Surgical Neurology International

Original Article

Permanent cerebrospinal fluid diversion in subarachnoid hemorrhage: Influence of physician practice style

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Received: 11 June 11 Accepted: 14 July 11 Published: 30 August 11

This article may be cited as:
Esposito DP, Goldenberg FD, Frank JI, Ardelt AA, Roitberg BZ. Permanent cerebrospinal fluid diversion in subarachnoid hemorrhage: Influence of physician practice style. Surg Neurol Int 2011;2:117

Available FREE in open access from: http://www.surgicalneurologyint.com/text.asp?2011/2/1/117/84241

Abstract

Background: Acute hydrocephalus (HCP) after aneurysmal subarachnoid hemorrhage (SAH) often persists. Our previous study described factors that singly and combined in a formula correlate with permanent CSF diversion. We now aimed to determine whether the same parameters are applicable at an institution with different HCP management practice.

Methods: We reviewed records of 181 consecutive patients who presented with SAH and received an external ventricular drain (EVD) for acute HCP. After exclusion and inclusion criteria were met, 71 patients were analyzed. Data included admission Fisher and Hunt and Hess grades, aneurysm location, treatment modality, ventricle size, CSF cell counts and protein levels, length of stay (LOS) in the hospital, and the presence of craniectomy. Outcome measures were: (1) initial EVD challenge outcome; (2) shunting within 3 months; and (3) LOS.

Results: Shunting correlated with Hunt and Hess grade, CSF protein, and the presence of craniectomy. The formula derived in our previous study demonstrated a weaker correlation with initial EVD challenge failure. Several parameters that correlated with shunting in the previous study were instead associated with LOS in this study.

Conclusions: The decision to shunt depends on management choices in the context of a disease process that may improve over time. Based on the treatment strategy, the shunting rate may be lowered but LOS increased. Markers of disease severity in patients with HCP after SAH correlate with both shunt placement and LOS. This is the first study to directly evaluate the effect of different practice styles on the shunting rate. Differences in HCP management practices should inform the design of prospective studies.

Key Words: External ventricular drain, hydrocephalus, subarachnoid hemorrhage, shunt

Access this article online
Website: www.surgicalneurologyint.com
DOI: 10.4103/2152-7806.84241
Quick Response Code:

INTRODUCTION

Acute hydrocephalus (HCP) after subarachnoid hemorrhage (SAH) is common, may cause neurological damage and may persist, resulting in the need for permanent cerebrospinal fluid (CSF) diversion with a shunt.[2-4,6,10,15,19-21] Acute HCP is typically treated with emergency insertion of an external ventricular drain (EVD).[3,4,6,15,20,21] Ideally, it is best to avoid an unnecessary shunt, but this must be balanced against the risks of prolonged EVD duration such as infection and obstacles to expeditious institution of rehabilitation. In order to help decide if a patient should receive a CSF shunt, an empirical "challenge" process is usually employed, where the EVD is clamped and the patient is observed clinically for an increase in intracranial pressure (ICP), neurological deterioration, and for progressive HCP with serial computed tomography (CT) scans. This process is inexact, highly variable in how it is approached, and carries some risks.[2,9] It may be safer to find parameters that can predict who will fail or pass the "challenge" in order to have a more rational "evidence-based" approach that can impact the intensity and duration of the challenge process. Several studies, including one recently published by the senior author at another institution (The University of Illinois at Chicago, Chan *et al*.[2]), described a set of objective factors that singly and in combination can help predict who among the patients with acute HCP following aneurysmal SAH and an EVD were most and least likely to pass the EVD challenge. However, those results were based on the practices and patient population at a single institution. Often these results are published as an implicit advice to others, or ideally as a basis for a prospective multicenter study. The influence of variability in the treatment strategy and preferences among institutions has not been addressed in the context of neurointensive care and specifically EVD management. We believe that in order to have wide applicability, and before considering extensive prospective data collection, the results have to be replicated at other institutions. We decided to investigate whether a set of parameters exists that will help predict EVD challenge failure and shunt placement in the aneurysmal SAH population at our current institution, The University of Chicago (UC). We wanted to find out whether the predictive parameters found by Chan *et al*.[2] are translatable to another institution, where EVD challenge practices are different.

MATERIALS AND METHODS

After receiving approval from the Institutional Review Board, we performed a retrospective chart review of 181 consecutive patients who presented with SAH and received an EVD for acute HCP. Eighty-four of the 181 patients were excluded due to nonaneurysmal SAH (trauma or arteriovenous malformation), death, or being under 18 years old at time of admission. Another 26 patients were excluded due to lack of EVD challenge (not performed due to clinical judgment, CSF leak, or unintentional removal of EVD by the patient) or lack of available data. Therefore, 71 patients were analyzed in our study.

Data collection

Patient demographic data, Fisher grade at admission, Hunt and Hess grade at admission, aneurysm location, and treatment modality (clip placement or coil embolization) were recorded. CT scans obtained at the time of admission and the onset of the EVD challenge were analyzed for the third ventricular diameter and bicaudate diameter by a single author who was blinded to patients' outcomes. The red blood cell (RBC), white blood cell (WBC), and protein levels in the CSF as well as the serum sodium were recorded at the time of admission and the onset of the EVD challenge. The number of days in the neurological intensive care unit (NICU), the length of stay (LOS) in the hospital, and the presence of craniectomy were also recorded. The initial choice of parameters was based on prior publications, particularly the recent study performed at The University of Illinois at Chicago (UIC) by Chan *et al*.[2]

External ventricular drain challenge

In this retrospective review, we relied on the physician's decision at the time of the challenge. There is no standardized protocol, rather the decision is made by the attending neurointensivist with the overall philosophy at this institution of avoiding an unnecessary shunt as the overriding priority. Factors such as neurological status, severity of initial HCP, initial indications of EVD placement, extent and location of subarachnoid and/or intraventricular blood, volume of CSF drainage, and CSF analysis all influence the clinical decision. Typically, once patient stability was achieved and CSF drainage no longer had independent clinical advantage, the EVD was gradually elevated over several days, or clamped completely, while the patient was observed clinically, by ICP numbers and with CT scan. When a patient was able to tolerate the clamped EVD for 48 h, the catheter was removed. A "pass" score for initial challenge was defined as removal of the EVD following the challenge, while a "fail" was defined as the unclamping of the EVD and continued drainage.

Analysis

Three outcome measures were analyzed: (1) initial EVD challenge outcome; (2) placement of a ventriculoperitoneal (VP) shunt within 3 months of admission; and (3) LOS. In regards to these three measures, univariate analysis was performed to identify statistically significant ($P < 0.05$) predictive parameters. The significant parameters were combined into a multivariate regression analysis.

In addition, we sought to determine the level of correlation between the equation formulated in the prior study and our current data set. A "failure risk index" (FRI) was derived at the UIC study; FRI = −3.589 + 0.074 (TA) – 0.02 (TC) + 0.151 (HH) + 0.011 (CSFP) + 0.042 (BC) + 1.398 (sex) + 0.750 (circulation) where TA is the third ventricular diameter on admission in mm, TC is the third ventricular diameter at challenge in mm, HH is the Hunt and Hess grade, CSFP is the protein level in CSF at challenge in mg/dL, BC is the bicaudate diameter at challenge in mm, sex = 1 for female, 0 for male, and circulation = 1 for posterior location, 0 for anterior location. The data for the initial EVD challenges were used to calculate the correlation using linear regression. We hypothesized that the FRI derived from UIC data will help predict who passed or failed the EVD challenge when applied to a new patient population at our institution.

RESULTS

Population characteristics

The average age of the study group was 54.8 years. The group was made up of 54 (76.1%) females and 17 (23.9%) males. The aneurysm location distribution was 64 (90.1%) anterior and 7 (9.9%) posterior. Sixty-six (93.0%) of the patients underwent clipping of the aneurysm while 5 (7.0%) underwent coil embolization. Table 1 compares the UC population with the population in the previous study (from Chan *et al*.[2]).

External ventricular drain challenge correlation with failure risk index

Figure 1 depicts the correlation of the data for the initial EVD challenge with the FRI formula derived directly from the previous (UIC) study. The bars represent the percent of patients who failed the EVD challenge based on their FRI. The regression line represents the correlation. We chose the initial challenge as the best correlate of the practice in the other study, because there the practice was to consistently place a shunt upon failure of initial EVD challenge.

Table 1: Comparison of patient population and treatment

	Prior study (UIC)	Current study (UC)
Number of patients	89	71
Age	53	55
Sex	64% F	76% F
Location of aneurysm	65 ant, 24 post	64 ant, 7 post
Percent clipped	64%	93%
Days in NICU	16.0	22.7
LOS	21.1	29.3
Percent shunted	43/89 (48%)	19/71 (27%)

NICU: Neurological intensive care unit, LOS: Length of stay

Shunt placement

Due to the local philosophy of optimizing attempts to achieve "shunt-free" survival, not all patients who failed initial EVD challenge were shunted in the current study; therefore, we performed a separate analysis of factors correlating with eventual shunt placement in the entire patient group regardless of the outcome of initial EVD challenge. Only three variables were found to be statistically significant in predicting shunt placement at UC [Table 2].

There was no significant difference whether the patient passed or failed the initial EVD challenge based on number of days from admission until initial EVD challenge. Of the 32 patients that failed the initial EVD challenge, 69% (22/32) were challenged within 10 days of admission while the other 31% were challenged at 10 days or longer from admission.

Delayed shunting

At UC, 16 patients initially passed an EVD challenge but ended up getting a VP shunt later. Ten of these patients never left the hospital in the interval, and six were discharged but then returned for a VP shunt (range 1.7 month to 1 year after original admission). Fourteen patients were shunted within 90 days and were within the "shunting rate" as defined by us before the study. Two were shunted later (4 and 12 months from admission).

Length of stay

In a fashion similar to shunt placement itself, LOS is a consequence of factors such as severity of illness and treatment strategy, therefore we wanted to examine the factors that correlate with LOS [Table 3].

These parameters closely resemble the parameters that correlated with shunting in the previous (UIC) study. We suspected that given greater LOS at UC and greater shunting rate at UIC, LOS partly replaced the shunting

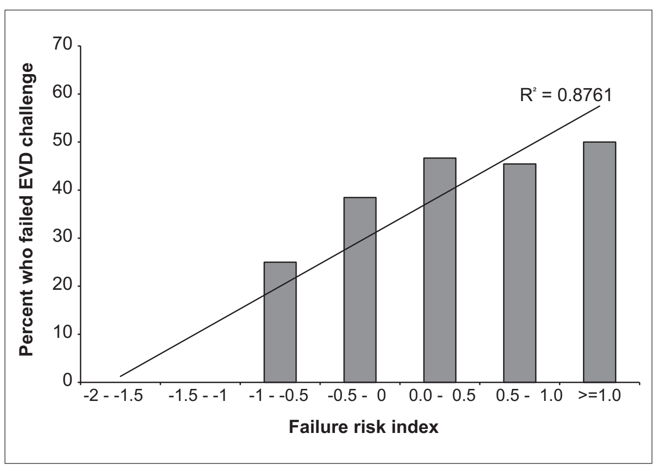

Figure 1: Correlation of failure risk index with the outcome of the initial external ventricular drain challenge at University of Chicago

Table 2: Statistically significant parameters correlating with shunt placement at University of Chicago

Variable	Shunted	Shunt free	*P* value
Hunt and Hess grade	3.6	2.8	0.0416
Protein level in CSF at challenge (mg/dL)	71.9	45.2	0.0348
Presence of craniectomy	26.3%	3.8%	0.0139

CSF: Cerebrospinal fluid

Table 3: Statistically significant parameters correlating with length of stay at University of Chicago

Variable	*P* value
Fisher grade	<0.0001
Hunt and Hess grade	<0.0001
Protein level in CSF on admission	0.0065
Bicaudate diameter at challenge	0.0243
Third ventricular diameter at challenge	0.0131
Days in NICU	<0.0001

CSF: Cerebrospinal fluid, NICU: Neurological intensive care unit

rate as an outcome variable. A multivariate regression equation was calculated based on the significant predictive variables (except days in NICU, which is not independent from total LOS). Our patient data were then applied to this equation to calculate a predicted LOS for each patient. These predicted values were plotted against the actual LOS for each patient and the correlation was calculated (r = 0.69). This correlation was found to be statistically significant (P < 0.0001). In other words, a similar set of predictors that strongly correlated with the shunting rate in the previous study instead correlated with LOS, suggesting a trade-off between LOS and shunting rate.

DISCUSSION

This is the first study to address the importance of institutional policies and treating physician choices as key factors in the patient outcome in the context of EVD management. Our data suggest that the increased LOS and lower shunting rate are a trade-off and also support the notion that HCP after SAH tends to improve with time. In a practice style that chooses early shunting and discharge, these parameters will correlate with higher shunting rate. If the managing physician chooses to minimize the shunting rate, the same parameters will now be predictive of greater LOS and be weaker predictors of the shunting rate. Hypothetically, a further increase in LOS will decrease the shunting rate further, although very prolonged EVD times can arguably increase the rate of infection.[1,7,13,14,22]

In this study we re-demonstrated objective parameters which correlate with the outcome of the initial EVD challenge and eventual shunting at UC: the Hunt and Hess grade on admission, protein level in CSF at challenge, and presence of craniectomy. These findings were in principle similar to the UIC study findings. The study was not intended as validation, but rather a comparison given varying practices. Indeed, there were important differences. Applying a formula identical to the one used by Chan *et al.*[2], yielded a significant (R^2 = 0.88) albeit weaker correlation between FRI and shunting rate in our patient population. Instead, a strong correlation was seen with LOS in the hospital. The correlation and the difference in findings between the two studies reflect a different treatment philosophy, with the UC group emphasizing avoidance of shunt-dependency even if it means longer hospital stays. Indeed, LOS was greater at UC than at UIC, whereas the shunting rate was lower. Plausibly, the natural history of HCP after SAH is that of recovery, and longer hospital stays may result in lower shunting rates. Our data suggest that a correlation between the shunting rate and LOS probably does not mean that increased drainage duration causes shunt dependence, rather both may be markers of disease severity.

Although physicians practicing neurointensive care may have inferred an LOS–shunting rate trade-off, it was not clearly demonstrated. On the contrary, increased drainage duration has been associated with "shunt dependence".[16,26] It is possible to state that many patients with persistent HCP will eventually "need" a shunt, and a longer LOS reflects either an attempt to wean the EVD and avoid the shunting, or is simply a marker of disease severity. Severe SAH may cause both prolonged hospital stay and HCP. In our sample, there was no significant difference in the shunting rate between patients who had their first challenge performed within 10 days after the SAH or later. This result is expected—patients were not randomly assigned to early or late challenge, rather their condition was carefully considered by an expert to decide on an optimal challenge time for them. The more appropriate comparison in our opinion is between two strategies by two qualified physician teams, applied to a similar patient population.

The patient populations in both institutions were derived from the same pool, and had a similar severity and demographic composition. The greatest difference was the greater prevalence of open surgery in our sample compared to the Chan *et al.* study. Arguably this can affect HCP severity and shunting rate, but in both studies the choice of coiling *vs.* clipping was not one of the factors correlating with the shunting rate.

Previous studies have addressed risk factors for shunting after SAH. Most of them were not significantly different from what we found. They included higher Fisher grade,[5,10,11,19,21,25] higher Hunt and Hess,[2,3,5,10-12,20,23-25] increased bicaudate diameter or index,[2,12,19,26] presence of acute HCP,[3,10,11,17,21,23,27] intraventricular hemorrhage,[5,10,12,18,19,23] cisternal hemorrhage,[12,18,24] posterior circulation location of the ruptured aneurysm,[2,3,12,17,18,21,23,24,27] female sex,[2,3,23,24] advanced age,[3,10,11,17,24,27] development of nosocomial meningitis,[10,19,23] admission glucose of greater than or equal to 126 mg/dL,[19] ventilation on admission[17] and continuous drainage.[8] Different studies came up with different correlations, without a consistent message and therefore with limited practical consequences. We believe that variability among treatment practices at different institutions was an important and underestimated factor precluding widespread applicability of conclusions from past research.

Our data suggest that automatic acceptance of the shunting rate as a quality parameter is not justified. Minimizing the shunting rate has benefits—patients do not receive hardware they may not need, and avoid an additional surgical procedure. On the other hand, aggressive reduction of the shunting rate risks missing patients who have HCP—delayed shunting was seen at UC, albeit only in 6/71 patients, but not at UIC with its much higher initial shunting rate. Arguably, some patients with delayed hydrocephalus after discharge may be missed and suffer serious neurological consequences. Early and more aggressive shunting may prevent these cases and allow for earlier discharge and rehabilitation.

Although the cost of health care is an important parameter in many clinical situations, this study was not designed to address this question. We believe that any such analysis should include the total cost—not only the hospital bill, but also the cost of rehabilitation, the patients' outcome and return to function, etc.

Similar to surgical studies where equipoise must be explored before embarking on a multicenter study, we recommend a similar process for ICU-based clinical trials. In the case of a trial of shunting for those patients who had an EVD placed for acute HCP, a consensus or at least equipoise for a particular set of patients must be first achieved among participating physicians regarding what constitutes the requirement for shunting. Ultimately, for multicenter studies, we may need to uniformly define shunt "requirement" to normalize the way we guide families in the consent. This uniformity will be difficult to achieve until we have a better idea of what is better for the long-term outcome of the patient—earlier discharge and rehabilitation with a shunt, or longer hospital stay and avoidance of CSF shunting.

Our study was limited by its retrospective nature and inability to include information on patients' co-morbidities. Despite this, our study provides important insights into current practices of management of patients with HCP after SAH and may eventually lead to better management and trial design.

CONCLUSIONS

This is the first study that addresses the importance of physician practice on the shunting rate and discharge statistics in patients with SAH. Based on our findings, any prospective study of shunting after EVD for acute HCP should acknowledge the variability of physician choice and opinion, similar to the principle of surgical equipoise advocated in prospective surgical studies. Otherwise, the applicability of any study to other practices will remain limited.

Specific parameters correlate with risk of shunting in patients with HCP after SAH.

They may vary among institutions based on the patient population and local physician practice.

We demonstrated a potential trade-off between LOS and shunting rate, where longer LOS may allow a lower shunting rate. Our study suggests that lowering shunting rate should not be an automatic goal of management of patients with HCP after SAH. The definition of shunt requirement after SAH is ambiguous and depends on management choices in the context of a disease process that may improve over time.

ACKNOWLEDGMENTS

The authors would like to thank Weihua Gao for her contribution in the statistical analysis of this study.

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