Postoperative Reduction of Intraventricular Hemorrhage Volume: Single- Versus Dual-Catheter Drainage

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Abstract

Background/Aims The use of single/dual external ventricular drains (EVD) for reducing intraventricular hemorrhage (IVH) is under investigation. A randomized controlled trial was conducted to compare postoperative reduction of IVH volume using single- and dual-catheter drainage in spontaneous IVH patients. We investigated factors that may influence an effective hematoma volume reduction by EVDs.

Materials and Methods The average cerebrospinal fluid (CSF) drainage volumes were analyzed. Computed tomography (CT) scans were performed on admission, 24 hours and 48 hours after EVD placement, and then on days 5 and 8. Patient group 1 was treated with a single EVD; patient group 2 was treated with bilateral EVDs. The IVH volume was calculated in all ventricles. A multivariate analysis was conducted to investigate variables that can influence the extent of hematoma volume reduction with a bilateral EVD. Regression followed by a Pearson correlation was performed to observe the strength of association of cofounders with the IVH volume reduction.

Results The percentage of IVH volume change was found to be significantly higher in the dual-catheter group compared with the single-catheter group ($p = 0.0034$) after 5 days of EVD. The mean reduction in IVH volume was 17.36 (mL) in patients ≤ 45 years of age and 20.50 (mL) in patients > 45 years. The multivariate analysis suggested the following significant predictors for IVH volume reduction: age of the patient ($p = 0.011$) and longer duration (days) of EVD ($p = 0.028$). The age of the patient had a weak positive association and duration of EVD had a positive association with the IVH volume reduction.

Conclusion Intraventricular drainage via bilateral EVDs may provide a better draining of blood-mixed CSF because it led to faster clot clearance. It is suggested that a longer duration of bilateral EVDs may lead to a greater reduction in IVH volume. Older patients may experience a greater IVH volume reduction by EVD because the volume of CSF increases with cerebral atrophy.

Keywords
- ► external ventricular drainage
- ► intraventricular hemorrhage
- ► cerebrospinal fluid

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Introduction

An external ventricular drain (EVD) is an important diagnostic and therapeutic tool for the management of intracranial pressure (ICP) and cerebrospinal fluid (CSF) analysis and drainage.[1] The use of single or dual EVDs to reduce intraventricular hemorrhage (IVH) volume is still under investigation and the impact on outcome remains controversial.[2,3] However, EVD placement is considered beneficial in terms of survival in IVH patients.[4]

The primary objective of this prospective randomized controlled trial was to compare the mean postoperative reduction of IVH volume (mL) using either single- or dual-catheter drainage in patients with spontaneous IVH. We also investigated factors that might have played a significant role in effective hematoma volume reduction especially with bilateral EVDs.

The prevalence of intracerebral hemorrhage (ICH) is 15 to 35 cases per 100,000 annually.[5–7] It was observed that functional outcome and mortality remained unchanged in the last 20 to 30 years.[5,8–12]

Intracerebral hemorrhage (ICH) with extensive ventricular extension has a high morbidity and mortality rate.[1,4,11,12] IVHs caused by ICH initially present with a focal neurologic deficit of sudden onset that progresses gradually (from minutes to hours) as compared with other subtypes of strokes.[13,14] The IVH patients are at higher risk and have threefold higher mortality rates than those with ICH only.[15–18] There is a 50 to 80% mortality rate in patients with both ICH and IVH. It was reported by Hallevi et al. (2008),[18] that half of the ICH in addition has an IVH. A rupture of an aneurysm, together with subarachnoid hemorrhage (SAH), also might result in IVH. IVHs related to ICH or aneurysm rupture are termed secondary IVHs and make up 70% of all IVHs.[5,14,19]

Approximately 30% of IVH cases are considered primary, confined to the ventricular system, and typically emerge from arteriovenous malformations, trauma, or from tumors of the choroid plexus. Moderate to severe injuries of the brain precede ~ 35% of IVH cases.[20] The worldwide incidence of an IVH is attributed more to older female patients[5,21,22] and in certain populations such as the Japanese.[5,23]

An EVD is in practice to manage ICP, diverting the CSF in hydrocephalus and clearing ventricular blood.[5,24 25]

Material and Methods

Study Design

A prospective randomized controlled trial was conducted to compare the mean postoperative reduction of IVH volume using single- versus dual-catheter EVD in IVH patients. The study was conducted at the Department of Neurosurgery, Jinnah Hospital, Lahore, Pakistan. The duration of the study was 6 months. The sample size of 60 cases was calculated (30 in each group) with 80% power of the test, 9% level of significance, and taking expected percentages. Nonprobability consecutive sampling technique was performed. Half of the patients ($n = 30$) were treated with a single catheter; the other half ($n = 30$) were treated with two catheters. The primary outcome parameter was intraventricular clot resolution.

Inclusion and Exclusion Criteria

Both male and female patients with ages 25 to 80 years with spontaneous IVH were included. Those patients who had a Glasgow Coma Scale (GCS) score between 6 and 12 and blood volume $\geq$ 30 mL on their computed tomography (CT) scan were included. Patients with posterior fossa hematoma and IVH, traumatic IVH, IVH due to arteriovenous malformation and aneurysm and patients with a severe complicating illness (e.g., congestive heart failure, end-stage kidney disease, or a condition with a life expectancy $<$ 1 year) were excluded. Patients with coagulopathy (prothrombin time [PT] or partial thromboplastin time [PTT] outside the normal range [PT $>$ 3 seconds, PTT $>$ 5 seconds reference values])[26] and a platelet count $< 75 \times 10^3/mm^3$ were excluded. Patients who were taking heparin but not antiplatelet agents were also excluded.

Patient Groups and Data Collection

A total of 60 patients were enrolled in this study after written and informed consent from their first-degree caretakers. The following data were collected: patient characteristics (sex, age, and duration of EVD) and outcome (reduction of IVH volume). Patients were grouped either for single EVD (group 1; $n = 30$) or for bilateral EVD (group 2; $n = 30$) based on generating random numbers.

Surgical Procedure

The EVDs were placed under local anesthesia. The entry point was the Kocher's point. In the single EVD group, the side of the drain placement was decided individually. Postoperatively, a 10 mL/hour drainage protocol was adopted. Routine CT scans were performed on admission, 24 hours and 48 hours after EVD placement, on postoperative days (PODs) 5 and 8. The clinical condition of the patients was recorded using the GCS. The reduction in IVH volume was calculated by tracing the hematoma using the freehand method.

In the single EVD group the EVD was clamped for 24 hours. If the CT proved that the third and fourth ventricles were free of blood and that the ventricle size remained unchanged, the EVD was removed in the next 24 hours. In general, the EVD was removed within 5 days.

In the dual EVD group the EVD in the less enlarged lateral ventricle was removed, if CT scan proved blood clearance of the third and fourth ventricles. In general, one catheter on the side with less clot volume was removed on POD 5.

The IVH volume was calculated in all the ventricles using a computerized freehand tracing technique provided by the software of the CT machine. In this technique, the hematoma was outlined in each slice and in all ventricles. The software automatically calculated the volume of the hemorrhage, according to the slice thickness.

Statistical Analysis

Representation of Data

The statistical analyses were performed with SPSS v.22.0 (IBM Corp., Armonk, New York, United States). The study was a double-blind randomized controlled trial to eliminate bias. The patients were randomly assigned to the single or double catheter group. The participating patients or attendant(s) and the researcher(s) were blinded regarding the number of catheters. Continuous variables like age and IVH volume were cited as mean plus or minus standard deviation. Categorical variables such as sex were described as frequencies and percentages. The data were stratified for age, sex, and the duration of EVD.

The *t* Test

A *t* test (independent samples) was used to compare and determine the significant difference in both groups of patients between single and dual EVD use. The *p* value of $\alpha \leq 0.050$ was considered significant.

Multivariate and Regression Analyses

A multivariate analysis was conducted to investigate those factors (variables) that can influence the extent of hematoma volume reduction with bilateral EVDs. Regression analyses were performed to estimate the relationships between the dependent and independent variables. Pearson correlation analysis was conducted to observe the strength of association of significant factors with the extent of the IVH volume reduction. The *p* value $\alpha \leq 0.050$ was considered significant.

Graphical Comparison

R software, v. 3.2.3 (R Project for Statistical Computing, https://www.r-project.org/), was used to generate box whisker plots for graphical comparison purposes between the two groups of patients.

Results

Background Information

A total of 60 patients were included in this study. Twenty-eight (46.67%) were female; 32 (53.33%) were male (►**Table 1**). The mean age was 46.87 ± 10.58 years (range 30 to 65 years). The 60 patients were equally divided into two groups of 30 each (►**Table 1**). Thirty (50%) patients were treated with a single catheter, and 30 (50%) were treated with two catheters. Of the patients in the single-catheter group, 18 patients (60%) were male and 12 patients (40%) were female. Of the patients of the dual-catheter group, 14 patients (46.7%) were male; 16 (53.3%) were female (►**Table 1**). The mean age at presentation in the single-catheter group was 48.40 ± 11.14 years; in the dual-catheter group it was 45.33 ± 9.92 years (►**Table 2**). ►**Fig. 1a–c** shows a preoperative as well as postoperative CT scans. It can be seen that on POD 5, a gross hematoma volume reduction was achieved. The mortality rates were comparable in both groups, with a slightly better outcome in the patients with bilateral EVDs.

Table 1 Distribution of sex between groups

Sex	Treatment	
	Single catheter	Dual catheter
Male (%)	18 (60)	14 (46.7)
Female (%)	12 (40)	16 (53.3)
Total (%)	30 (100)	30 (100)

Table 2 Descriptive statistics of age

	Treatment	
	Single catheter ($n = 30$)	Dual catheter ($n = 30$)
Age, mean ± SD	48.40 ± 11.14	45.33 ± 9.92

Abbreviation: SD, standard deviation.

The *t* Test Comparison (Single Catheter versus Bilateral Catheter)

The mean value of the duration (in days) of EVD was higher in the dual-catheter group compared with the single-catheter group: 4.6 ± 0.7 days versus 4.8 ± 0.6 days, respectively (►**Table 3**). However, this difference was not statistically significant. A statistically significant difference between the two groups was seen concerning mean IVH volume on POD 5 (p value $= 0.020 < 0.050$; t test $= 2.3932$; degrees of freedom [df] = 58), whereas no significant difference was found before EVD (►**Table 3**).

Additionally, the percentage change in IVH volume was significantly higher in the dual-catheter group compared with the single-catheter group ($p = 0.0034 < 0.050$; t test $= 3.0519$; df = 58). On POD 5, the IVH volume was reduced in both groups, but significantly more reduced in the dual-catheter group (p value $= 0.0034 < 0.050$) (►**Table 3**). The mean reduction in IVH volume was 16.38 ± 11.2 mL in the 32 male patients and 21.96 ± 9.8 mL in the 28 female patients. The mean reduction in IVH volume was 17.36 ± 10.0 mL in the 29 patients ≤ 45 years of age and 20.50 ± 11.5 mL in the 31 patients > 45 years. The mean reduction in IVH volume was 14.17 ± 8.8 mL in the patients in which the EVD was removed before POD 5, and 20.19 ± 11.0 mL in patients in which the EVD was removed on POD 5.

Multivariate Analysis, Regression, and Correlations

The multivariate analyses (Pillai's trace, Wilks' Lambda, Hotelling's trace, and Roy's largest root) indicated the following significant predictors that influence the reduction of IVH volume: the age of the patient ($p = 0.011 < 0.050$; F = 5.409) and a longer duration of the EVD (0.028 < 0.050; F = 4.104). The regression analysis showed a positive relationship (r = 0.449; 95% confidence interval [CI], 2.090–16.069) between percentage reduction of IVH volume and duration of a bilateral EVD (days) and a weak positive relationship between percentage reduction of IVH volume and the age of the patient (r = 0.234; 95% CI, − 0.115 to 0.648). These results suggested that a longer duration of bilateral EVD will lead to a greater percentage reduction in IVH volume. Moreover, older patients may experience a greater percentage reduction in IVH volume with an EVD. A regression equation to predict percentage IVH volume reduction (mL) from bilateral EVD duration (days) is % IVH Volume Reduction (mL) = [− 20.598 + 0.449{EVD Duration (days)}].

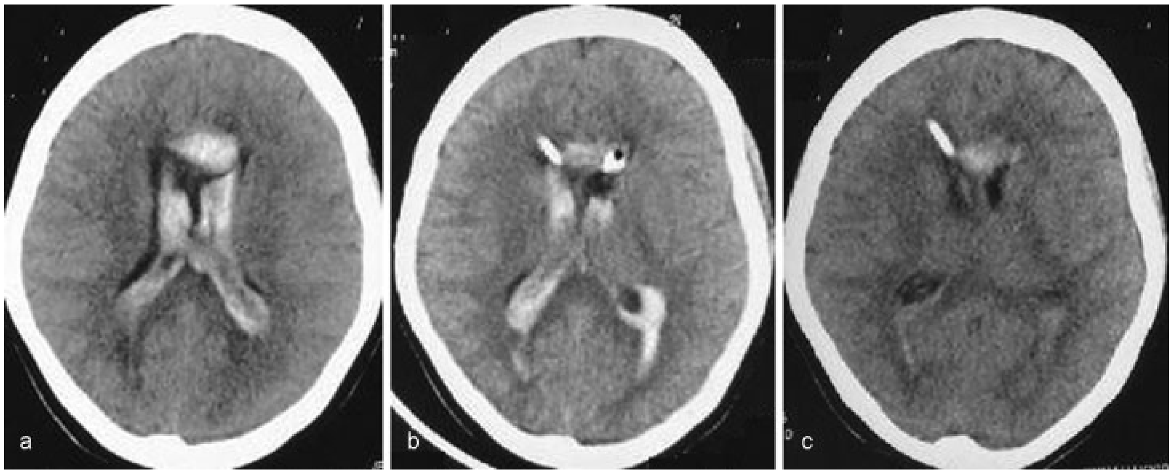

Fig. 1 Computed tomography (CT) scans show a pronounced reduction in intraventricular hemorrhage volume on postoperative day (POD) 5. (**a**) Preoperative CT. (**b**) First postoperative CT. (**c**) CT on POD 5.

Table 3 Intraventricular hemorrhage volume using single- versus dual-catheter drainage

		Treatment		*p* value	*t* test	df	95% CI of the difference
		Single catheter	Dual catheter				
Duration of EVD, d		4.6 ± 0.7	4.8 ± 0.6	0.2396	1.1882	58	−0.537 to 0.137
IVH volume, mL	Before EVD	58.35 ± 9.22	62.59 ± 10.7	0.105	1.6445	58	−9.4019 to 0.9219
	After 5 d of EVD	43.35 ± 5.4	39.59 ± 6.7	0.0200[a]	2.3932	58	0.6151 to 6.9049
Change in volume, %		14.98 ± 9.07	22.98 ± 11.13	0.0034[a]	3.0519	58	−13.2472 to −2.7528

Abbreviations: CI, confidence interval; df, degrees of freedom; EVD, external ventricular drainage; IVH, intraventricular hemorrhage.
[a]Significant value.

Graphical Comparison

The comparison via box whisker plots is represented in ►**Fig. 2** for both groups (single/dual catheter). The duration of EVD (days), IVH volume reduction before and after 5 days of EVD, and change in volume (%) are compared (►**Table 3**). The medians are almost the same in both boxes. The tails' length of the dual-catheter box is lengthier compared with the single catheter box. The medians, minimums, maximums, lower quartiles, and upper quartiles for each box are shown in ►**Fig. 2**.

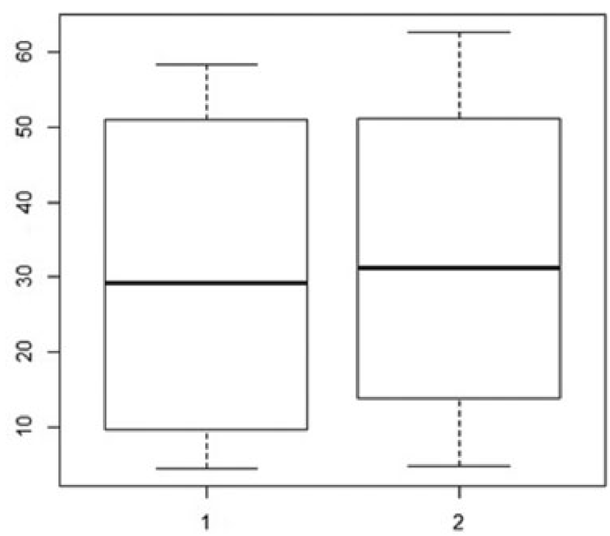

Fig. 2 Comparison via box whisker plots. For each catheter (single/dual) the duration of drainage (days), intraventricular hemorrhage (IVH) volume reduction before external ventricular drain (EVD) and after 5 days of EVD and change in volume (%) are compared (Table 3). The medians are almost the same in both boxes. The tail lengths of the dual-catheter box are longer compared with the box of the single catheter. 1 = single catheter; 2 = dual catheter. Box 1: minimum: 4.6; lower quartile: 12.39; median: 29.17; upper quartile: 47.1; maximum: 58.35. Box 2: minimum: 4.8; lower quartile: 18.43; median: 31.29; upper quartile: 45.34; maximum: 62.59.

Discussion

For IVH, several surgical and medical treatments have been tried until recently, but unfortunately no gold standard treatment for IVH yet exists. The blood in the ventricular system is leading to an obstructive hydrocephalus that leads to a poor outcome. Therefore, EVD is considered a valuable treatment option to resolve the acute hydrocephalus and the resultant intracranial hypertension, but mortality is still 50%.[27,28] We evaluated the intraventricular hematoma volume reduction in IVH patients if either a unilateral or a bilateral EVD was placed. In our study, the primary outcome parameter was reduction of IVH volume in the single and dual catheter group, and the secondary outcome parameter was the mortality rate in both groups.

Lovasik et al[4] showed that EVD use was linked with decreased mortality but with altered Rankin scores. We assumed that the use of two EVDs might result in a better removal of the IVH compared with a single EVD. We indeed found a significant difference ($p = 0.0020$) between use of a single catheter and dual catheter after 5 days of drainage concerning IVH volume reduction. It was observed that IVH volume decreased especially on the fourth/fifth day of drainage and that the percentage volume reduction on POD 5 was significantly greater in the dual-catheter group. The results of Du et al[29] supported the use of dual EVDs for IVH, whereas no effect of dual EVD was seen by Staykov et al.[30] Du et al observed a higher rate of daily CSF drainage with two catheters, which might be beneficial by faster reducing increased ICP (with the effect of a faster improvement in the consciousness level and reduction of mortality rate). However, the higher risk of subdural hematoma formation by an enhanced CSF drainage rate should be kept in mind, if two EVDs are used.

Hinson et al conducted a post hoc analysis of IVH patients treated either with dual catheters or a single catheter with and without recombinant tissue plasminogen activator. They found a trend to a greater reduction in IVH volume in the dual catheter group, thereby supporting the findings of the present study.[26] It is also proposed by some that placing the EVD into the lateral ventricle without or with less blood minimize the risk of catheter obstruction.[14] Those catheters also are efficient in clearing the third and fourth ventricle.[31]

Apart of the use of dual catheters, we identified factors being related to a more effective reduction of IVH volume. If bilateral catheters are used for a longer time, more effective volume reduction could be achieved. Further, a weak positive correlation between percentage of IVH volume reduction and age can be seen. In our series, patients > 45 years experienced a greater IVH volume reduction by EVD than the younger patients. One explanation might be the higher CSF volume in elderly because of cerebral atrophy.[32,33] We should also keep in mind that the use of two EVDs plus a longer duration increases the risk for complications, especially for infection.[27,29,30,34] As mentioned above, higher age is related to a higher IVH volume reduction. On the other hand, higher age is found by some to be the most important predictor for poor outcome among other independent predictors such as hemorrhage size (if IVH is caused by an ICH) and intraventricular spread of hemorrhage.[35]

Conclusion and Recommendations

We reported that IVH reduction was more pronounced in the group of patients treated with bilateral EVDs and we therefore believe that the use of two EVDs might be beneficial in severe IVH. A longer drainage period and higher age are factors promoting faster clearance of the ventricles. Up to now, there is no procedure for preventing and handling complications of EVD. Further investigations in IVH treated by dual catheters should focus on specific protocols to reduce the complication rate and, thus, improve outcome.

Limitations

Intraventricular fibrinolysis for faster clot resolution and ICP monitoring were not used in this study.

Compliance with Ethical Standards
Informed consent was obtained from all patients included in the study that conformed to institutional ethical standards. The study was approved by the institutional ethical review committee.

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