

Risk Factors of Delayed Intracranial Hemorrhage Following Ventriculoperitoneal Shunt

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Objective: Placement of a ventriculoperitoneal (VP) shunt is a common neurosurgical procedure for cerebrospinal fluid diversion. A rare complication is delayed intracranial hemorrhage (ICH) secondary to VP shunting, and only a few patients with this complication have been reported. We investigate the incidence and risk factors of delayed ICH development following VP shunt placement.

Methods: Over an 11-year period, 167 patients received a VP shunt for hydrocephalus, and of these, 138 patients were eligible for this study. All medical records and computed tomography scans obtained within 48 h after the operation and at post-operative day 7 were reviewed. The risk factors of developing delayed ICH (≥ 48 hr after VP shunt placement) were analyzed according to the demographic data, including sex and age, original intracranial lesions, co-morbid diseases, and laboratory findings.

Results: Delayed ICH following VP shunt placement developed in 34 (24.6%) of the 138 patients. Risk factors for developing delayed ICH were age ($p=0.037$) and the partial thromboplastin time (PTT) ($p=0.032$). Intraventricular hemorrhage after VP shunting was the most common complication, occurring in 16 cases. Hemorrhagic volume was < 1 mL in 28 cases and > 1 mL in 6 cases.

Conclusion: This study suggests that old age and delayed PTT are major risk factors for developing delayed ICH following VP shunting. Additionally, delayed ICH after VP shunting commonly occurs even when most patients are asymptomatic. Therefore, extra care should be taken to observe and follow-up with patients who have undergone VP shunt placement.

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KEY WORDS: Hydrocephalus · Intracranial hemorrhage · Risk factor · Ventriculoperitoneal shunt.

Introduction

Hydrocephalus is a common condition accounting for 69,000 hospital discharges each year in the United States.³⁾ Cerebrospinal fluid (CSF) shunt procedures have dramatically reduced the morbidity and mortality of hydrocephalus.

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Among CSF diversion techniques, the ventriculoperitoneal (VP) shunt is the routine, first choice, due to easy placement and functional reliability as compared to the other alternatives. However, there are potential complications that may require multiple surgical procedures during the lifetime of a patient. Postoperative complications after VP shunt placement include shunt obstruction, subdural hematoma, infection, seizures, catheter migration, and shunt malfunction.^{2,6)}

Among these complications, delayed intraparenchymal hemorrhage (IPH) or intraventricular hemorrhage (IVH) secondary to VP shunt placement is not common. Although the mechanism of delayed intracranial hemorrhage (ICH) after VP shunt has been reported, the risk factors for the development of delayed ICH are still not understood. Therefore, we evaluate the risk factors and incidence of delayed ICH

following VP shunt with a review of the relevant literature.

Materials and Methods

Patient population

Clinical data were investigated in patients who underwent VP Shunt between March 2003 and December 2013. Initially, 167 patients were identified as having a VP shunt using a Codman Hakim programmable valve (Codman, Johnson & Johnson, Raynham, MA, USA). Twenty-nine patients were excluded from this study because they had not undergone brain computed tomography (CT) scanning within 48 hours after operation and within postoperative 7 days, and early hemorrhage developed within 48 hours after VP shunt.

The inclusion criteria were as follows: 1) VP shunt was performed in our single center; 2) Post-operation brain CT scanning was done within 48 hours after operation; 3) Follow-up brain CT scan was done within postoperative 7 days. The exclusion criteria were as follows: 1) VP shunt in another institution; 2) a revision of the VP shunt; 3) less than 15 years old. The patients were categorized into two groups according to delayed ICH. We defined delayed ICH as subsequent occurrence of ICH which was not seen in CT scans within post-operative 48 hours.

Brain CT scans

Non-enhanced brain CT scans were obtained using a standard technique with thickness of 4.5 mm supratentorial slices. Brain CT scans were obtained immediately after operation, within 48 hours after VP shunt, and postoperative day 7. ICH was defined as hyperdense lesion in the cerebral parenchyme, ventricle, or along the catheter track. When neurologic deficits or any symptomatic change of mentation were developed in patients, brain CT scans were performed immediately. Delayed ICH associated with a VP shunt was classified according to the volume of the hematoma: 1) <1 mL; 2) 1 to 15 mL; 3) ≥15 mL. The volumetric measurement of hematoma was calculated by ellipsoid method ($a \times b \times c/2$) in CT images.¹¹⁾

Data collection

All medical records including emergency department records, admission notes, progress notes, outpatient notes, and serial brain CT scans were reviewed in all patients. The following baseline patient characteristics were collected: demographic data including sex and age; predisposing intracranial lesions including trauma, brain tumor, spontaneous intracerebral hemorrhage, normal hydrocephalus, ischemic

cerebral infarction and subarachnoid hemorrhage (SAH), co-morbid conditions including hypertension (HT), diabetes mellitus (DM), laboratory assessment including international normalized ratio (INR), partial thromboplastin time (PTT), platelet counts, and blood glucose level.

Statistical analysis

SPSS version 18.0 (SPSS Inc., Chicago, IL, USA) was used to analyze all data. Pearson's χ^2 test, Fisher's exact test, and the Student's *t*-test were used depending on the characteristics of the variables being compared. Statistical significance was accepted for *p* values of <0.05.

Results

Patient characteristics

ICH following VP shunt was detected on CT scan in 40 (27.9%) of the 143 patients. The early ICH (within 48 hours after VP shunt) were 6 (4.2%) and delayed ICH were 34 (23.7%) among 143 patients. Therefore, a total 138 patients were involved in this study, excluding 6 patients who developed early hemorrhage (Table 1). The mean age of the 138 patients was 58.9 ± 14.0 years (range, 17–88 years), and 83 (60.1%) patients were male. Original intracranial lesions were aneurysmal SAH in 36 (26.1%), trauma in 30 (21.7%), ICH in 31 (22.5%), normal pressure hydrocephalus (NPH) in 24 (17.4%), cerebral infarction in 9 (6.5%), and brain tumor in 8 (5.8%) patients. Regarding co-morbid diseases, 70

TABLE 1. Clinical summary of patient data

Variables	n (%)
Mean age (years)	58.9 ± 14.0
Male:Female	83:55
Comorbid disease	
Hypertension	70 (50.7%)
Diabetes	23 (16.7%)
Primary intracranial lesions	
SAH (aneurysm rupture)	36 (26.1%)
Trauma	30 (21.7%)
ICH	31 (22.5%)
NPH	24 (17.4%)
Infarction	9 (6.5%)
Tumor	8 (5.8%)
Mean INR	0.67 ± 0.15
Mean PTT (seconds)	22.8 ± 6.9
Mean platelet counts ($\times 10^3/\mu\text{L}$)	162 ± 94
Mean blood glucose level (mg/dL)	87 ± 49

SAH: subarachnoid hemorrhage, ICH: intracranial hemorrhage, NPH: normal pressure hydrocephalus, INR: international normalized ratio, PTT: partial thromboplastin time

patients had HT and 23 patients had DM. In laboratory assessment, the mean INR was 0.67 ± 0.15 , mean PTT was 22.8 ± 6.9 seconds, mean platelet count was $162 \pm 94 \times 10^3/\mu\text{L}$, and mean glucose level was 87 ± 49 mg/dL.

IVH and hemorrhage along the track were the most common, and were present in 16 (47.1%) and 8 (23.5%) patients, respectively. Five patients (14.7%) had IPH, 2 patients (5.9%) had concomitant IPH with IVH and two had IVH with hemorrhage along the track, and 1 patient (2.9%) had IPH and hemorrhage along the track (Table 2).

Risk factors

No statistically significance was found for sex ratio, co-morbid diseases (HT, DM), or preferred intracranial lesions

TABLE 2. Characteristics of the delayed intracerebral hemorrhage after ventriculoperitoneal shunt

Variables	Number (%)
Early vs. delayed	
Early	6 (4.3%)
Delayed	34 (24.6%)
Types of hemorrhage	
IVH	16 (47.1%)
Tract hemorrhage	8 (23.5%)
Remote IPH	5 (14.7%)
Remote IPH+IVH	2 (5.9%)
Remote IPH+tract hemorrhage	1 (2.9%)
IVH+tract hemorrhage	2 (5.9%)
Volume of hematoma	
<1 mL	28 (82.4%)
1–15 mL	5 (14.7%)
≥15 mL	1 (2.9%)
Complications after shunt	
ICH	34
Subdural hygroma	18
Subdural hemorrhage	4

IPH: intraparenchymal hemorrhage, IVH: intraventricular hemorrhage, ICH: intracranial hemorrhage

(SAH, trauma, ICH, NPH), INR, or the platelet count in delayed hemorrhage after VP shunt (Pearson's χ^2 test) (Table 3). Previous co-morbid disease like cerebral infarction and tumor history did not have significant correlation in delayed ICH after VP shunt (Fisher's exact test). Although mean INR, blood glucose level tended to be greater in the delayed ICH group, it was not statistically significant ($p=0.460$ and $p=0.958$, Student's *t*-test). However, the old age and the prolonged PTT were found to be significantly associated with developing delayed ICH ($p=0.037$ and $p=0.032$,

TABLE 3. Comparison of risk factors for the delayed intracerebral hemorrhage after ventriculoperitoneal shunt

Variables	Delayed hemorrhage		p-value
	(+)	(-)	
Age (years)	62.9 ± 11.4	58.0 ± 14.5	0.037*
Sex (Male:Female)	20:14	63:41	0.841
Comorbid disease			
Hypertension	18	52	0.844
Diabetes	4	19	0.440
Primary intracranial lesion			
SAH (aneurysm rupture)	8	28	0.823
Trauma	10	20	0.235
ICH	4	27	0.101
NPH	5	19	0.102
Infarction	4	5	0.489
Tumor	3	5	0.407
INR	0.70 ± 0.12	0.67 ± 0.18	0.460
PTT (seconds)	25.3 ± 9.0	23.1 ± 7.4	0.032*
PLT ($\times 10^3/\mu\text{L}$)	150 ± 95	164 ± 94	0.344
Glucose level (mg/dL)	90.5 ± 58.3	88.7 ± 49.0	0.958

*Statistical significance was accepted for p-values of <0.05 (Student's *t*-test). SAH: subarachnoid hemorrhage, ICH: intracranial hemorrhage, NPH: normal pressure hydrocephalus, INR: international normalized ratio, PTT: partial thromboplastin time, PLT: platelet

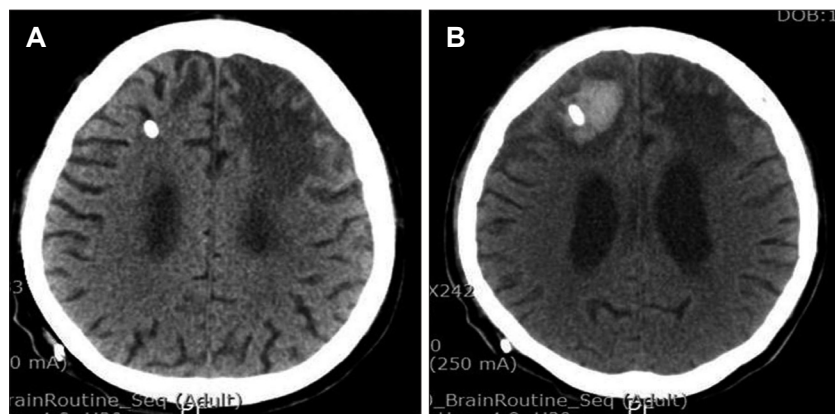


FIGURE 1. Illustration of case 1. (A) Intracranial hemorrhage (ICH) was not developed on the postoperative day 1 after ventriculoperitoneal shunt. (B) Delayed ICH along the path of the catheter was developed on the postoperative day 7.

Student's *t*-test).

Illustrative cases

Case 1

A 57-year-old woman presented with declined mentation and difficulty voiding. Initial brain CT scans revealed that ventricular size was enlarged, and communicating hydrocephalus was confirmed with radioisotope cisternography. She was suffering from cerebral infarction, but there were no co-morbid disease. In laboratory examination, INR/PTT, and platelet counts were within normal range, but the blood glucose level was slightly increased on 131 mg/dL. VP shunt was performed and ICH did not occur postoperatively 1 day after VP shunt (Figure 1A). However, delayed ICH along the path of the catheter developed on postoperative day 7 (Figure 1B). Fortunately, ICH did not increase, nor did neurologic deficits develop. As a result, ICH was treated conservatively.

Case 2

A 56-year-old man presented with voiding difficulty and gait disturbance. He had a history of burr hole trephination for chronic subdural hemorrhage. INR and PTT were with-

in normal ranges, but the platelet counts were decreased to $109 \times 10^3/\mu\text{L}$. A VP shunt was performed and no hemorrhage occurred postoperative a day after VP shunt (Figure 2A). But the delayed IVH developed on postoperative day 3 (Figure 2B). No intraparenchymal hemorrhage was seen along the path of the catheter on postoperative day 3 (Figure 2C). In addition, the other hemorrhage in catheter path occurred on postoperative day 7 (Figure 2D).

Discussion

VP shunt is one of common procedure for neurosurgeons to control the communicating hydrocephalus.^{2,4)} As is well-known, complications after insertion of a CSF shunt, such as infection, obstruction, subdural hematoma, malfunction, seizures, migrating or kinked catheter; obstruction or blockage of the ventricular and abdominal ends of the catheter, and infection of the shunt apparatus are the major problems of CSF shunting procedures.^{19,25)} In this study, radiological complications of VP shunt developed ICH in 34 patients, hygroma in 18 patients, and subdural hematoma in 4 patients.

IPH or IVH secondary to VP shunt placement is not common. Savitz and Bobroff⁽¹⁸⁾ reported that the incidence of

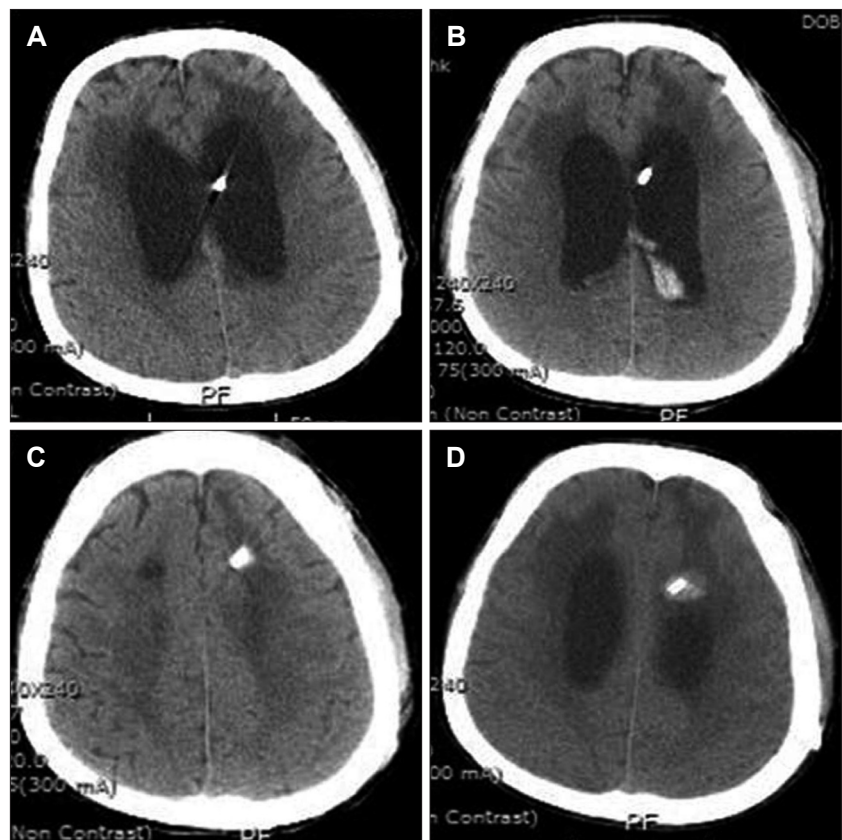


FIGURE 2. Illustration of case 2. (A) Intracranial hemorrhage (ICH) was not developed on the postoperative day 1 after ventriculoperitoneal shunt. (B) Delayed intraventricular hemorrhage was developed on the postoperative day 3. (C) No intraparenchymal hemorrhage was seen in along the path of the catheter. (D) Another ICH was developed on the postoperative day 7.

delayed ICH was 4% following VP shunt. Fukamachi et al.⁸⁾ performed CT scans on 242 patients within the first week of ventricular shunting procedures and found that ten of them had small ICH (3 cm in the maximal diameter). Postoperative IPH or IVH usually develops at the timing of ventricular puncture.⁸⁾ Sayers¹⁹⁾ reported six cases with ICH among 1,390 cases with VP shunt. The CT findings of IVH with small amounts were observed in 10% of the cases in the Palmieri's series;¹⁶⁾ less frequently, small pools of blood were noted under the ependyma next to the catheter tip or along its path in the parenchyma.¹²⁾ ICH has been reported in 0.4% to 4% of patients undergoing shunt procedures.^{4,25)} In this study, delayed ICH of less than 1 mL was observed in 20% patients with VP shunt. Only 6 (4%) patients showed the delayed ICH with more than 1 mL. This is comparable to the incidence of delayed ICH of Savitz and Bobroff's report.¹⁸⁾ However, the overall incidence of delayed ICH was 24%, which is a higher incidence than other studies. The reason may be that it included a small ICH with less than 1 mL.

Several mechanisms leading to ICH after insertion of the shunt catheter have been proposed: 1) co-existence of coagulopathy; 2) shunt-induced disseminated intravascular coagulation (DIC); 3) mechanical disruption of intravascular vessel by catheter; 4) hemorrhage into intraparenchymal tumor; 5) hemorrhage from an occult intravascular malformation; and 6) head trauma occurring shortly after VP shunt placement.²²⁾ DIC has been reported after head trauma, brain tumor surgery, or VP shunting.^{8,10,13,20)} Bleeding along the path of the ventricular catheter and into the ventricular system has been reported previously following VP shunt placement; it may be caused by puncture of the choroid plexus, repeated attempts at perforation of the ventricles or inadequate placement of the catheters in the parenchyma of the brain.^{5,8)} Savitz and Bobroff⁽¹⁸⁾ reported the mechanism was more likely disruption of a cerebral blood vessel by the catheter; the normal pulsations of the CSF transmitted to the catheter might have caused the catheter to erode through a blood vessel with subsequent ICH. Fujioka et al.⁷⁾ presented ICH in the same location after a ventricular puncture. He hypothesized that the bleeding might have occurred by the same mechanism as traumatic delayed ICH. Hypoxia, hypercapnia, and venous congestion also produce cerebral hyperemia, which encourages gradual haematoma formation particularly at the sites of injury.^{1,6,21)} Misaki et al.¹⁴⁾ suggested that early hemorrhage was attributable to venous occlusion due to intraoperative manipulation whereas delayed bleeding has occurred in fragile brain tissue compromised by co-existence of brain disorders. However, previous intracranial diseases were not affected the development of

delayed ICH in our study.

A previous study demonstrated the mechanisms of delayed intracerebral hemorrhage after a VP shunt. However, there have been few studies of factors influencing the actual occurrence of delayed ICH. In this study, the risk factors of delayed ICH were old age and PTT. Zia et al.²⁷⁾ found that only age was an independent risk factor for recurrence of ICH. Pennlert et al.¹⁷⁾ suggested that age and diabetes mellitus were associated with recurrent ICH in their study. DIC is commonly a manifestation of a severe systemic disorder, including infection, malignancies, trauma or surgery, shock, or obstetric complications.^{9,12)} The laboratory diagnosis of DIC is made in the presence of thrombocytopenia, elevated prothrombin time (PT) and activated PTT values, low fibrinogen, and elevated fibrin degradation products. Potential risk factors for progressive intracerebral hemorrhage include abnormalities in coagulation parameters such as PTT, PT, and platelet count, which have been associated with delayed and postoperative ICH.^{23,24)} Oertel et al.¹⁵⁾ determined that male, time to 1st CT scan, older age, PTT was correlated with progressive hemorrhage and PT, but platelet did not show a similar correlation. Even if a small amount of ICH or IVH developed, it can induce a mechanical obstruction of the VP shunt requiring shunt revision.

Conclusion

This study suggests that old age and prolonged PTT are major risk factors for development of delayed ICH following VP shunt. In addition, delayed ICH after VP shunt frequently develops, even though most patients are asymptomatic even when there develops a small amount of IPH or IVH that does not require surgical evacuation. The findings of this study indicate that patients should be carefully observed after VP shunt and followed-up with a neuroimaging study.

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■ The authors have no financial conflicts of interest.

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