Turk Neurosurg, 2024

Original Investigation

DOI: 10.5137/1019-5149.JTN.45739-23.1

Received: 14.10.2023
Accepted: 02.01.2024

Published Online: 13.06.2024

Unlocking the Battle-Clipping vs. Endovascular Therapy for Shunt-Dependent Hydrocephalus After Aneurysm Rupture: An In-Depth Institutional Analysis

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ABSTRACT

AIM: To compare microsurgical clipping and endovascular therapy (EVT) for the management of shunt-dependent hydrocephalus (SDH) in patients with subarachnoid hemorrhage (SAH) and hydrocephalus.

MATERIAL and METHODS: This retrospective study was conducted from July 2018 to December 2022 and included 67 patients with SAH accompanied by acute hydrocephalus. Patients' demographic, clinical, and radiological data, such as age, sex, Glasgow Coma Scale scores, Hunt and Hess scale, Fischer grade, external ventricular drain (EVD) duration, complications, Ommaya reservoir placement, cerebrospinal fluid drainage, and outcomes, were obtained. Statistical analyses, including univariate analysis and stepwise logistic regression, revealed significant risk factors for shunt dependence.

RESULTS: Of the 67 patients, 33 underwent microsurgical clipping and 34 received EVT. Spasmolysis reduced shunt dependency, whereas early EVD placement correlated with reduced shunt dependence (p=0.002). The Ommaya reservoir helped in the management of meningitis but was found to be associated with shunt dependency (p=0.04). Multiple logistic regression analysis revealed that perioperative infarct was a significant risk factor for shunt dependence (p=0.05). No significant difference in patient outcomes was observed between the two treatment groups. However, patients who received EVT had shorter intensive care unit and hospital stays.

CONCLUSION: This study shows that managing clinical vasospasm with spasmolysis may reduce shunt dependency. Overall, both microsurgical clipping and EVT offer similar long-term outcomes and efficacy in preventing shunt dependence, but the latter has the advantage of shorter hospital stay. These findings provide crucial insights for clinical decision-making and patient care in SDH after SAH.

KEYWORDS: Hydrocephalus, Aneurysm rupture, Clip vs EVT, Shunt dependence, Outcome

ABBREVIATIONS: CSF: Cerebrospinal fluid, **DSA:** Digital subtraction angiography, **EVD:** External ventricular drain, **GCS:** Glasgow Coma Scale, **GOS:** Glasgow Outcome Score, **ICP:** Intracranial pressure, **ICU:** Intensive care unit, **SDH:** Shunt-dependent hydrocephalus

INTRODUCTION

Subarachnoid hemorrhage (SAH) is a critical medical concern with potentially grave consequences. Among the complications that can arise from SAH, shunt-dependent hydrocephalus (SDH) stands out as a significant issue, accounting for 6% to 60% of all SAH cases (7). Within the realm of neurosurgery, the optimal approach to managing this condition remains a subject of ongoing research and spirited debate.

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While the prevailing body of research has favored microsurgical clipping over endovascular coiling as the preferred treatment for ruptured aneurysms associated with SAH, several studies have indicated the absence of a statistically significant difference in the reduction of long-term SDH incidence (7,16,14). The management of hydrocephalus frequently involves interventions such as cisternostomy during aneurysm clipping and placement of an external ventricular drain (EVD) both during and after surgery. This approach is mirrored in patients with ruptured aneurysms accompanied by SAH undergoing endovascular procedures. Nonetheless, approximately 40%–50% of these patients experience ventriculomegaly and clinical deterioration upon EVD removal, requiring ventriculoperitoneal shunt placement (12).

The literature has highlighted various risk factors for SDH after SAH, such as age, presence of infarction on CT head scans, higher Hunt and Hess grade, and intraventricular hemorrhage with acute dilatation (5,7). However, studies on additional variables such as cisternostomy, duration of EVD placement, Ommaya reservoir placement, vasospasm, and effects of spasmolysis during aneurysm management, be it through clipping or coiling, remain scarce (2,7,8). These factors have the potential to independently influence patient outcomes and contribute to shunt dependency.

Given the complications and uncertainties associated with SDH management after SAH, we conducted a comprehensive analysis. Our primary objective was to assess the efficacy of microsurgical clipping versus endovascular therapy (EVT) in preventing SDH in patients with ruptured aneurysms. The secondary objective was to explore the impact of various factors, such as age, sex, duration of EVD placement, Ommaya reservoir placement, cisternostomy, Hunt and Hess grade, Fischer grade, intraventricular bleed, vasospasm, and meningitis, on the shunt dependence of patients who developed acute hydrocephalus after SAH.

MATERIAL and METHODS

This study was conducted from July 2018 to December 2022 at the neurosurgery department of our institution. The study protocol was approved by the ethics committee also of our institution (approval no. IEC/2021/278). During the study period, 300 patients with aneurysmal SAH, who also presented with intracranial bleeding at other sites, were treated. Of these patients, 67 were ultimately included in the study. These patients had acute hydrocephalus detected via repeat noncontrast computed tomography (NCCT) head scans, which were conducted either during their ward admission or as part of their follow-up assessments after treatment due to new neurological complaints. Notably, this condition was not detected in the initial CT head scans conducted immediately after the ictus.

Data Collection

The patients' demographic data, such as age and sex, as well as clinical data were obtained from their medical records. A comprehensive set of data points was meticulously gathered, encompassing age, sex, Glasgow Coma Scale (GCS) score upon admission, Hunt and Hess grade, Fischer grade based on brain NCCT, duration of EVD placement, complications associated with EVD, Ommaya reservoir placement, history of cerebrospinal fluid (CSF) drainage (continuous/intermittent), CSF protein levels measured via EVD, Glasgow Outcome Score (GOS), and modified Rankin scale (mRS) score during follow-up.

The presence of comorbidities, such as obstructive lung disease (e.g., asthma and chronic obstructive pulmonary disease), coronary artery disease, heart failure, stroke, diabetes, cirrhosis, chronic kidney disease, SAH-associated metastases, and being on hemodialysis.

Radiological and Laboratory Data

The patients' radiological data from the NCCT head scans, such as Fischer grade, Evans index, and periventricular lucency, were extracted from their medical records. Additional investigative information, including pre- and postoperative digital subtraction angiography (DSA) and brain magnetic resonance imaging results, were also obtained. For postoperative patients, CT angiography was performed within 24 h or whenever neurological deterioration was detected (e.g., a drop in GCS or the emergence of new neurological deficits). In patients with evident vasospasm, spasmolysis was administered during DSA, and vasospasm reduction and clinical improvement were documented.

Other laboratory data obtained from the patients' medical records were pre- and postoperative routine blood investigations, CSF routine microscopy at regular intervals, associated complete blood count, CSF culture, and sensitivity report.

Cisternostomy and EVD Management

Instances of cisternostomy, including the opening of the lamina terminalis alone or in conjunction with other cisternostomies, such as fenestration of the Liliequist membrane, were recorded.

For patients who developed hydrocephalus after aneurysmal SAH, particularly those with deteriorating GCS scores, we implemented EVD placement. Initially, we implemented intermittent CSF drainage through the EVD, irrespective of the treatment method used—endovascular coiling or microsurgical clipping. As postoperative improvement occurred, we progressively weaned the patients off the EVD by intermittently closing it. Simultaneously, we closely monitored GCS fluctuations and any increase in blood pressure as indicators of elevated intracranial pressure (ICP). We conducted EVD weaning trials every 48–72 h, which allowed for multiple tube clamping attempts to determine the optimal time for EVD removal. During these trials, some patients experienced hardware complications, such as frequent blockages or infections, necessitating replacement with the Ommaya reservoir. Ommaya reservoir placement served as a conduit for intermittent CSF drainage and antibiotic administration, thereby reducing the risk of intracranial infection and facilitating gradual, intermittent EVD.

The Ommaya reservoir was positioned 2.5 cm lateral and 1 cm in front of the coronal suture through a 2-cm horizontal straight incision within the scalp. Ommaya reservoir tapping was performed using a scalp vein set, typically over two to three times per day for patients requiring more frequent drainage. This frequency was gradually reduced to once daily, then every 24 and 48 h, and ultimately ceased after three to four trials if the patient exhibited stable GCS.

We recorded the average duration of EVD placement, the duration for which the Ommaya reservoir was retained, and the need for ventriculoperitoneal shunt placement from the available patient case records.

Intracranial Pressure Monitoring

Due to the difficulty of regularly measuring CSF pressure or ICP using various monitoring devices, it was not carried out in this study. Instead, we mainly relied on clinical parameters, such as GCS, blood pressure, pulse rate, respiratory rate, and O_2 saturation, as indicators of increased ICP.

Length of Stay and Follow-Up

Data on intensive care unit (ICU) and overall hospital stays were obtained from patient records. The GOS and mRS scores were recorded during follow-up assessments.

Statistical Analysis

All statistical analyses were conducted using the Statistical Package for the Social Sciences version 20.0. Continuous variables were compared using *t*-tests. On the other hand, categorical variables were expressed as numbers and percentages and compared using the chi-squared test or Fisher's exact test. To identify the factors associated with shunt dependency, multiple logistic regression analysis was employed. Variables with a significance level below 0.05 in the univariate analysis were subsequently included in the stepwise logistic regression analysis. A two-tailed P-value <0.05 was considered statistically significant. This rigorous statistical approach ensured comprehensive exploration and assessment of the factors that contribute to shunt dependency.

RESULTS

This study included 300 patients with ruptured aneurysms. Among them, 67 (22.33%) developed hydrocephalus accompanied by new neurological complaints during treatment. Of the 67 patients, 33 (49.25%) and 34 (50.74%) were managed with microsurgical clipping and EVT, respectively (Table I).

The average age of the patients in the clipping group was 47.66 (standard deviation [SD], 8.6) years, whereas that of the patients in the EVT group was 54.17 (SD, 10.30) years (p=0.007). The male-to-female ratio in the clipping group was 1.06, whereas that in the EVT group was 0.7 (p=0.39).

In the clipping group, 22 patients (66.66%) had anterior circulation aneurysms whereas 11 (33.34%) had posterior circulation aneurysms. In the EVT group, on the other hand, 10 had anterior circulation aneurysms and 24 had posterior circulation aneurysms. Interestingly, patients with posterior circulation aneurysms had a higher risk of developing hydrocephalus (p=0.002).

Regarding the initial GCS scores, 21 patients in the clipping group had scores between 9 and 12 whereas 20 in the coiling group had the same score range (p=0.065). The preoperative Hunt and Hess grade, indicating SAH severity, was similar between the groups, with 26 and 24 patients in the clipping and coiling groups, respectively, having grades of 3–5 (p=0.44). Furthermore, the mRS score, which reflects functional status, indicated no significant difference, with 24 and 22 patients in the clipping and coiling groups, respectively, having scores higher than 2 (p=0.54).

In terms of major comorbidities, hypertension was a significant factor in 14 patients and diabetes in 12 in the clipping group. In the EVT group, hypertension was a major comorbidity in 19 patients and diabetes in 14 (Table I).

On NCCT head scans, 19 and 10 patients in the clipping and coiling groups, respectively, had intraparenchymal bleeding. Furthermore, 22 patients in the clipping group and 26 in the coiling group had intraventricular bleeding (p=0.04) (Table I).

After microsurgical clipping or coiling, patients who experienced a decline in GCS score or developed new neurological deficits underwent brain CT angiography to identify potential issues such as infarction, rebleeding, vasospasm, and ventricular dilatation. After evidence of infarction or vasospasm was obtained, DSA was performed on these patients. Angiographic evidence of vasospasm was found in 26 patients in the clipping group and 28 in the coiling group. Subsequently, spasmolysis was administered to these patients. Of the aforementioned 26 patients, 20 demonstrated improvements in vasospasm. Conversely, of the 28 patients, 22 exhibited improvement. Six patients in the clipping group did not respond to spasmolysis and required a ventriculoperitoneal shunt during follow-up (Figures 1 and 2). All of these patients eventually developed shunt dependency during follow-up (Figures 3 and 4) (Table II).

Cisternostomies with and without fenestration of the lamina terminalis were performed on 24 and 9 patients, respectively. EVD placement was carried out in 21 patients in the clipping group and 33 in the coiling group (p=0.001). This decision was made in response to increasing ventricular dilatation or ventricular dilatation accompanied by new neurological complaints (Table III).

Patients who underwent early EVD placement were less dependent on shunt placement compared with those who had delayed EVD placement (p=0.002) (Figure 5).

A total of 14 and 15 patients in the clipping and coiling groups, respectively, required Ommaya reservoir placement after EVD placement. This was due to persistent meningitic CSF conditions resulting from contamination of the long EVD tubing at the bedside and frequent EVD repositioning during patient mobilization (Table III).

In the clipping group, 10 patients required shunt placements during follow-up, whereas in the coiling group, 12 were found to be shunt-dependent (p=0.66) (Table III).

We analyzed the risk factors for SDH during follow-up in patients with ruptured aneurysms. Initially, we identified

Table I: Risk Factors Associated with Shunt-Dependent Hydrocephalus Following an Aneurysmal Bleed: Clipping vs. Endovascular Therapy (EVT)

Variables (Risk factors)	Clipping (n=33)	Endovascular therapy (n=34)	p-value
Age (Years)	47.66±8.6	54.17±10.30	**0.007**
Sex	17:16	14:20	0.39
Location of the aneurysm			
Anterior circulation	22	10	
Posterior circulation	11	24	**0.002**
GCS ->12	9	12	0.065
9-12	21	20	
≤8	3	2	
Hunt and Hess grade			
1-2	7	10	
3-5	26	24	0.44
mRS score (Pre-op)			
1-2	9	12	
3-4	24	22	0.54
Fischer grade			
1	4	0	**0.05**
2	10	8	
3	16	22	
4	3	4	
CT finding -SAH	33	34	
Intraparenchymal bleed	19	10	
Intraventricular bleed	10	25	**0.04**
Duration to perform EVD	5.39±5.42	4.32±3.46	0.43
Average duration for EVD trial	6.49±6.41	7.45±6.36	0.67
Average duration for Omaya reservoir trial	6.69±6.36	7.67±5.43	0.71
CO-morbidities			
Stroke	2	3	
CAD	2	2	
hypertension	14	19	
diabetes	12	14	

GCS: *Glasgow comma scale,* ***EVD:*** *External ventricular drainage,* ***CAD:*** *coronary artery disease,* ***SAH:*** *Subarachnoid haemorrhage*

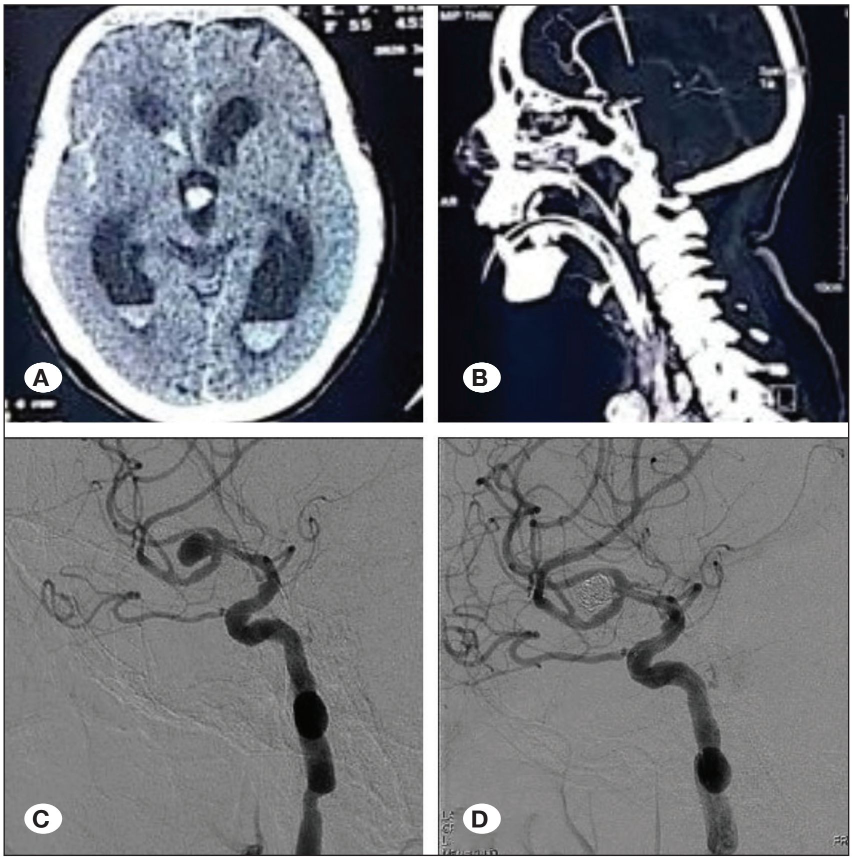

Figure 1: A) Brain Noncontrast Computed Tomography (NCCT) depicting diffuse subarachnoid hemorrhage (SAH) with interhemispheric and intraventricular bleeding and dilated ventricles in a 65-year-old female patient. **B)** Sagittal Brain CT Angiography illustrating the presence of an External Ventricular Drain (EVD) in the frontal horn along with an anterior communicating artery aneurysm (Acom) projecting anteriorly. **C)** Cerebral Digital Subtraction Angiography of a left internal carotid artery injection displaying the Acom aneurysm with evidence of vasospasm in the internal carotid artery (ICA), anterior cerebral artery (ACA), and middle cerebral artery (MCA). **D)** Cerebral Digital Subtraction Angiography of a left internal carotid artery injection revealing a coiled Acom aneurysm with relieved spasm after spasmolysis through injectable nimodipine infusion.

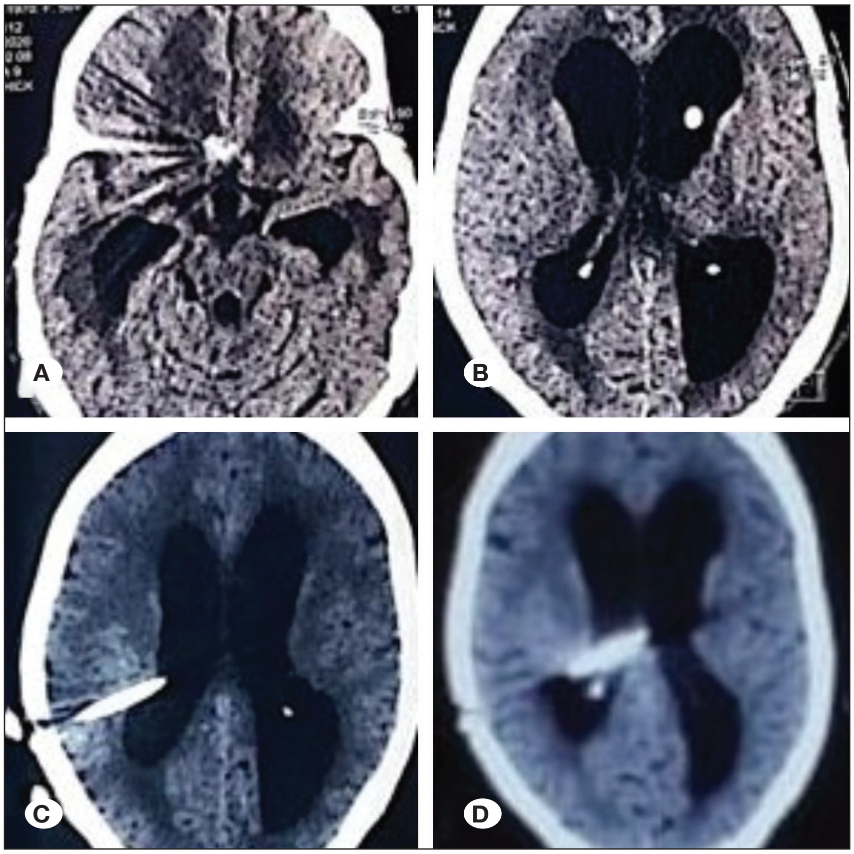

Figure 2: A) Brain Noncontrast Computed Tomography (NCCT) indicating a coiled aneurysm with persisting ventricular dilatation. **B)** Brain Noncontrast Computed Tomography (NCCT) showing the tip of the EVD tube in the frontal horn. **C)** Brain Noncontrast Computed Tomography (NCCT) displaying the proximal end of the ventriculoperitoneal shunt in the atrium. **D)** Brain Noncontrast Computed Tomography (NCCT) presenting the proximal end of the ventriculoperitoneal shunt in the atrium with reduced ventricular dilatation in the same patient.

Table II: Vasospasm, Infarction, and Shunt Dependence in Hydrocephalus Following Aneurysmal Bleeding: A Comparison of Clipping and Endovascular Therapy (EVT)

	Clipping (n=33)	EVT (n=34)	p-value
Vasospasm	26	28	0.06
Infarct on NCCT Head	18	20	**0.02**
Responders to spasmolysis	14	15	0.54
Non responders to spasmolysis	12	13	0.61
Shunt dependence	10	12	0.66

NCCT: *Non contrast computed tomography.*

Table III: Perioperative Cerebrospinal Fluid Diversion and Shunt Dependency in Hydrocephalus Following Aneurysmal Bleeding: A Comparison of Clipping and Endovascular Therapy (EVT)

CSFD Performed	Clipping (n=33)	Coiling (n=34)	p-value
Cisternostomy with lamina terminalis fenestration	24	-	
Cisternostomy without lamina terminalis fenestration	9	-	
EVD	21	33	**0.0006**
Ommaya	14	15	0.88
Ventriculoperitoneal shunt	10	12	0.660

EVD: *External ventricular drainage,* ***CSFD:*** *Cerebrospinal fluid diversion.*

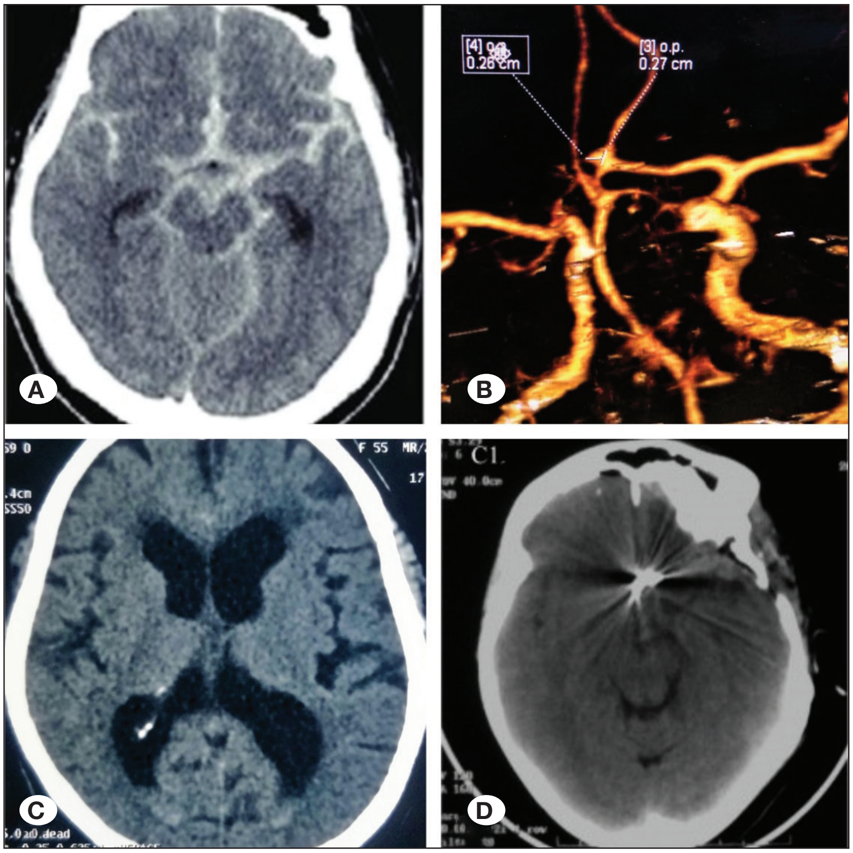

Figure 3: A) Brain Noncontrast Computed Tomography (NCCT) illustrating diffuse subarachnoid hemorrhage (SAH). **B)** Brain CT Angiography with 3-D reconstruction revealing an Acom aneurysm projecting posteriorly with a hypoplastic right A1 vessel. **C)** Brain NCCT displaying dilated ventricles. **D)** Brain Noncontrast Computed Tomography (NCCT) indicating a clipped Acom aneurysm.

several potential risk factors via univariate analysis, including age, Hunt and Hess grade, Fischer grade on CT, periprocedural infarct on CT, acute infarct, evidence of vasospasm, nonresponsiveness to spasmolysis, choice of procedure (clipping vs. coiling), duration of EVD placement, and use of additional procedures such as placement of EVD and Ommaya reservoir. Subsequently, we employed stepwise logistic regression analysis to determine which of these factors significantly contributed to SDH development during the follow-up period (Table IV). The analysis revealed that perioperative infarct on NCCT head scans (p=0.04) was a statistically significant contributor to SDH development (Table IV). Comparative receiver operating characteristic curve demonstrated the largest area under the curve, indicating the highest predictive value for shunt dependence during follow-up when comparing perioperative infarct on NCCT head scans with other risk factors. This significance extended to factors such as higher Hunt and Hess grades and Ommaya reservoir placement (Figure 6).

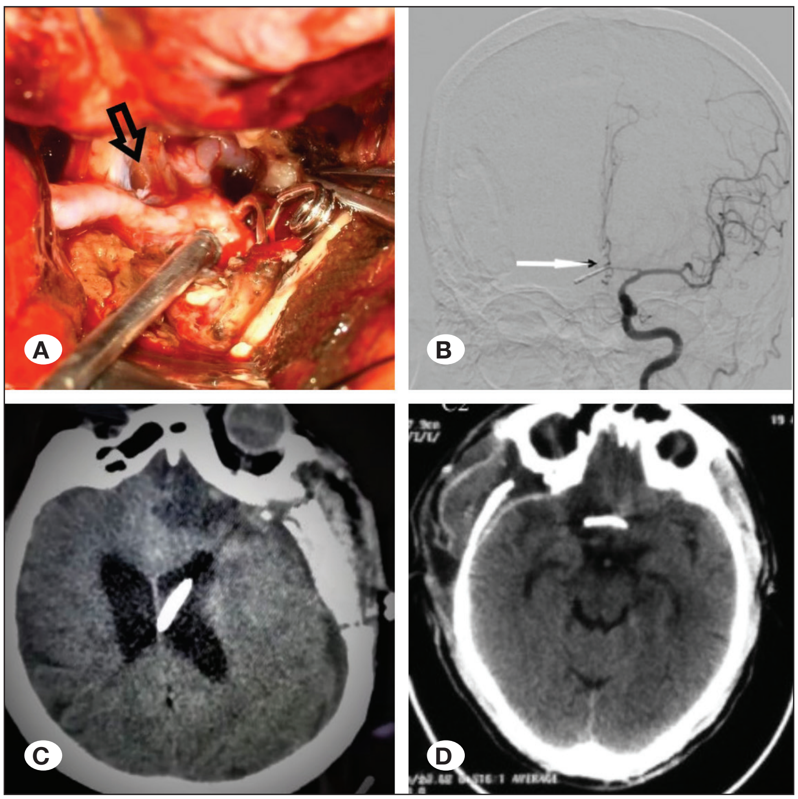

Figure 4: A) Intraoperative image depicting a clipped Acom aneurysm with a wide cisternostomy and fenestration of the lamina terminalis (black arrow). **B)** Postoperative DSA (Digital Subtraction Angiography) with left ICA (Internal Carotid Artery) injection showing normal-calibre vessels of the distal ACA (Anterior Cerebral Artery) and MCA (Middle Cerebral Artery) with a clipped Acom aneurysm (white arrow). **C)** Brain Noncontrast Computed Tomography (NCCT) indicating a clipped EVD tube in the atrium. **D)** Brain Noncontrast Computed Tomography (NCCT) showing a clipped Acom aneurysm with non-dilated ventricles on follow-up.

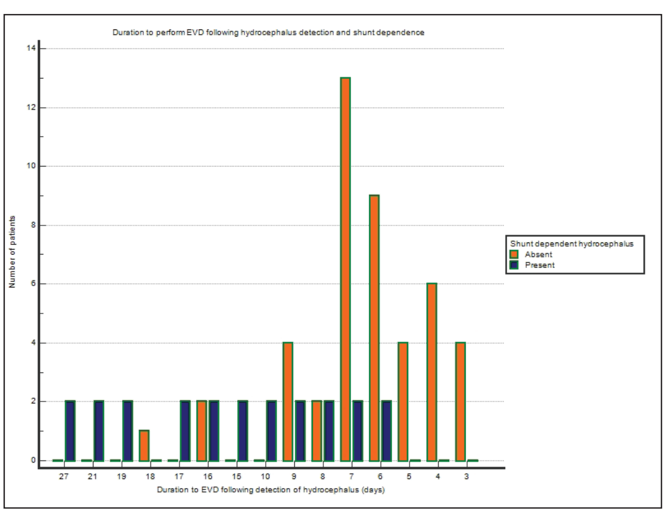

Figure 5: Graph depicting the relationship between the duration in days to perform EVD following the detection of symptomatic hydrocephalus and shunt dependence.

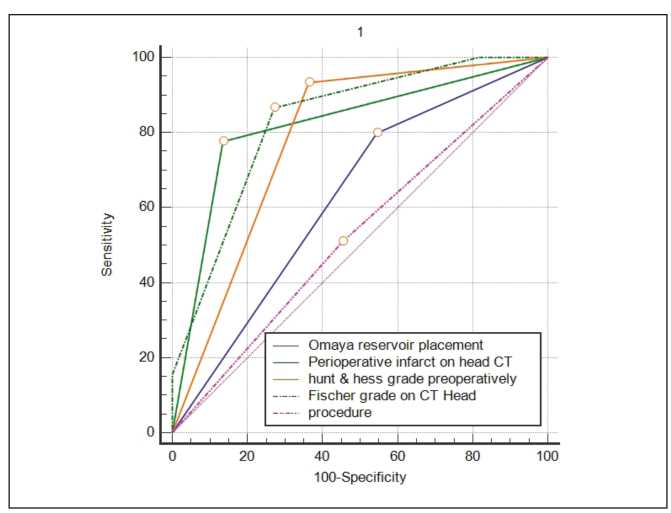

Figure 6: Comparison of Receiver operator characteristics curve (ROC) suggesting largest area under curve(AUC) and highest predictive value of perioperative infarct on head CT.

Table IV: Utilizing Logistic Regression Analysis to Investigate Risk Factors Including the Procedure Performed (Clipping and Coiling) Contributing to Shunt Dependence in Hydrocephalus Following Aneurysmal Bleeding

Variable	Coefficient	Std. Error	Wald	Odds ratio	95% CI	p-value
Age	0.59497	0.35324	2.8369	1.8130	0.9072 to 3.6231	0.0921
Procedure(clip vs.coil)	-6.20320	3.47299	3.1902	0.0020	0.0000 to 1.8292	0.0741
Duration to EVD	-0.92483	0.49534	3.4859	0.3966	0.1502 to 1.0471	0.0619
Fischer grade on NCCT Head	2.42314	1.39770	3.0056	11.2812	0.7288 to 174.6242	0.0830
Hunt and Hess grade	-11.36593	6.20351	3.3569	0.0000	6.0716 to 2.2099	**0.0569**
Omaya reservoir placement	-3.44347	2.29642	2.2485	0.0320	0.0004 to 2.8792	0.1337
Sex	8.98511	4.99747	3.2326	7983.2956	0.4449 to 143255453.1508	0.0722
Infarct on NCCT Head	7.99428	4.07347	3.8515	2963.9584	1.0103 to 8695228.9036	**0.0497**
Constant	-15.14417	11.50026	1.7341			0.1879

***CI:** Confidence interval, **EVD:** EVD-External ventricular drainage, **NCCT:** Non contrast computed tomography.*

In our analysis, we observed a higher prevalence of shunt dependency among patients who underwent clipping, although the difference was not statistically significant (p=0.6). Furthermore, when we evaluated the long-term outcomes, we found that the mRS score during follow-up and the GOS were quite similar between the groups (p=- 0.21 and p=0.26, respectively) during an average follow-up period of 34.26 ± 11.48 months in the clipping group and 31.45 ± 12.67 months in the EVT group. There were two mortalities in the clipping group and one in the coiling group, which were caused by uncontrolled chest infection leading to multiple organ dysfunction syndrome. Notably, all of these patients had comorbidities, such as coronary artery disease, hypertension, and diabetes.

However, it is noteworthy that the two groups exhibited a significant difference in the length of ICU stay and overall hospital stay (p=0.001). The coiling group had shorter stays (p=0.0001) (Table V).

DISCUSSION

The development of hydrocephalus after bleeding due to a ruptured aneurysm was first described by Bagley in 1928. This condition has the following development phases: acute (<3 days), subacute (3–14 days), and chronic (after 14 days). The incidence rates of hydrocephalus in such scenarios have been reported to range from 15% to 58% in the acute stage and 4% to 37% in the chronic stage (2,8,14), consistent with the rates reported in the present study. The significant variability observed in these patients may be attributed to the different definitions of hydrocephalus in such contexts. Notably, there is limited literature on the development of hydrocephalus after aneurysmal bleeding using established criteria such as Evans index >0.3, the emergence of new neurological deficits attributable to it, and the presence of evidence of increased ICP during procedures such as external CSF drainage as well as placement of EVD, Ommaya reservoir, or ventriculoperitoneal shunt, as we observed in our study (14).

Various risk factors have been identified as significant contributors to the development of hydrocephalus after aneurysmal bleeding, including advanced age, presence of a posterior circulation aneurysm, high Hunt and Hess grade upon admission, low GCS score, high Fischer grade, presence of infarction on CT scans, extended duration of EVD placement, and occurrence of intraventricular bleeding. These findings are consistent with those reported in previous studies, showing the strong association between these factors and the development of hydrocephalus after aneurysmal bleeding (2,5,7,8,12–16).

Interestingly, patients who underwent clipping and those who received EVT exhibited nearly similar clinical and radiological characteristics. This similarity may explain why both groups had a comparable number of patients who developed hydrocephalus after aneurysmal bleeding, despite differences in the treatment strategies used.

In our study, we observed that patients diagnosed with clinical vasospasm, characterized by neurological deterioration and confirmed vascular spasm on CT angiography, followed by subsequent DSA, had a higher need for EVD placement. Notably, the majority of patients who positively responded to spasmolysis achieved stability after EVD placement and did not require shunt dependence during follow-up. Contrarily, those who did not respond to spasmolysis eventually developed shunt dependency.

Several studies have proposed that elevated CSF protein levels, which are associated with the prevailing inflammatory conditions during this condition, play a significant role (13,14). In previous studies conducted by Kwon et al. and Black et al., clinical vasospasm was managed with triple-H therapy, which resulted in a high rate of shunt dependency among the cases (3,8). In our study, we adopted a different approach, i.e., directly addressing arterial vasodilation using a microcatheter upon vasospasm detection on DSA. This direct spasmolysis approach appeared to be more effective

Table V: Comparative Outcomes in Patients at Follow-Up: Clipping vs. Endovascular Therapy for Symptomatic Hydrocephalus Development

mRS scale postoperative	Microsurgical clipping	Endovascular coiling		P value
0-No symptoms	0	0		
1-Able to carry all work with symptoms	1 33.3% RT 9.1% CT 4.5% GT	6 66.7% RT 17.6% CT 9.0% GT	9 (11.9%)	0.205
2-Unable to carry all previous work	2 50.0% RT 42.4% CT 20.9% GT	4 50.0% RT 41.2% CT 20.9% GT	6 (8.95 %)	
3-Able to walk unassisted	14 50.0% RT 42.4% CT 20.9% GT	14 50.0% RT 41.2% CT 20.9% GT	28 (41.8%)	
4-Unable to walk unassisted	14 100.0% RT 6.1% CT 3.0% GT	10 0.0% RT 0.0% CT 0.0% GT	24 (35.8%)	
Glasgow outcome score	Microsurgical clipping	Endovascular coiling		0.288
1-(Death)	2 100.0% RT 3.0% CT 1.5% GT	1 0.0% RT 0.0% CT 0.0% GT	1 (1.5%)	
2-(Neurovegetative state)	0 0.0% RT 0.0% CT 0.0% GT	3 100.0% RT 8.8% CT 4.5% GT	3 (4.5%)	
3-(Severe disability pt dependent for daily work)	15 54.8% RT 51.5% CT 25.4% GT	12 45.2% RT 41.2% CT 20.9% GT	27 (47.7%)	
4-(Moderate disability (pt independent in daily life)	12 54.5% RT 36.4% CT 17.9% GT	10 45.5% RT 29.4% CT 14.9% GT	22 (32.8%)	
5-(Resumption of normal life with minor neurological deficits)	2 30.0% RT 9.1% CT 4.5% GT	7 70.0% RT 20.6% CT 10.4% GT	9 (13.5%)	
Length of stay in ICU(days)	**23.60±6.29**	**9.27±2.6**		**0.001**
Length of stay in hospital(days)	**33.6±7.9**	**18.72±2.19**		**0.001**
Mortality	**2**	**1**		
Follow up in months	**34.26±11.48**	**31.45±12.67**		**0.062**

under these circumstances, resulting in the early reduction of vasospasm, inflammation, and CSF protein levels. This, in turn, contributed to reduced need for EVD placement and less shunt requirements.

In a systematic review conducted by Komotar et al., no significant difference was observed in SDH after SAH between the clipping groups with and without fenestration of the lamina terminalis (6). In our study, patients who underwent lamina terminalis fenestration for early clot removal from the ventricle followed by EVD placement for CSF drainage had a lower rate of shunt independence than those who did not. However, this difference was not statistically significant, consistent with the findings by Komotar et al. (6).

Varela et al. reported that the average time for EVD replacement was 17 days, whereas Erixon et al. reported an average of 45 days (5,12). In our study, the duration of EVD replacement was shorter than those previously reported. In a meta-analysis conducted by Xie et al., the range for EVD replacement varied from a minimum of 17 days to a maximum of 45 days (14).

In our study, the decision to perform early EVD placement was prompted by the worsening neurological status and increasing ventricular dilatation detected on repeat CT scans. These features may have been associated with the high Fischer grade observed on the initial CT scans, indicating a thicker blood clot and earlier CSF outlet obstruction. We found that earlier EVD placement was associated with a lower likelihood of requiring ventriculoperitoneal (VP) shunt in our patients. This could be due to the removal of blood degradation products known to induce inflammation and fibrosis.

The importance of early EVD placement after the development of hydrocephalus post-SAH has also been highlighted in other studies (9,15). Elsharkawy and Abdelhameed reported that simultaneous EVD placement after cisternal fenestration reduced shunt dependence, potentially due to the combined effect of reducing the burden of blood clots and continuous CSF drainage, which minimizes inflammation along the CSF drainage pathway, consequently reducing the need for shunting (4). However, it is noteworthy that prolonged duration of EVD placement increases the risk of meningitis and its associated complications.

In our study, we opted to use the Ommaya reservoir as a replacement for EVD in cases where hardware problems occurred, such as impending infection due to bedside contamination of long tube settings or tube blockage. This approach was used to manage patients with persistent meningitis features and ICP by enabling antibiotic instillation and CSF drainage as needed, with fewer complications associated with long tube settings. A study by Sing et al. also reported that using the Ommaya reservoir as an alternative may reduce complications associated with meningitis compared with long tube settings for EVD drainage (11). However, in our study, the use of the Ommaya reservoir was a significant factor associated with shunt dependency. These findings suggest that while the Ommaya reservoir can help in the management of meningitis, the inflammatory cascade induced in the CSF drainage pathway by the external draining tube may become irreversible if continued for an extended period. Therefore, early weaning from EVD has been proposed to reduce shunt dependency, as suggested in several studies (1,14).

The mRS scores during follow-up and the GOS were strikingly similar among the patients, irrespective of the treatment method used—clipping or EVT. However, there was a significant disparity in the duration of ICU and overall hospital stays between the groups. Interestingly, the patients in the coiling group had significantly shorter hospital stays.

This finding indicates the potential advantage of EVT (coiling, spasmolysis, etc.) in terms of postoperative recovery and resource use. These findings have substantial implications for healthcare management and patient comfort. Rao et al. suggested similar outcomes, which are consistent with our own observations (10).

Strengths of the Study:

1. Comprehensive Data Collection: In this study, demographic, clinical, radiological, and laboratory data were thoroughly collected, providing a robust dataset for analysis.
2. Large Sample Size: A total of 300 patients were included in the study, with 67 cases selected for detailed analysis, strengthening the statistical significance of the findings.
3. Detailed Risk Factor Analysis: This study extensively investigated various risk factors for SDH after aneurysm rupture, providing valuable insights into the field.
4. Use of Logistic Regression: The use of logistic regression analysis facilitated the identification of statistically significant factors contributing to shunt dependency, enhancing the reliability of the study conclusions.
5. Clinical Relevance: The study findings have direct clinical relevance by shedding light on the management and prediction of SDH in patients with ruptured aneurysms.

Limitations of the Study:

1. Single-Center Study: The study was conducted in a single institution, which may limit the generalizability of the findings to other healthcare settings.
2. Retrospective Design: The retrospective nature of the study may introduce selection bias and incomplete data despite comprehensive data collection.
3. Small Subgroup Sizes: Some subgroup sizes, such as the number of patients requiring Ommaya reservoir placement, may be relatively small, potentially affecting the statistical power of the analysis.
4. Treatment Choice Bias: The study found a disparity in the length of stay between the clipping and endovascular coiling groups, potentially indicating a treatment choice bias that could influence the outcomes.

Despite these limitations, this study provides valuable insights into the management of and risk factors for SDH after aneurysm rupture, providing a foundation for further research and clinical decision-making.

CONCLUSION

The present study significantly contributes to the ongoing discussion on the management of SDH after aneurysm rupture. Although the study did not establish definitive treatment superiority between microsurgical clipping and EVT, it highlights the pivotal role of tailored treatment decisions, early EVD placement, and judicious use of Ommaya reservoirs. Furthermore, the study highlights the potential benefits of promptly identifying vasospasm and administering spasmolysis, as this approach may decrease the likelihood of shunt dependency. These insights provide healthcare professionals with valuable guidance in optimizing care for patients dealing with this intricate condition, with the goal of enhancing their overall quality of life and treatment outcomes. Nevertheless, further research through prospective studies and

Disclosure Statement:

1. Funding: No funding available
2. Conflicts of interest/Competing interests: There are no conflict of interest among authors and all authors have agreed to the submission and publication of the research paper.
3. Availability of data and material: Data will be made available only upon request from corresponding author
4. Code availability: No specified code used
5. Ethics approval: the authors disclose that this research has been conducted in compliance with all applicable ethical standards and guidelines. Ethical approval was obtained from the institutional ethical committee (Approval No. IEC/2022/278) to conduct this study.
6. Consent to participate: Written informed consent was obtained from the patient to participate and use their medical records for research and academic purpose.
7. Consent for publication: Written informed consent was taken to publish this manuscript and any accompanying images.

AUTHORSHIP CONTRIBUTION

Study conception and design: VCJ, RJ, VVS

Data collection: RJ, VSS, NK

Analysis and interpretation of results: VCJ, RJ, VVS

Draft manuscript preparation: VCJ, RJ, VVS

Critical revision of the article: VCJ, RJ, VVS

Other (study supervision, fundings, materials, etc...): VCJ, VVS, NK.

All authors (VCJ, RJ, VVS) reviewed the results and approved the final version of the manuscript.

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