Complications in Patients Undergoing Microsurgical Clipping of Intracranial Aneurysms with Pre-existing Ventriculoperitoneal Shunts Following a Cranial Procedure

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Introduction: Patients with ventriculoperitoneal/pleural (VP) shunts occasionally must undergo subsequent craniotomy, craniectomy, or cranioplasty. Due to changes in pressure dynamics following shunt placement, we hypothesized that such patients may have an increased risk of developing symptomatic collections of extra-axial blood, fluid, and/or air postoperatively, leading to longer stays and worse outcomes compared to those undergoing cranial operations without a VP shunt.
Methods: From a retrospective cohort of patients who underwent cranial operations for management of cerebral aneurysms in 2005-2014, we identified patients who previously had a VP shunt placed, determined the temporal relationship between shunt placement and cranial operation, and investigated outcomes in those with and without a shunt.
Results: Of 818 patients who underwent cranial operations, 28 (3.4%) had a VP shunt. Four of these 28 (14.3%, 95% confidence interval [CI] 4.0%-32.7%) developed postoperative complications, compared to 42 of 790 (5.3%, 95% CI 4.0%-7.1%) without a history of VP shunt ($P = .07$). In addition, patients with a shunt were more likely to have longer cranial procedures ($P = .04$), longer hospital stays ($P = .05$), and more computed tomography scans during their craniotomy-associated admission ($P = .002$). Multivariate analysis, though not significant, demonstrated that the presence of a shunt contributed to the development of complications (odds ratio [OR] 2.24, 95% CI .70-7.13, $P = .17$). Length of surgery (OR 1.17, 95% CI 1.04-1.31, $P = .01$) and length of stay (OR 1.04, 95% CI 1.01-1.07, $P = .01$) were significantly longer in those with a postoperative complication.
Conclusion: We found a nonsignificant trend toward increased postoperative complications in patients with a VP shunt who underwent a subsequent cranial operation.
Key Words: Ventriculoperitoneal shunt—craniotomy—complication—cerebrospinal fluid—shunt

Introduction

Ventricular shunting is a routine neurosurgical procedure for conditions that require cerebrospinal fluid (CSF) diversion, including congenital hydrocephalus, normal pressure hydrocephalus, pseudotumor cerebri, and acquired hydrocephalus, secondary to conditions such as subarachnoid hemorrhage (SAH), trauma, infection, and mass occupying lesions.[1,2] The most common type of ventricular shunt placed is a ventriculoperitoneal (VP) shunt. Although commonly performed, VP shunting is not without complications.

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In fact, single-center studies investigating shunt-related complications have reported a major complication rate of 17.1%, overall complication rate of 58%, and shunt reoperation rates ranging from 17% to 69%.[3-5] Examples of complications include intracerebral hemorrhage, mechanical dysfunction, and shunt infection.

VP shunt-related CSF diversion alters pressure and fluid dynamics within the brain.[6-8] These alterations have the potential to complicate future cranial operations, a not uncommon occurrence for patients harboring vascular or tumor-associated pathologies. We postulated that the alteration of pressure and fluid dynamics from CSF diversion could potentially put patients undergoing subsequent cranial operations at higher risk of complications.

The purpose of this study was to determine whether patients with VP shunts are at increased risk of complications in subsequent neurosurgical cranial operations. To standardize the cohort, we chose to examine patients whose initial cranial operation was for the management of a cerebral aneurysm. We hypothesized that such patients may be at an increased risk of developing symptomatic hemorrhages, hygromas, or infections due to enlargement of epidural and subdural potential spaces initially created during the cranial procedure.[9]

Methods

Study Design

We performed a retrospective cohort study of all patients undergoing a cranial operation for management of cerebral aneurysms. Patient medical record numbers were collected through the University of Michigan Data Office for Clinical and Translational Research. Approval for this study was obtained from the University of Michigan Institutional Review Board.

Patient Selection

Adult patients (≥18 years old) who presented for cerebral aneurysm clipping from January 1, 2005 through December 31, 2014 with Current Procedural Terminology codes 31080 through 31087 and International Classification of Diseases, Ninth Revision (ICD-9) codes 22.41 and 22.42 were included in the analysis.

Clinical Data

The following data were collected for each patient meeting the above selection criteria: age, sex, history of diabetes mellitus, current smoking status, presence of a SAH at the time of microsurgical clipping, location of the aneurysm (anterior versus posterior circulation), length of surgery (in hours), number of postoperative head computed tomography (CT) scans during the hospital admission, length of hospital admission (in days), presence of postoperative complication, and presence of a pre-existing VP shunt (i.e., a shunt placed prior to the cranial procedure). Data were collected by using the Electronic Medical Record Search Engine (EMERSE), a free-text search engine designed to interrogate medical records at the University of Michigan.[10] EMERSE searches all clinical notes and imaging studies, using Boolean terminology, for any search terms entered.

We defined postoperative complications as any one of the following: (1) evidence of new or enlarging hemorrhage of any kind on follow-up CT scans; (2) evidence of new or enlarging subdural hygromas on follow-up CT scans; or (3) the development of postoperative infections, such as meningitis, epidural abscess, or osteomyelitis. Additionally, for the purposes of this study, we defined cranial procedures as either a craniotomy, a craniectomy, or a cranioplasty.

When querying EMERSE, the following terms were used to identify the presence of a VP shunt: "ventriculoperitoneal shunt," "VP shunt," or "shunt." We only considered VP shunts for this study; therefore, patients with a ventriculostomy or other type of shunt were excluded.

Statistical Analysis

Chi-squared, Fisher exact, and *t* tests were used to investigate (1) the demographic differences between patients who developed a complication and those who did not develop a complication, and (2) the demographic and clinical differences between patients with a VP shunt in place before a cranial procedure and those without a VP shunt before a cranial procedure. To evaluate the relative contributions of the covariates, we performed a univariate logistic regression for each variable against the presence of postoperative complications. All variables with $P < .20$ on univariate analysis were included in a multivariate logistic regression. We considered a 2-sided P value $\leq .05$ to be statistically significant. All data were analyzed using SPSS software, Version 24.0 (IBM Corp., Armonk, NY) or SAS 9.4 software (SAS Institute Inc., Cary, NC).

Results

Of the 818 patients who underwent cranial operations for aneurysm clipping, 71.8% were females and the average age was 52.7 ± 10.8 years old. Twenty-eight (3.4%) of the patients with a cranial procedure had a VP shunt already in place at the time of their cranial operation. Over 98% of clipped aneurysms were anterior circulation aneurysms; aneurysm location was not associated with the presence of a postoperative complication. Additional demographic and clinical data are given in Table 1.

In summary, 46 (5.6%) patients developed a postoperative complication. Patients with complications had significantly longer surgeries (8.6 ± 3.0 versus 7.3 ± 2.2 hours, $P < .001$), significantly more head CT scans during their hospital admission (2.6 ± 2.9 versus .9 ± 1.6, $P < .001$), and a significantly longer length of stay in the hospital

Table 1. *Demographic and clinical characteristics of patients with and without a postoperative complication*

	Patients with a complication (n = 46)	Patients with no complication (n = 771)	*P* value
Age (y)	52.3 (11.8)	52.7 (10.8)	.82
Female sex	33 (70.2%)	554 (71.9%)	.81
Diabetes	5 (10.6%)	80 (10.4%)	.95
Currently smoking	20 (42.6%)	330 (42.8%)	.97
Subarachnoid hemorrhage	14 (29.8%)	216 (28.0%)	.79
Aneurysm location			.99
Anterior circulation	46 (100.0%)	760 (98.4%)	
Posterior circulation	0 (0.0%)	12 (1.6%)	
Length of surgery (h)	8.6 (3.0)	7.3 (2.2)	<.001
Shunt before cranial procedure	4 (8.7%)	23 (3.0%)	.07
Number of head CT scans during hospital admission	2.6 (2.9)	.9 (1.6)	<.001
Length of hospital admission (d)	11.9 (9.1)	7.5 (7.4)	<.001

Abbreviation: CT, computed tomography.

(11.9 ± 9.1 versus 7.5 ± 7.4 days, $P < .001$) compared to patients without a complication. Nearly 9% of patients with a complication had a shunt before their cranial operation compared to only 3.0% of patients without a complication ($P = .07$).

Demographic and clinical details on patients with and without a VP shunt placed before a cranial operation are presented in Table 2. Patients with a VP shunt in place before their cranial procedure were significantly more likely to have presented with a SAH (57.1% versus 27.1%, $P = .001$) compared to patients without a pre-existing VP shunt. Additionally, these patients had significantly longer operations (8.3 ± 2.3 versus 7.4 ± 2.3 hours, $P = .04$), significantly longer hospitalizations (10.5 ± 13.2 versus 7.7 ± 7.3 days, $P = .05$), and significantly more CT scans during their hospital admission (2.0 ± 3.3 versus 1.0 ± 1.7, $P = .002$) compared to patients without a VP shunt before their cranial operation.

Of the 28 patients with a VP shunt placed prior to their cranial operation, 4 (14.3%, 95% confidence interval [CI] 4.0%-32.7%) developed postoperative complications compared to 42 of the 790 (5.3%, 95% CI 4.0%-7.1%) without a history of VP shunt ($P = .07$, Table 1). Summaries of the clinical courses of these 4 patients are provided in Table 3. All 4 patients presented with a SAH. One patient had a complication related to the development of an epidural abscess, whereas the other 3 experienced complications related to new hemorrhage or hygroma formation.

Multivariate analysis demonstrated a nonsignificant trend toward increased complications for craniotomies performed in the presence of a pre-existing VP shunt compared to those without a shunt (odds ratio [OR] 2.24, 95% CI .70-7.13, $P = .17$). Length of surgery (OR 1.17, 95% CI 1.04-1.31, $P = .01$) and length of hospital stay (OR 1.04, 95% CI 1.01-1.07, $P = .01$) were significantly longer in those with a postoperative complication compared to those without a postoperative complication (Table 4).

Table 2. *Demographic and clinical characteristics of patients with and without a prior shunt*

	Patients with a shunt before cranial procedure (n = 28)	Patients without a shunt before cranial procedure (n = 790)	*P* value
Age (y)	54.1 (7.4)	52.6 (11.0)	.46
Female sex	26 (92.9%)	561 (71%)	.01
Diabetes	3 (10.7%)	82 (10.4%)	.96
Currently smoking	14 (50.0%)	336 (42.5%)	.43
Subarachnoid hemorrhage	16 (57.1%)	214 (27.1%)	.001
Length of surgery (h)	8.3 (2.3)	7.4 (2.3)	.04
Aneurysm location			.99
Anterior circulation	28 (100.0%)	778 (98.5%)	
Posterior circulation	0 (.0%)	12 (1.5%)	
Number of head CT scans during hospital admission	2.0 (3.3)	1.0 (1.7)	.002
Length of hospital admission (d)	10.5 (13.2)	7.7 (7.3)	.05

Abbreviation: CT, computed tomography.

Table 3. *Clinical course of patients with complications who had ventriculoperitoneal (VP) shunt prior to cranial procedure*

Patient number	Age (y)	Sex	Clinical course
1	69	F	Presented to the ED with ruptured PCOM artery aneurysm that was emergently coiled. After 2 failed ventriculostomies, a VP shunt was placed. Twelve days later, a craniotomy was performed for aneurysm clipping. A month later, computed tomography was concerning for hygroma and intraventricular hemorrhage.
2	56	F	Presented to the ED with a ruptured ACOM artery aneurysm that was emergently coiled. She experienced acquired hydrocephalus for which a VP shunt was placed. Six months later, a recurrence of the aneurysm was noted so clip ligation of the aneurysm was performed. A re-do craniotomy was ultimately performed secondary to an epidural abscess.
3	42	F	Presented to ED with ruptured middle cerebral artery aneurysm. Underwent clip ligation and hematoma evacuation. A hemicraniectomy was subsequently performed secondary to malignant cerebral hypertension. A VP shunt was placed 2 mo later, followed by a cranioplasty that was complicated by an intraoperative hematoma.
4	53	F	Presented to the ED with a ruptured ACOM aneurysm and underwent clip ligation of the aneurysm. After multiple failed attempts to wean from the ventriculostomy, a VP shunt was placed. About a month later, she presented to the ED with a second intracranial bleed that necessitated a decompressive hemicraniectomy.

Abbreviations: ACOM, anterior communicating; ED, emergency department; PCOM, posterior communicating.

Table 4. *Univariate and multivariate logistic regression models of variables associated with complication*

	Univariate analysis			Multivariate analysis		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Age (y)	1.00	.97-1.02	.82			
Female	.92	.49-1.76	.81			
Diabetes	1.03	.40-2.67	.95			
Currently smoking	.99	.55-1.80	.97			
Subarachnoid hemorrhage	1.09	.57-2.08	.79			
Length of surgery (h)	1.21	1.09-1.35	<.001	1.17	1.04-1.31	.01
Length of hospital admission (d)	1.05	1.02-1.08	<.001	1.04	1.01-1.07	.01
Shunt before cranial procedure	2.97	.99-8.95	.05	2.24	.70-7.13	.17

Abbreviations: CI, confidence interval; OR: odds ratio.

Discussion

The placement of a VP shunt is a common neurosurgical procedure for the treatment of hydrocephalus and other CSF-related pathologies. Placement of a VP shunt has been shown to alter intracranial fluid dynamics, leading to potential collections within the epidural and subdural spaces.[11] When comparing outcomes for cranial operations in patients with and without a previously placed VP shunt, we demonstrate a nonsignificant trend toward increased postoperative complications in shunted patients compared to those without a shunt.

When a craniotomy, craniectomy, or cranioplasty is performed, the meninges are disturbed and potential spaces are created below the surgical site. Bullock et al demonstrated that nearly 7% of patients who underwent craniotomy for evacuation of a traumatic intracranial mass developed a second hematoma at the operative site.[9] The authors postulated that the large potential spaces remaining under the craniotomy predisposed this population to rehemorrhage. Multiple additional authors have published on the risk of postcraniotomy hemorrhage.[12-14] The altered fluid dynamics introduced with the placement of a VP shunt could enlarge the potential spaces created by the cranial operation. With enlargement of potential spaces, there is an increased risk of hemorrhage, hygroma, and infection.[9,15]

Among the 4 patients in our study who had a previously placed VP shunt and also had a postoperative complication, 2 had postoperative hemorrhage, 1 had a hygroma and intraventricular hemorrhage, and 1 had an epidural abscess. Two of these complications required further operative care to treat the complication. Interestingly, presentation with a SAH was not significantly associated with postoperative complications, suggesting that presence of a VP shunt may more strongly predict the development of postoperative complications than does the severity of the presenting pathology. The lack of statistical significance found in this study is likely due to the small sample size, with preexisting VP shunts present in just over 3% of the patients undergoing a cranial operation.

Patients who had a VP shunt in place before their cranial operation had significantly longer operations, longer hospital admissions, and more CT scans during their hospital admission. This suggests that the presence of a VP shunt could potentially complicate the initial procedure and establish a level of concern in the operating surgeon that causes an increased propensity to order further diagnostic imaging and keep a patient in the hospital longer. Longer operations and longer hospital admissions were also both significantly associated with an increased complication rate, which is expected. Given that the majority of the aneurysms treated in this series were anterior circulation aneurysms, the location of the aneurysm was not associated with any increased complication rate. Similarly, since there were no giant aneurysms in this study, aneurysm size was not considered in the analysis.

This study is limited by the retrospective nature of its design and resulting errors in data acquisition. Additionally, this study is limited by the small number of patients with a VP shunt prior to their cranial operation. Due to the small number of patients, we were not able to standardize what the preoperative state was for those with and without shunts. This study is also limited by the lack of standardized clinical outcome scores for patients such as a modified Rankin Score. To provide an understanding of the severity of the complications, we utilized qualitative data regarding the complications. Future research studies that prospectively gather these data or utilize a national registry could allow for a more robust analysis of this important question. Finally, this study is limited by the heterogenous nature of the cranial procedures performed. Since some patients had multiple cranial procedures (e.g., a craniectomy followed by a cranioplasty), there is potential confounding introduced by the prior cranial procedures. With a larger sample size, there would be additional opportunity to homogenize the population and appropriately adjust for the confounding variable.

Conclusion

We found a nonsignificant trend toward an increase in postoperative complications in patients with a VP shunt who underwent subsequent cranial procedures when compared to patients without a VP shunt.

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