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Intraventricular Hematoma Removal with Combined Drainage Techniques in Patients with High-Grade Subarachnoid Hemorrhage: A Surgical Technique

Eyup BAYATLI, Ihsan DOGAN, Onur OZGURAL, Umit EROGLU, Bilal ABBASOGLU, Melih BOZKURT

Ankara University School of Medicine, Department of Neurosurgery, Ankara, Turkey

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Corresponding author: Melih BOZKURT ✉ melihbozkurt@hotmail.com

ABSTRACT

AIM: To describe a surgical technique for removal of hematomas in the third ventricle in patients with high-grade aneurysmal subarachnoid hemorrhage (SAH) and report our intraoperative observations and surgical and clinical outcomes.

MATERIAL and METHODS: Ninety-four patients with high-grade aneurysmal subarachnoid hemorrhagic were included in the study. Prior to Sylvian dissection, a ventricular catheter was inserted as soon as possible. After surgical corridor opening and aneurysm clipping, the lamina terminalis (LT) was fenestrated. The free flow of isotonic solution from the back-side open syringe to the distal end of the catheter inside the third ventricle was allowed under gravitational force. The blood clot trapped in the third ventricle was removed through the aperture of the LT by propulsion of blood through the anterior movement of the solution. The procedure was continued until the clearance of solution was observed.

RESULTS: The study population consisted of two groups, the combined surgical technique group and the control group, which included patients who underwent operation before the planned study, with 47 patients in each group. The Glasgow Coma, Hunt and Hess, and Fisher scales were used to determine the clinical and radiological severities of the cases. The Modified Rankin Scale was used to evaluate the surgical outcomes at presentation and the 6th and 12th postoperative months.

CONCLUSION: Our reported surgical technique, which combines ventricular drainage and opening of the LT, will be useful for removing blood clots and blood breakdown products, and recirculating cerebrospinal fluid as much and as soon as possible in high-grade SAH patients with ventricular hemorrhage. Although combining these two well-known procedures as a novel technique does not have any reducing effect on mortality, it may have a significant reducing effect on hydrocephalus and shunt dependency.

KEYWORDS: Intraventricular haematoma, Drainage, Fenestration, Lamina terminalis, Aneurysmal subarachnoid haemorrhage

ABBREVIATIONS: AcomA: Anterior communicating artery, **aSAH:** Aneurysmal subarachnoid haemorrhage, **CSF:** Cerebrospinal fluid, **CT:** Computed tomography, **CVH:** Cerebrovascular haemorrhage, **EVD:** External ventricular drain, **GCS:** Glasgow coma scale, **GS:** Graeb score, **HH:** Hunt and hess scale, **IVH:** Intraventricular haematoma, **LT:** Lamina terminalis, **mRS:** Modified rankin scale, **VSP:** Cerebral vasospasm

Eyup BAYATLI : 0000-0001-6246-4247
Ihsan DOGAN : 0000-0002-1985-719X
Onur OZGURAL : 0000-0003-0592-6139
Umit EROGLU : 0000-0001-8623-071X
Bilal ABBASOGLU : 0000-0002-9083-4038
Melih BOZKURT : 0000-0001-7433-081X

INTRODUCTION

Cerebrovascular hemorrhage (CVH) is a common neurosurgical pathology that can lead to various neurological manifestations, with a wide range of clinical severity (7,18). CVH may cause life-threatening conditions in the acute phase by creating a mass effect and causing long-term complications. These complications may also reduce patient quality of life and lead to patient disability. Aneurysmal subarachnoid hemorrhage (aSAH) has a complex pathophysiology and is a peculiar subtype of CVH in terms of etiology, area of influence, and acute-chronic outcome.

Intracranial hemorrhages extending into the ventricles or pure intraventricular hematomas (IVHs) complicate the progress of cases, regardless of the primary cause. Management of ventricular hematomas and the associated complications of aSAH becomes as important as aneurysm clipping itself. The mass effects of blood clot, obstructive hydrocephalus, and toxicity of blood breakdown products and the development of chronic hydrocephalus are the main issues in the management of SAH (13). In cases of IVH, complete hematoma removal within the shortest amount of time is suggested (4).

In this report, we describe a novel technique that combines two well-known traditional techniques for evacuating IVHs, removing intraventricular clots, and clearing the ventricular passage. We discuss the intraoperative observations and surgical and clinical outcomes of 47 patients with high-grade aSAH.

MATERIAL and METHODS

The medical records of patients who were admitted to the Ankara University School of Medicine, Department of Neurosurgery between 2015 and 2020 and subsequently diagnosed as having aSAH were reviewed. Patients with available follow-up data who had intraventricular extension of hemorrhage due to aSAH and had undergone operation with the combined technique were included. In addition, patients who had an intraventricular extension of hemorrhage due to aSAH and underwent operation before the planned study were randomly selected as a control group. Informed consent was obtained from the patients' first-degree relatives prior to the procedures. The study was approved by our institutional review board (Approval No. I6-313-20).

The Glasgow Coma Scale (GCS), Hunt and Hess (HH) Scale, and Fisher Scale were used to determine the clinical and radiological severities of the cases. The Modified Rankin Scale (mRS) was used to evaluate the surgical outcomes at presentation and the 6th and 12th postoperative months (46).

The independent-samples *T* test and chi-square test were used determine whether any statistical relationships exist between age, the surgical technique used, and survival. Regarding the scoring systems, the Mann–Whitney *U* test and Spearman correlation analysis were used to evaluate the differences. The IBM SPSS Statistics 20 software was used for the statistical analysis. $P<0.05$ were considered indicative of statistical significance.

Surgical Technique

Right-sided placement of an external ventricular drain (EVD) was preferred when possible through Kocher's point prior to craniotomy to manage increased intracranial pressure and acute hydrocephalus. In cases of a slit ventricle or acute deterioration in consciousness, the cerebrospinal fluid (CSF) drainage was postponed to decompress the brain by craniotomy as soon as possible. In appropriate cases, an EVD catheter was inserted through Paine's point after craniotomy and prior to Sylvian dissection (38).

Opening of the Lamina Terminalis (LT)

After EVD placement, in regard to aneurysm localization, both the proximal and distal segments of the Sylvian cistern were widely opened with a sharp dissection, exposing the M2 middle cerebral artery bifurcation, M1 internal carotid artery (ICA) bifurcation, and A1 and anterior communicating artery (AComA). As previously described by Yasargil, the LT is exposed by following the A1 throughout the AComA and the intersection of the A1 with the optic nerve. This should be considered an important landmark, and care must be taken with the optic perforating branches of both A1 and ICA during dissection (Figure 1A). Fenestration of the LT was performed with an arachnoid knife or number 11 blade (Figure 1B). After the initial CSF drainage through the LT, the clot in the third ventricle was removed using small tissue forceps (Figure 1C, D). Next, the second surgeon manually delivered the isotonic solution continuously through the ventriculostomy catheter (Figure 1E). Ventricular clots were removed from the fenestrated LT until the isotonic solution became transparent (Figure 1F).

LT fenestration is usually postponed till aneurysm clipping to prevent blood passage into the ventricular system through the fenestrated LT in case of intraoperative rupture. In addition, ventricular catheter placement and further fenestration of the LT facilitate CSF circulation and enable brain relaxation. This strategy has the advantage of preventing reflux of blood into the ventricles if premature aneurysmal rupture occurs during surgery. These surgical steps are also summarized and illustrated step-by-step in Figure 2 to provide better understanding of our surgical technique and the main mechanism of this procedure.

RESULTS

Patients' Characteristics

A total of 94 patients with aSAH extending into the lateral and third ventricles were included in this study. The study population consisted of two groups, the combined surgical technique group and the control group, which consisted of patients who underwent operation before the planned study, with 47 patients in each group. The primary and control groups consisted of 23 (48.9%) and 20 females (42.6%), and 24 (51.1%) and 27 (57.4%) males, respectively. The mean ages of the patients in the primary and control groups were 56.6 and 57.6 years, respectively. No significant difference was observed regarding patient age ($p>0.05$). The main characteristics of the study population are shown in Table I.

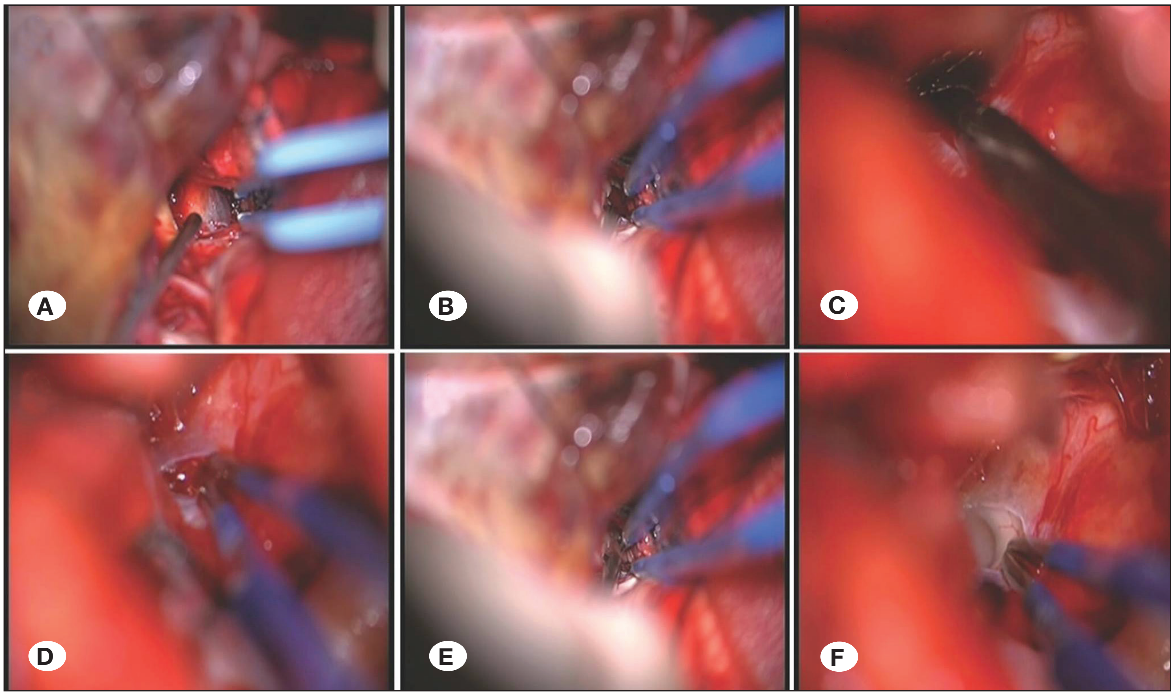

Figure 1: A) Exposure of the lamina terminalis (LT). **B)** Fenestration of the LT. **C, D)** Removal of clot from the third ventricle using small tissue forceps; **E:** Continuous delivery of isotonic solution through the ventriculostomy catheter. **F)** Removal of ventricular clots through the fenestrated LT until the isotonic solution becomes transparent.

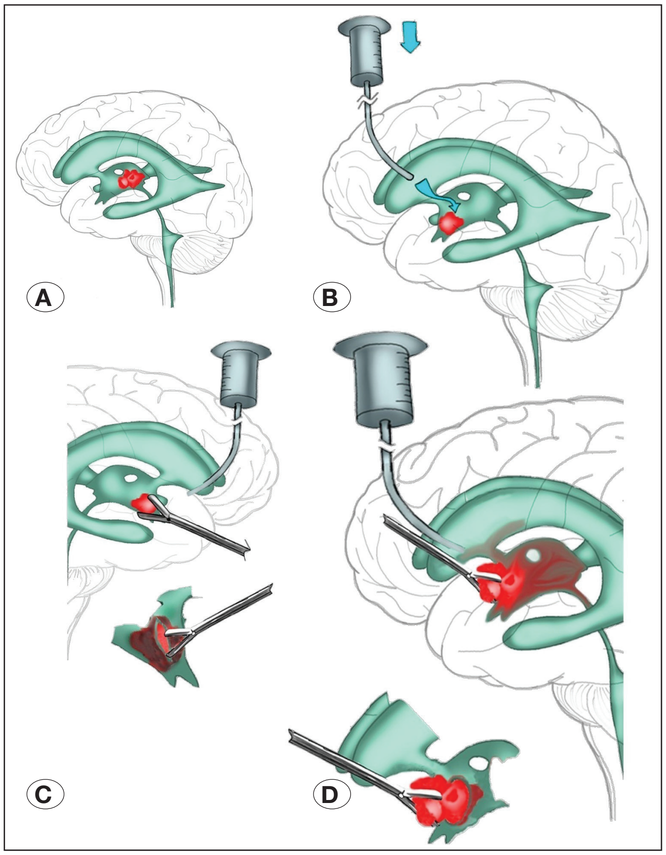

Figure 2: Surgical steps of clot removal from the third ventricle step-by-step.

The patients presented with primary complaints of severe headache and sudden deterioration in consciousness. Routine radiological imaging included cranial computed tomography (CT) and CT angiography. The maximal diameters of the aneurysms were 6.81 and 7.16 mm in the primary and control groups, respectively, with no significant difference ($p>0.05$; Table I). The distribution of the detected bleeding aneurysms is shown in Table II. Hypertension (34%), arteriosclerotic coronary disease (10.6%), diabetes mellitus (2.1%), and chronic obstructive pulmonary disease (4.2%) were the primary accompanying comorbidities.

Operative Experience and Outcome

All the patients underwent operation as soon as possible, and ventricular clearance and passage were achieved in all 47 patients by using the described combined techniques. Routine CT imaging was performed immediately after surgery and on the first postoperative week. Unfortunately, owing to the lack of some radiological data and technical issues, radiological comparison could not be performed. An EVD was placed initially during the operation in all the patients with a non-slit ventricle (12; 25.53%) and was removed on the 10th postoperative day. The time from bleeding ($p<0.01$) and presentation ($p<0.05$) to surgery was significantly longer in the primary group than in the control group (Table I).

Permanent preoperative hydrocephalus was detected in 19 (40.43%) and 8 patients (17%), and ventriculoperitoneal shunt placement was required in only one (2.13%) and 5 patients (10.6%) in the primary and control groups, respectively. Twenty (42.6%) and 19 patients (40.4%) died during hospitalization

Table I: Main Characteristics of Study Population

	Control Group Mean± SD (Min-Max)	Primary Group Mean± SD (Min-Max)	p
Age	57.64 ± 12.73 (31-90)	56.55 ± 15.01 (22-89)	0.706[a]
Maximal Diameter of Aneurysm (mm)	7.16 ± 3.40 (3-16)	6.81 ± 3.77 (2-18)	0.288[b]
Bleeding-Surgery Time (hours)	27.70 ± 70.61 (1-480)	49.11 ± 69.82 (8-360)	**0.002[b]**
Presentation-Surgery Time (hours)	18.53 ± 71.02 (1-480)	25.87 ± 54.03 (1-192)	**0.047[b]**
Hunt & Hess Score	2.51 ± 0.95 (1-5)	2.74 ± 1.13 (1-5)	0.429[b]
Fisher Score	3.28 ± 0.85 (2-4)	3.21 ± 0.93 (1-4)	0.807[b]
GCS Score	12.89 ± 3.04 (3-15)	11.19 ± 4.41 (3-15)	0.453[b]
Presentation mRS Score	2.79 ± 1.37 (1-5)	3.38 ± 1.41 (1-5)	**0.044[b]**
6. month mRS Score	3.34 ± 3.25 (0-6)	3.38 ± 2.45 (0-6)	0.902[b]
12. month mRS Score	0.66 ± 0.74 (0-3)	1.50 ± 1.59 (0-6)	**0.031[b]**

***a**: Independent Samples t Test,* ***b**: Mann Whitney U Test*
***GCS:** Glasgow coma scale, **mRS:** Modified rankin scale, **SD:** Standard deviation.*

Table II: Distribution of Aneurysms in Location

	Primary Group n (%)	Control Group n (%)
AComA	20 (42.5)	16 (34)
Right		
ICA	3 (6.38)	4 (8.5)
MCA	8 (17)	12 (25.5)
ACA	2 (4.25)	3 (6.4)
dACA	1 (2.13)	1 (2.13)
Left		
ICA	2 (4.25)	1 (2.13)
MCA	6 (12.76)	4 (8.5)
ACA	0	2 (4.26)
dACA	2 (4.25)	0
Basillar Tip	2 (4.25)	1 (2.13)
Posterior Circulation	1 (2.13)	3 (6.4)

***AComA:** Anterior communicating artery, **ICA:** Internal carotid artery, **MCA:** Middle cerebral artery, **ACA:** Anterior cerebral artery, **dACA:** Distal anterior cerebral artery.*

in the primary and control groups, respectively. The mean hospitalization durations for the rest of the patients were 10.5 ± 4.3 and 14.3 ± 7.9 days in the primary and control groups, respectively. No significant difference was observed between the groups regarding survival (p=0.903). The mean follow-up duration for the survivors was 11 ± 5.9 and 43 ± 16.6 months in the primary and control groups, respectively.

Both study groups were evaluated using the HH Scale (p=0.429), Fisher Scale (p=0.807), GCS (p=0.453), and mRS scores. No statistically significant differences were found between the scores except for the mRS scores. The mRS score was significantly higher in the primary study group at the first presentation (p=0.044) but not at the sixth postoperative month (p=0.902), but that at the 12th month (p=0.031) was slightly but significantly higher than that in the control group. In the related group, a positive linear correlation was observed between presentation and the 12th month scores, which may explain the difference (p<0.05).

Case Sample

A 62-year-old man was admitted to the emergency department with complaints of nausea, vomiting, and deteriorated consciousness. His GCS score was 5 but decreased to 3 soon after admission. Parenchymal, IVH, and diffuse SAH were observed on cranial CT imaging (Figure 3A). A ruptured AComA aneurysm was detected, and the surgery was started

80 min after admission. Intraoperatively, the AComA was clipped, and ventricular blood clot removal using the combined technique was preferred. In addition, the parenchymal hematoma was evacuated. Postoperatively, the patient was followed up in the intensive care unit under sedation, which was stopped after 24 h. His GCS score increased to 11 at 72 h after operation. Cranial CT images of the patient obtained in the early postoperative period (Figure 3B) and 4 years after operation (Figure 3C) are shown in Figure 3. His Graeb scores were 10 and 3 in the preoperative and postoperative periods, respectively (14).

DISCUSSION

CVH is a common health issue with a heavy socioeconomic burden. Aggressive surgical approach for such cases is still the cornerstone of management (36). Many risk factors such as increased age, female sex, high HH and Fisher scores, low GCS scores, acute hydrocephalus, IVH, and vasospasm were studied as outcome predictors (48). Ota et al. reported that factors such absence of CSF density around the ambient cistern and high-convexity cortical sulci in radiographic findings that indicate high intracranial pressure are related to poor-grade SAH (32). Almost half of all ICH cases and 25% of aSAH cases extend to the ventricles (9,10,33). IVH is known to potentially double the risk of poor outcomes (16,32). Moreover, low GCS scores were suggested to be relatively persistent due to the large volume of blood in the ventricles (27,33,41).

Animal studies showed that blood clot removal prevents tissue inflammation and improves consciousness levels in patients (18). Early surgical intervention comprised of decompressive evacuation of the hematoma and cisternal clot removal was suggested to stabilize intracranial pressure and prevent irreversible brain injury (27,32). For clot removal in patients with IVH, a range of 10% to 15% of the potential benefit was reported (17,43). Available data support the hypothesis that the mass effects of blood clot and the toxicity of the blood breakdown products determine the outcome (13,36). Accordingly, ventricular blood and clot removal might be considered a cornerstone goal of such surgery.

Hydrocephalus is a well-known complication of aSAH. The most important factor contributing to the pathogenesis of hydrocephalus after aSAH is reported to be altered CSF circulation due to subarachnoid and cisternal hematomas (15,38). In cases with high-grade SAH, hydrocephalus was reported to be the major cause of coma rather than the severity of the primary brain injury, and CSF drainage may provide a prognosis similar to that of lower-grade SAH (2). Morbidity and mortality rates are relatively higher in aSAH patients with hydrocephalus than in those without hydrocephalus (10). The reported incidence of hydrocephalus after surgical intervention for aSAH ranges from 6% to 67% (5,47).

Xie et al. reported AComA and postcirculation aneurysms as risk factors of shunt-dependent hydrocephalus (48). They explained that such issue is due to the close location of AComA aneurysms to the third ventricle and that clots from a ruptured aneurysm can block the CSF circulation. Moreover, a meta-analysis reported a higher risk of shunt dependency after coiling than after clipping (8,48). Mechanical, ischemic, and metabolic events are the primary mechanisms that may be involved in brain damage due to dilated ventricles (9,11). Hydrocephalus severity seems to be related to CSF exposure to blood clots and high IVH volume (1,49). However, high failure rates of 43% at 1 year and 85% at 10 years have been reported with shunt placement for hydrocephalus after aSAH (6,45).

Ventriculostomy is accepted as a useful technique despite the increased risk of aneurysmal rebleeding, infection, and shunt dependency (19,21,29,34). Early EVD placement before any intervention toward the aneurysm is known to improve the level of consciousness, clinical grade, and outcome (35,37). Our combined surgical technique may aid in limiting the effects of blood clot and toxicity of blood breakdown products as early as possible. In addition, as reported previously for placing a catheter through the LT (28), combining the techniques in one procedure seems to be safer for cases of angry and swollen brain and may prevent large frontotemporal contusions. EVD is supposed to be a life-saving procedure in cases of severe IVH, but the potential for catheter obstruction via blood clot or infection may worsen the outcome (39). Basaldella et al. reported reduced frequency of subsequent shunt surgery using flexible neuroendoscopic aspiration plus external drainage, but outcomes were not significantly better (4). Neuroendoscopic maneuvers for performing lavage may cause rebleeding or tissue damage due to endoscope rigidness (31). Our suggested combination of the two techniques in one procedure may prevent long-term use of EVD and may provide direct visualization of the created passage.

LT fenestration has been suggested to provide better outcomes after ruptured intracranial aneurysms (40,44). Yasargil et al. recommended LT fenestration in the case of basal cistern blockage by hematomas (49). Fox and Sengupta also suggested fenestration for the treatment of acute hydrocephalus and prevention of the development of chronic hydrocephalus (12). Moreover, a decrease in shunting rate from 12.6% to 2.3% in patients who did and did not undergo LT fenestration had been previously presented (28,40). In addition, a decreased vasospasm severity was reported after LT fenestration (22,26,30,40). Tomasello et al. reported improved clinical outcome in patients who underwent LT fenestration during surgery (44). In cases of SAH due to aneurysm, Hernesniemi stressed that a slack brain is as important as clipping itself and reported the achievement of this goal by removing CSF by opening the LT and/or basal cisterns, particularly the Liliequist membrane, or by puncturing the lateral ventricles (20,42). However, in our study, slight but higher mRS scores in the 12th postoperative month in the primary group was considered statistically related to the higher presentation scores in the same group. This may reflect that such population with poorer status at presentation may experience more chronic problems and morbidity. Larger and homogeneous studies might eliminate such possible confusion.

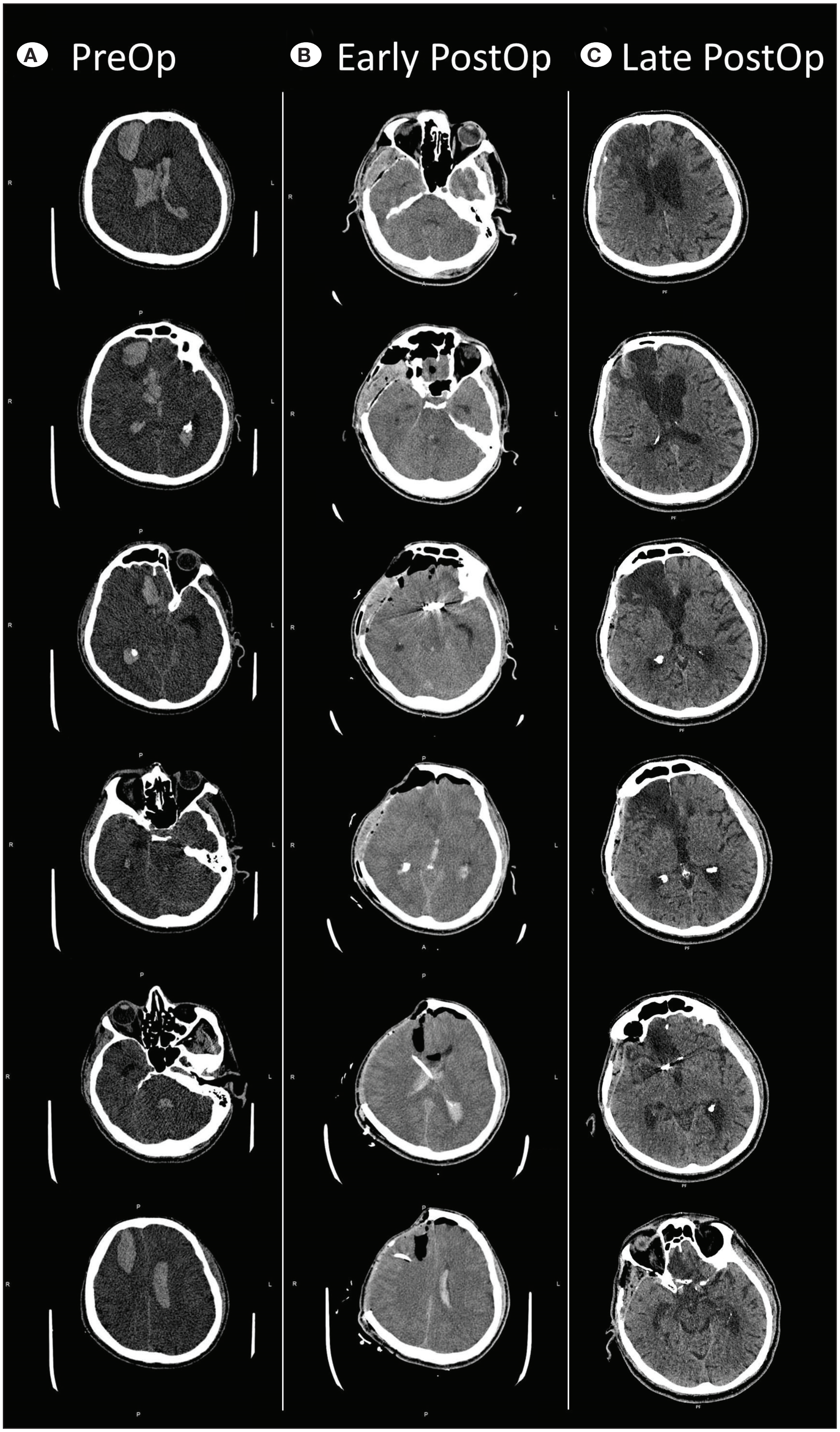

Figure 3: Axial brain computed tomography (CT) images of the present case. **A)** Parenchymal and intraventricular hematomas and diffuse SAH on a cranial CT image. **B)** Early postoperative and **C)** late postoperative (4 years) cranial CT images.

More than 60% of patients with aSAH were reported to develop cerebral vasospasm (VSP) (5,25). Although controversial, circulating heme products have been blamed for the development of VSP (24). Kiphuth et al. reported a higher incidence of VSP in patients with large intraventricular blood volume than in those with only small amounts of IVH (23). In their series of 106 patients with Fisher grade 3 aSAH, Andaluz et al. reported that 29.6% and 54.7% of clinically evident vasospasms occurred in patients who did and did not undergo LT fenestration, respectively (3). Although controlled and randomized studies are necessary, our reported data support the use of the combined technique for such therapeutic goals.

Study Limitations

Lack of data regarding the volume of the ventricular hematoma, which is known to be a major contributor to the prognosis of patients with aSAH, is one of the limitations of our study. Therefore, detailed prospective radiological comparison using the Graeb scoring system or other similar scoring systems might be useful. The coexistence of all determinants that prevented hydrocephalus in each patient, vasospasm, and clearance of blood from the ventricular system are other aspects of this study that may be controversial. Randomized controlled trials are needed to confirm the effectiveness of the reported surgical technique.

CONCLUSION

Use of transcortically placed ventricular drainage to provide brain relaxation and achieve effective and safe Sylvian dissection is preferable as an initial step in patients with angry and swollen brain. In addition, combining this procedure with opening of the LT in patients with high-grade SAH who have ventricular hemorrhage will be useful for removal of blood clots and blood breakdown products, recirculating CSF as much and as soon as possible. Although combining these two well-known procedures as a novel procedure does not have any reducing effect on mortality, it may have significant reducing effects on hydrocephalus and shunt dependency.

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AUTHORSHIP CONTRIBUTION

Study conception and design: EB, ID, OO, UE, BA, MB

Data collection: EB, BA

Analysis and interpretation of results: EB, ID, OO, UE, MB

Draft manuscript preparation: EB, ID, OO, UE, BA, MB

Critical revision of the article: EB, ID, MB

Other (study supervision, fundings, materials, etc...): EB, ID, MB

All authors (EB, ID, OO, UE, BA, MB) reviewed the results and approved the final version of the manuscript.

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