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# Prediction of ventriculoperitoneal shunt placement based on type of failure during external ventricular drain wean

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ABSTRACT

*Objective:* There are multiple etiologies for failure while weaning an external ventricular drain (EVD) after subarachnoid hemorrhage (SAH), but there is little data on the relationship between etiology of wean failure and ventriculoperitoneal shunt (VPS) placement.
*Methods:* We performed a retrospective analysis of SAH patients who had an EVD placed between January 2008 and June 2012 at our institution. For each wean step (defined as raising or clamping the EVD), we recorded success or failure. We categorized failure as lowering or opening the EVD due to elevated intracranial pressure (ICP), clinical failure (due to headache or vomiting or altered mental status), leakage from the EVD site, or development of radiographic hydrocephalus. We evaluated the relationship between etiology of wean failure and subsequent need for VPS.
*Results:* Of 116 patients with an EVD placed, 35 required VPS placement (30%). Patients who required VPS placement had a median of 2 (interquartile range (IQR) 1–4) wean failures and those who did not require VPS placement had a median of 1 (IQR 0–1) wean failure ($p = 0.001$). There was no significant relationship between age, sex, Hunt Hess score, Fisher score, Glasgow coma scale, aneurysm location, aneurysm size, aneurysm treatment method, vasospasm and need for VPS. There was a significant relationship between patients with at least one wean failure due to clinical changes or radiographic hydrocephalus and need for VPS ($p = 0.007$ and $p = 0.029$, respectively). After multivariate analysis, there was only a significant relationship between clinical changes and need for VPS (OR 2.76, CI 1.03–7.36, $p = 0.04$).
*Conclusion:* There is a significant association between wean failure due to clinical changes and requirement for VPS placement after SAH.



## 1. Introduction

7–65% of patients with subarachnoid hemorrhage (SAH) require external ventricular drain (EVD) placement [1,2] to facilitate cerebrospinal fluid (CSF) drainage to treat symptomatic hydrocephalus or to promote brain relaxation during aneurysm clipping [3,4].

The management of CSF drainage from an EVD varies. At some institutions, the EVD is kept clamped, to force CSF along normal pathways and prevent formation of occlusive membranes and clots, and is only opened if intracranial pressure (ICP) is greater than 20 mmHg [4]. At others, the EVD remains open and is then clamped after day four or five if there is no evidence of vasospasm [5] or after the CSF red blood cells (RBC) are less than 10,000 cells per cubic millimeter and there is no evidence of hydrocephalus, leakage from the EVD, or pseudomeningocele [6]. Many other institutions employ a progressive weaning strategy whereby the EVD is gradually raised over multiple days then ultimately clamped, a process that is extrapolated from evidence about chest tube and endotracheal tube management [3,7,8]. While at some institutions, patients have multiple EVD challenges [9], at others, failure of a single EVD clamp trial results in placement of a ventriculoperitoneal shunt (VPS) [6], and at still others there are radiologic [10] or clinical criteria [3,6] for VPS placement without a clamp trial.

8–63% of SAH patients with EVDs require permanent VPS placement [1,4,7,10–12]. Previous studies that evaluated predictors of VPS placement explored a wide variety of variables, including age [8,10,12–15], sex [8,10,12,13], presence of comorbidities [15], intubation status on admission, initial Glasgow coma

*Abbreviations:* CSF, cerebrospinal fluid; CT, computed tomography; EVD, external ventricular drain; GCS, Glasgow coma scale; ICD9, International Classification of Diseases 9; IQR, interquartile range; ICP, intracranial pressure; IVH, intraventricular hemorrhage; MGH, Massachusetts General Hospital; RBC, red blood cell; SD, standard deviation; SAH, subarachnoid hemorrhage; VPS, ventriculoperitoneal shunt.

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scale (GCS) [12,14], initial Hunt Hess [6,8–10,13,16] and Fisher scores [5,10,13,14,16,17], admission glucose [17], aneurysm location [8,10,12,13], aneurysm size [8,12], treatment method (clip versus coil) [9,10,12,15,16], third ventricle diameter at admission [6], intraventricular hemorrhage (IVH) [2,5,8,10,13,16], vasospasm [8], admission CSF red blood cells (RBC) and protein [6,9], ventriculitis [13,17], and number of EVD days [9]. Of these, the most reproducible factors include age, sex, Hunt Hess and Fisher scores, and the existence of many others suggests that local practice may influence the decision to place a VPS.

The use of a stepwise weaning strategy at our institution provides the opportunity to assess whether types of EVD failure predict VPS placement and whether some types of failure do not necessitate a VPS. Clamp trials are frequently repeated with the goal of removing the EVD. Accordingly, our institution's VPS placement rate is lower than some reported rates. In this context, we hypothesized that there would be a relationship between failure etiology during an EVD wean and need for VPS placement. We also sought to identify low risk causes of failure that would not necessitate VPS placement.

## 2. Methods

### 2.1. Study population

We used the Research Patient Data Registry to generate a list of all neurosurgery inpatients at our institution from 1/1/08 to 6/30/12 with the diagnosis of SAH (International Classification of Diseases (ICD) code 430). Through review of daily progress notes, we excluded patients whose primary diagnosis was not SAH, received greater than 48 h of care elsewhere, had a history of SAH, had traumatic brain injury precipitating SAH, did not have an EVD at any point during their hospitalization, or who had care withdrawn during the acute hospitalization.

### 2.2. EVD management

At Massachusetts General Hospital (MGH), EVDs placed prior to securing an aneurysm are clamped at 20 cm to decrease risk of rebleeding [18] then opened and lowered once the aneurysm is secured to facilitate drainage of CSF. EVD wean is not initiated if there is evidence of active vasospasm. If there is no evidence of vasospasm, the EVD is slowly raised then clamped. If a patient develops clinical changes (headache, altered mental status, nausea/vomiting), ICP elevation above 20 mmHg for 5 min, leakage from the EVD site, or worsening radiographic hydrocephalus after raising/clamping the EVD, it is lowered and/or unclamped. At the discretion of the treating neurosurgeon, there may be further attempts to wean the EVD with the goal of removing it after a successful clamp trial, but if a patient develops clinical changes or has elevated ICP after one or more clamp trials, a VPS is placed.

### 2.3. Data ascertainment

We recorded age, sex, admission Hunt Hess/Fisher/GCS (interpreted through review of clinical and radiographic data if not stated in the notes), presence of an aneurysm felt to be responsible for the bleed, and aneurysm size (larger if there were two aneurysms), location (as reported from the formal angiogram or the computed tomography angiogram if no formal angiogram was done), treatment method (coil/clip/onyx), and presence of vasospasm (defined as peak velocities greater than 200 cm/s).

Using the data in procedure notes, we recorded the day of EVD placement relative to day of admission and location of EVD placement (operating room or emergency room/ICU). We reviewed progress notes to ascertain the number of EVD days, the EVD day the drain was first weaned (excluding clamping prior to securing the aneurysm), the number of EVD wean trials (defined as raising/clamping the EVD including clamping the EVD after initial placement), the number of EVD clamp trials prior to EVD removal or VPS placement, the CSF output prior to the final clamp trial, and the success/failure of each trial (failure defined as reopening or lowering the EVD, except when it was reopened/lowered after the aneurysm was secured) and the reason for failure. This study was approved by the local institutional review board.

### 2.4. Statistical analysis

Statistical analysis was performed using JMP Pro 10. Categorical variables were recorded as percentages and evaluated using a Fisher's two-tailed exact test. Parametric continuous variables were recorded as mean ± standard deviation (SD) and evaluated using a Student's two-tailed *t*-test. Nonparametric continuous variables were recorded as median and interquartile range (IQR) and evaluated using a Wilcoxon ranked sum test. Multivariate analysis was performed using nominal logistic regression. A $p$-value of $<0.05$ was considered statistically significant.

## 3. Results

### 3.1. Patient selection

Our query generated a list of 390 neurosurgical inpatients at MGH with the diagnosis of SAH between 1/1/08 and 6/30/12. Of these, 75 were eliminated because their primary diagnosis was not SAH (31 arteriovenous malformations/fistulas, 12 intraparenchymal hemorrhages, 11 ischemic strokes, 10 subdural hematomas, 3 elective aneurysm clippings, 3 cavernous malformations, 2 traumatic brain injuries, 1 epidural hematoma, 1 idiopathic intracranial hypertension, and 1 angiogram to check on a prior coil). Five patients with the diagnosis of SAH were eliminated because they received greater than 48 h of care elsewhere and one patient with the diagnosis of SAH was eliminated because of a history of a prior SAH. Of the remaining 309 patients, 150 were excluded because they did not have EVDs and 43 patients were excluded because care was withdrawn. The final study population consisted of 116 patients.

### 3.2. Demographic data

Table 1 shows the clinical characteristics of the study population. Thirty-five patients (30%) required VPS placement. There was no significant difference between patients with a VPS and those without a VPS and age, sex, Hunt Hess or Fisher scores, GCS, aneurysm location/size/treatment method, vasospasm, day of initial wean, or CSF output prior to final clamp trial. Patients who were shunted had an EVD for significantly longer than those who were not shunted ($p = 0.004$). The number of wean trials was higher in the group that had a VPS placed (mean of 5 with SD 2 compared with mean of 4 with SD 2, $p = 0.03$) as was the number of clamp trials (median of 2 with IQR of 1–3 compared with median of 1 with IQR of 1–1.5, $p = 0.01$). Patients who were shunted had significantly more wean failures than those who were not shunted (median of 2 with IQR of 1–4 compared with median of 1 with IQR of 0–1, $p = 0.001$).

### 3.3. External ventricular drain analysis

There were 469 total weaning trials for the 116 patients (mean of 4 trials per patient with SD of 2) and 174 of these (37%) were failures (median of 1 failure per patient with IQR of 0–2) and resulted