 (7.0-10.0)	10.0 (8.0-20.0)	14.0 (12.0-22.0)	**.001**
Mean (SD) days on nimodipine	8.2 (4.0)	11.5 (7.5)	15.1 (5.9)	**.01**
Hospital discharge destination				.29
Home/home health	13 (100%)	10 (91%)	11 (73%)	
SNF	0 (0%)	0 (0%)	2 (13%)	
Rehab	0 (0%)	1 (9%)	2 (13%)	
Discharge mRS				.53
0-2	11 (85%)	11 (100%)	13 (87%)	
3-6	2 (15%)	0 (0%)	2 (13%)	

Peri-1, bleeding located in the focal prepontine + foramen magnum (FM); Peri-2, pan-suprasellar cisterns + FM + intraventricular hemorrhage (IVH); (dSAH, diffuse): pan-suprasellar cisterns + FM + Sylvian fissures + IVH; IR, interventional radiology; NCCU, neurology critical care unit; LOS, length of stay; IQR, interquartile range; SNF, skilled nursing facility; mRS, modified Rankin Scale.

*Defined as mean days from admit to IR for vasospasm treatment.

Development of complications such as hydrocephalus, vasospasm, CI, and rebleeding, while rare in comparison to aSAHs, have been found in naSAHs in several studies.[5,7,8,10,16,17] Kang et al compared the clinical course and long-term outcomes of non-pmSAHs (N = 29) to pmSAHs (N = 23).[7] Compared to the pmSAHs, acute hydrocephalus developed more frequently in the non-pmSAHs (9% versus 38%) and 8% in the latter group required an EVD. Additionally, they found that angiographic vasospasm developed in 28% of patients with non-pmSAHs and in none with pmSAHs, with no CI observed and only 1 patient with rebleeding. Compared to Kang et al, this study observed higher rates of acute and symptomatic hydrocephalus between groups. Furthermore, this study found that of the pmSAHs, 2 in Peri-2 developed vasospasm, and 3 in Peri-2 developed CI; no rebleeding was observed.

Overall higher incidences of complications were observed in this study, such as symptomatic hydrocephalus, CI, and vasospasm, compared to several studies on naSAHs.[7,8,18-21] These complications were limited to patients with a more diffuse hemorrhage pattern. Higher incidences of complications were reported potentially because of the novelty of the pmSAH stratification. To our knowledge, this is one of the first studies to stratify pmSAH into 2 groups by bleeding pattern and examine differences between those groups. Based on the findings, patients with bleeding mainly localized to the prepontine (Peri-1) had a benign clinical course with no complications. When the bleeding pattern became more diffuse (Peri-2), complications were reported, and patients experienced a longer median hospital and NCCU LOS. Standard practice in patients with SAH is to obtain 2 angiograms 1 week apart, to definitively exclude an aneurysmal source,[14,22] but repeated imaging for pmSAHs have suggested only 1 angiogram may be sufficient.[23]

At this CSC, the decision was made on a case-by-case basis by a multidisciplinary team. Overall, 11 patients (7, Peri-1; 4, Peri-2) had only 1 angiography performed and 13 patients (6, Peri-1; 7, Peri-2) had at least 2 angiograms within 1 week of presentation. Although the majority of patients in the Peri-1 group had only 1 angiogram, 6 had a second angiogram. Because no patients in the Peri-1 group experienced complications, using the bleeding pattern in the decision analysis for this group should be examined in a larger study.

This study has several limitations. First, all patients included came from a single CSC reducing generalizability across different populations. Second, adjusting for covariates was unable to be performed due to the small number of patients identified and further stratified into smaller groups; however, because these groups were similar with respect to demographics, presenting symptoms and baseline mRS, there would be very few things that necessitated adjusting if possible. Third, there was no access to long-term follow-up data.

Conclusions

The results of this study suggest that pmSAH patients with localized bleeding have an excellent prognosis, whereas those with more diffuse bleeding tend to experience more complications and a longer LOS. Stratifying by distribution of blood on CT may improve the predictability of prognosis. Further studies are warranted to better delineate the potential benefits of more precise diagnostic stratification on clinical treatments and outcomes.

Compliance With Ethical Standards

All procedures performed in studies involve human participants were in accordance with the ethical standards of the local institutional review board (HCA IRB # 779117). Because the study was retrospective, informed consent was waived.

Authors' Contributions

All authors provided final approval of the submitted manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Specifically, B.A. is responsible for study conception, literature review, data acquisition, interpretation of the data, and critical revisions. C.M. is responsible for literature review, study design, data acquisition, data analysis and interpretation, and drafting the manuscript. K.M. and R.V. are responsible for data acquisition, data interpretation, study design, and critical revisions. D.F., A.B., J.W., R.B., A.O., and D.B.O. are responsible for interpretation of the data and critical revisions.

Data Sharing Statement

Anonymized data and statistical code are available from the corresponding author upon reasonable request.

Conflicts of interest

The authors declare no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2019.06.032.

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