Evaluation of Ventriculoperitoneal Shunt-Related Complications in Intracranial Meningioma with Hydrocephalus

Shyamal C. Bir¹ Shabal Sapkota¹ Tanmoy K. Maiti¹ Subhas Konar¹ Papireddy Bollam¹ Anil Nanda¹

¹Department of Neurosurgery, Louisiana State University Health-Shreveport, Shreveport, Louisiana, United States

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Address for correspondence Anil Nanda, MD, FACS, Department of Neurosurgery, Louisiana State University Health-Shreveport, 1501 Kings Highway, Shreveport, LA 71130-3932, United States (e-mail: ananda@lsuhsc.edu).

Abstract

Objective Meningioma is a common intracranial tumor that predisposes patients to hydrocephalus which may require a permanent cerebrospinal fluid (CSF) diversion procedure such as ventriculoperitoneal (VP) shunts. We reviewed our long-term experience with VP shunts for the management of hydrocephalus in patients with meningioma.

Methods and Materials A total of 48 Patients with meningioma who underwent VP shunt insertion for hydrocephalus from 1990 to 2013 was included in our case series. The study population was evaluated clinically and radiographically after VP shunt placement.

Results Overall shunt failure was seen in 13 (27%) patients. Single and multiple shunt revisions were required in eight (16.7%) and five (10.4%) patients, respectively. The overall shunt revision within 6 months, 1 , and 5 years was 19, 23, and 27%, respectively. Male patient was significantly associated with the longer survival after shunt placement. Revisions free survival after 3, 5, 10, and 15 years of VP shunt placement were 70, 46, 30, and 20%, respectively. Finally, in regression analysis, age greater than 65 years ($p = 0.02$, 95% confidence interval (CI) = 0.1–0.13), tumor in posterior fossa ($p < 0.0001$, 95% CI = 0.1–0.23), tumor size (> 5 cm) ($p = 0.3$, 95% CI = 0.01–0.19), and Simpson resection grades II to IV ($p = 0.04$, 95% CI = 0.07–0.2) were identified as positive predictors of requirement of CSF flow diversion

Conclusion The findings of the present study reveal that VP shunting is an important treatment option for the management of hydrocephalus in patients with meningioma. Further studies using less invasive techniques are warranted to compare the benefits of VP shunt for the management of hydrocephalus.

Keywords

- hydrocephalus
- meningioma
- VP shunt
- outcome
- complications
- predictive factors

Introduction

Hydrocephalus encompasses a group of disorders, including intracranial tumors, congenital anomalies, infections, and brain hemorrhage and head injury.^{1,2} Patients with intracranial tumors are at risk of developing hydrocephalus because tumors can block the cerebrospinal fluid (CSF) pathways. Among the all primary brain tumors, the incidence of intracranial meningioma

is 30% and hydrocephalus frequently develops in patients with meningioma.³ In general, management of hydrocephalus associated with meningioma is a growing concern in neurosurgery since there is no existing consensus regarding the management for these particular patients.⁴ During the last two decades, ventriculoperitoneal (VP) shunt was widely used for the management of hydrocephalus.^{4–6} Research-based evidence suggested that the VP shunt treatment reduced the morbidity

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and mortality of hydrocephalus. However, it is associated with potential complications including shunt failure due to obstruction, infections, and mechanical problems etc.^{7,8} The VP shunt failure may require repeated surgeries as well as multiple shunt revisions, and therefore, the management of hydrocephalus in patients with shunt failures is still a challenging problem for the neurosurgeons across the globe.⁴ In the present study, we retrospectively reviewed hydrocephalus patients associated with meningioma from our institutional database to investigate the outcome of the surgical management of hydrocephalus including the incidence of VP shunt revision and its complication rates.

Materials and Methods

The study was approved by the Institutional Review Board at LSU Health Shreveport, Shreveport, Louisiana, United States. Information related to clinical history, operative reports, imaging studies, and outcomes of the patients with hydrocephalus and meningioma between 1990 and 2013 were collected retrospectively by review of the patients' charts and follow-up notes. The details of the patients' inclusion and exclusion criteria and their selection for the study are summarized in ► **Fig. 1**. In this series, median follow-up time was 26 months and we have lost four (8.3%) patients from the follow-up. In the present study, almost half of the tumor location was in the

ventricle and petroclival region (47.5%). In this series, out of 48 patients, 14 patients received VP shunt before meningioma (ventricle and petroclival location) resection, 17 cases required VP shunt after initial resection of tumor. A total of 13 patients underwent VP shunt after second surgery of recurrent meningiomas. The cause of hydrocephalus could be intraventricular hemorrhage, blood in subarachnoid space or infection. Four patients who received Gamma Knife Radiosurgery (GKRS) as primary treatment developed hydrocephalus at late follow-up. GKRS, itself was not a predisposing factor for development of hydrocephalus in present cohort.

The primary outcome of interest was the overall shunt revision rate and revision-free survival rate in hydrocephalus patients with meningioma. The overall shunt failure was defined as either revision or replacement of an existing VP shunt performed during the follow-up period.

Statistical Procedures

Commercially available software, SPSS version 21.0 (SPSS, Inc., Chicago, Illinois, United States), was used for statistical analysis. The Cox proportional hazards regression model was used to determine independent significant factors for shunt survival. The Kaplan–Meier method of survival analysis was used to estimate the overall and revision-free survival rate. The log-rank (Mantel–Cox) test was used to analyze the survival difference in the cases. When necessary a chi-square test was also used. A *p* value of < 0.05 was considered as significant.

Results

A total of 1,018 patients who underwent shunting for hydrocephalus between 1990 and 2013 were initially screened and 249 intracranial tumor patients with VP shunt placement were taken for further screening. Of the 249 patients, 48 patients with hydrocephalus and meningiomas were included for the evaluation (► **Fig. 1**). Of these 48 patients, 15 (28.7%) were males and 33 (71.3%) were females, one-third (33.3%) of the patients were African Americans, and two-thirds (66.7%) were Caucasians. The median age of patients in our series was 64 years (range, 25–86 years). Overall, 12 (25%) tumors were located in the anterior cranial fossa, 7 (14.5%) tumors were in middle cranial fossa, and 23 (48%) tumors were located in the posterior cranial fossa. The average tumor volume before VP shunt placement was 5.7 cm³ (range, 1.2–17.6 cm³). Of the 48 patients, 46 (95.8%) had obstructive hydrocephalus and 2 (4.2%) patients had communicative hydrocephalus (► **Table 1**).

Shunt Revision

The median follow-up time of our series was 26 months. Out of 48 cases with hydrocephalus after VP shunt placement, 13 (27%) patients experienced single or multiple shunt failures requiring shunt revisions. Single shunt revision was required in eight (16.7%) patients and multiple shunt revisions were needed in five (10.4%) patients after the initial shunt placement. Moreover, after initial shunt placement, 7 (15%), 9 (19%), 11 (23%), and 13 (27%) patients developed shunt failures requiring shunt revisions within 3, 6 months, 1, and 5 years, respectively (► **Table 2**).

Fig. 1 Flowchart depicting the selection of the patients with hydrocephalus and meningiomas.

Table 1 Patient demographics

Variables	Value
Total patients	48
Age (y)	
Median	64
Range	25–86
Gender	
Male	15 (28.7%)
Female	33 (71.3%)
Ethnicity	
Caucasians	32 (66.7%)
African Americans	16 (33.3%)
Tumor location	
Anterior cranial fossa	12 (25%)
Middle cranial fossa	7 (14.5%)
Posterior cranial fossa	23 (48%)
Petroclival region	17 (35%)
Ventricles	6 (12.5%)
Hydrocephalus type	
Obstructive	46 (95.8%)
Communicative	2 (4.2%)
Reasons of ventriculoperitoneal shunt placement	
Before tumor resection	14 (29.3%)
After first surgery of meningiomas	17 (35.4%)
After second surgery for recurrent	
Meningiomas	13 (27%)
Radiosurgery	4 (8.3%)
Tumor size (cm ³)	5.7 (1.2–17.6)
Median follow-up time (mo)	26 (0.7–180)
Cohort attrition	4 (8%)

Note: Characteristics of patients (age, gender, and ethnicity) with hydrocephalus and meningioma.

Reasons of Shunt Revision

The most common reason for shunt revisions in hydrocephalus patients with meningioma are described in ►Table 3. A total of 26 shunt revisions were required in 13 patients for various reasons including infections, obstruction, over drainage of shunt, mechanical and other shunt-related complications. Among the above mentioned factors, obstructions accounted the total of 14 (29.17%) shunt revisions and proximal shunt complications caused 16 (33.3%) shunt revisions. Infections caused a total of four (8.3%) revisions. In this cohort, protein level in CSF was determined and average protein level was 97.06 ± 48.74. The average CSF protein level in the patients underwent shunt revisions was 115.07 ± 74.77 mg/dL. However, average CSF protein level in the patients without shunt revisions was 90.37 ± 33.77 mg/dL and there was no significant difference ($p = 0.12$) in CSF protein content between these two groups.

Table 2 Shunt revision in the patients

Parameter	Value
Total patients with shunt revision	13 (27%)
Single revision	8 (16.7%)
Multiple revisions	5 (10.4%)
Patients with shunt revision within 3 mo	7 (15%)
Patients with shunt revision within 6 mo	9 (19%)
Patients with shunt revision within 1–3 y	11 (23%)
Patients with shunt revision within 5 y	13 (27%)

Note: Summary of shunt revisions in the patients with hydrocephalus and meningioma after ventriculoperitoneal shunt placement.

Table 3 Reasons of shunt revision after ventriculoperitoneal shunt placement

Variables	Value
Infections	4 (8.3%)
Obstruction	14 (29.17%)
Overdrainage	1 (2%)
Proximal shunt complication	16 (33.33%)
Distal shunt complication	4 (8.3%)
Shunt externalization	3 (6.3%)
Shunt replacement	3 (6.3%)
Valve replacement	3 (6.3%)
Other	7 (14.6%)

Note Summary of factors responsible for shunt revisions in the patients with hydrocephalus and meningioma after ventriculoperitoneal shunt placement.

Table 4 Factors for shunt survival after placement

Variables	Odds ratio	95% confidence interval (lower-upper)	p Value
Gender (Male)	0.17	0.03–0.83	0.028
Ethnicity	0.68	0.18–2.52	0.56
Prior procedure	0.61	0.12– 3.06	0.54

Note: Predictive factor for shunt survival after ventriculoperitoneal shunt placement in the patients with hydrocephalus and meningioma.
^a $p < 0.05$ is considered as significant.

Factors of Shunt Survival

Shunt survival period differed based on various factors including gender, ethnicity, and procedure before shunt revision etc. The median survival period for the male patients was 39 months and the median shunt survival in the female patients was 20 months. This difference in median shunt survival time between the two groups reached statistical significance (log-rank $p = 0.016$, ►Fig. 2). Procedure before shunt insertion ($p = 0.545$) and ethnicity ($p = 0.56$) did not show any significant difference in shunt survival in our case series. In Cox regression analysis, only male gender was identified as the positive predictor of shunt survival ($p = 0.028$, ►Table 4).

Fig. 2 Comparison of shunt survival based on gender in the patients with hydrocephalus and meningioma. X-axis reports the time in months. A p value of < 0.05 is considered as significant.

Fig. 4 Kaplan-Meier revision-free survival rate in the patients with hydrocephalus and meningioma after VP shunt placement. X-axis reports the time in months. VP, ventriculoperitoneal.

Survivability of the Patients

The overall survival in the patients with hydrocephalus associated with meningioma after 3, 5, 10, and 15 years of VP shunt placement were 75, 50, 45, and 0%, respectively, whereas revision-free survival after 3, 5, 10, and 15 years was 70, 46, 30, and 20%, respectively (►Figs. 3 and 4). In earlier time points, there was no significant difference in revision-free survival rate compared with overall survival. However, the rate of revision-free survival was significantly higher after 15 years (20 vs. 0%, $p = 0.0001$) compared with overall survival (►Table 5).

Predictors of Requirement of CSF Flow Diversion

Regression analysis was performed to identify the predictors of requirement of CSF flow diversion in the patients underwent resection of meningiomas. The following covariates

were included in the model: age (≥ 65 vs. < 65 years), the World Health Organization (WHO) grade (I vs. II–III), location of tumor (posterior cranial fossa vs. others locations), Simpson grades (grade I vs. II–IV), tumor size (> 5 vs. ≤ 5 cm) and infection (yes vs. no). In regression analysis, age greater than 65 years ($p = 0.02$, 95% CI = 0.1–0.13), tumor in posterior fossa ($p < 0.0001$, 95% CI = 0.1–0.23), tumor size (> 5 cm) ($p = 0.3$, 95% CI = 0.01–0.19), and Simpson resection grades II to IV ($p = 0.04$, 95% CI = 0.07–0.2) were identified as positive predictors of requirement of CSF flow diversion. However, WHO grade ($p = 0.81$, 95% CI = 0.09–0.12) and infection ($p = 0.39$, 95% CI = 0.06–0.12) did not show any significant relation to requirement of CSF flow diversion.

Discussion

Current treatment modalities for hydrocephalus associated with meningioma include permanent placement of VP shunts, endoscopic third ventriculostomy (ETV) or temporarily external ventricular drains.⁴ Although VP shunts are beneficial for the treatment of hydrocephalus; shunt revision, removal, and

Fig. 3 Kaplan-Meier overall survival rate in the patients with hydrocephalus and meningioma after VP shunt placement. X-axis reports the time in months. VP, ventriculoperitoneal.

Table 5 Survivability after ventriculoperitoneal shunt placement

Variables	Overall survival (%)	Revision-free survival (%)	p Value
Overall vs. free survival			
After 3 y	75	70	0.63
After 5 y	50	46	0.67
After 10 y	45	30	0.057
After 15 y	0	20	0.0001

Note: Patient's overall survival after ventriculoperitoneal shunt placement in the patients with hydrocephalus and meningioma.

^a $p < 0.05$ is considered as significant.

replacement is imminent due to possible complications from the shunt itself.^{7,8} Thus, management of hydrocephalus-associated meningioma remains a great challenge to neurosurgeons and it is controversial. In this retrospective study of a cohort of 48 patients with meningioma with hydrocephalus, we analyzed the incidence of shunt failures, overall shunt survival, and predictive factors of shunt survival. This study has high potential for improving the management of hydrocephalus associated with meningiomas that are treated with VP shunts.

The present study revealed that the overall incidence of shunt revision was 27% in hydrocephalus patients with meningioma. The rate of shunt revision gradually increased from 15% at 3 months to 27% at 5 years after initial shunt insertion. This study finding on incidence of shunt revision is very consistent with the previous studies.^{7,9–11} The incidence of shunt revision differs considerably depending on the cause of hydrocephalus. Although our finding is consistent with earlier reports, the patient population in this study is confined to intracranial meningioma. However, present study is more comparable with other previous studies where authors reported that 27.8 and 30% patients with hydrocephalus associated with intracranial tumors required shunt revisions.^{4,12} Moreover, the 6-month shunt revision rate (19%) found in our study is consistent with earlier reports (18.7 and 18.5%).^{4,13} Among overall shunt revision (27%) in our series, 23% revision was within 1st year of shunt placement. Similarly, Khan et al reported median time for shunt placement to shunt revision was 120 days and tumor-related hydrocephalus patients are more prone for shunt malfunction.¹⁴ In this series, the cause of shunt revision within 1st year of shunt placement was either infection or obstruction. Protein level in CSF might play important role in development of shunt malfunction.^{15–19} On the contrary, several reports showed that there was no association with increased CSF protein level and shunt failure.^{20–26} Earlier report demonstrated that elevated level of CSF protein and subsequent deposition of that protein in VP shunt catheter did not cause obstruction of the shunt catheter.²⁵ Another study suggested that a high protein level in CSF did not cause to develop shunt infection.²⁶ Most importantly, a prospective study showed that an increased CSF protein did not influence the development of shunt complications, and placement of VP shunt should not be delayed in patients with elevated CSF protein.²³ In this cohort, there was no significant difference ($p = 0.12$) in CSF protein content between the group of patients with or without shunt revisions.

This study also demonstrated how multiple factors including obstruction, infection, and complications in the proximal or distal shunt, etc., are associated with shunt failure in the patients with hydrocephalus associated with meningioma. Among the above-mentioned factors, proximal shunt complication showed the higher number of multiple revisions in our series which is consistent with previous reports.^{4,27} We have also looked into the predictors of shunt survival in the patients with hydrocephalus associated with meningioma and found that only male gender positively affects the shunt survival in these patients.

Another objective of the VP shunt treatment in the patients with hydrocephalus associated with meningioma

is to identify the revision-free survival. Our finding showed that the overall survival in the patients with hydrocephalus and meningioma after 3, 5, 10, and 15 years of VP shunt placement were 75, 50, 45, and 0%, respectively. However, the shunt revision-free survival after 3, 5, 10, and 15 years was 76, 46, 30, and 20%, respectively. These findings were consistent with a previous report.⁴ Moreover, the rate of revision-free survival was significantly higher after 15 years (20 vs. 0%, $p = 0.0001$) compared with overall survival. Thus, multiple shunt revision has a negative impact on the survivability of the patients with hydrocephalus and meningioma.

In the past two decades, image-guided surgery is getting popularity in the field of neurosurgery, and has simplified the access to the region of surgery with minimal invasiveness, enhancement of proper shunt placement, and reduced morbidity. Wilson et al²⁸ reported statistically significant difference between freehand catheters and stereotactic-guided catheters ($p < 0.001$). With the technological advances in neuronavigation, the system became user friendly, perceptive, and able to provide real-time anatomical information.^{29–31} However, neuronavigation has certain limitations including chance of unintended brain injury due to change of surgeon's view from microscope and cost. Another limitation of neuronavigation is unable to obtain a more favorable surgical position after completion of patient-to-image registration.^{29–31} In this series, we have not performed neuronavigation before shunt placement, and this might have avoided some revisions.

ETV has certainly become an important mode of treatment in recent years.^{32–38} ETV before resection of tumor is controversial as the resection of tumor itself can lead to resolve of hydrocephalus. Moreover, it can be blocked by blood products and tumor debris. The procedure itself is not free from risks as well. But in patients where urgent management of hydrocephalus is required or patients with high risk of development of postoperative hydrocephalus, it is wise to do an ETV before resection the tumor. However, choice of ETV after resection of tumors is rewarding most of the times and less controversial. Several good literatures are available depicting the success of ETV after resection of tumors, especially for posterior fossa tumors (success rate is ~90%).³⁹ In our center we have changed our policy keeping in track with recent developments. However, in this particular study we have only included the patients who underwent VP shunt rather than ETV since our aim was to look for predictive factors for shunt malfunction in hydrocephalus with intracranial meningioma.

Adjustable or programmable valves including Polaris (Sophysa, Orsay, France), proGAV (Aesculap, Inc., Center Valley, Pennsylvania, United States) or Strata (Medtronic, Minneapolis, Minnesota, United States), have the characteristics of noninvasive readjustment of CSF pressure and flow in an implanted shunt. The objective of the newer adjustable valves was to aid better regulation of CSF pressure, flow, and drainage, and decrease the number of shunt failures due to underdrainage, overdrainage, and slit ventricle syndrome.^{40,41} Moreover, report has been showed that programmable valve reduced the number of proximal

obstruction and malfunctions.⁴² Recent study suggested that Polaris or proGAV shunt valve retained the pressure setting after exposure to static and radiofrequency magnetic field.^{43,44} The patients with these programmable valve is less likely to adjust the pressure after imaging procedure and these programmable valve may be beneficial for hydrocephalus patients with meningioma undergoing magnetic resonance imaging procedure.^{43,44} However, although technological advances in shunt development incredibly influenced the management of hydrocephalus, their impact was not very impressive on shunt failure. Earlier studies revealed that adjustable valve did not decrease the requirement of shunt revision in the adult patients with hydrocephalus.^{9,45} Our earlier report suggested that there was no difference in shunt failure between programmable valve and pressure-controlled valve.⁴¹ In this series, we have applied programmable valve in five (10.4%) patients but there was no difference in requirement of shunt revision. Thus far, literature remains undecided about using programmable valve for the treatment of hydrocephalus and further studies are warranted to address this issue.

In the present study, we have also sought to determine the predictors of requirement of CSF flow diversion. Burkhardt et al³ showed that patient's age, duration of surgery, duration of hospital stay, and large tumor volume, infection, and preoperative embolization were associated with occurrence of hydrocephalus after resection of meningiomas. Similarly, our data revealed that patients age ≥ 65 years and tumor size > 5 cm were significantly related to requirement of CSF flow diversion. In addition, although Burkhardt et al³ did find well correlation between Simpson grades of resection and occurrence of hydrocephalus, we have found that Simpson grades II to IV resection and tumor in posterior fossa have significant correlation with requirement of CSF flow diversion. This finding is consistence with result of the pervious report.⁴⁶ However, in our series, WHO grade and postoperative infection did show any significant correlation with requirement of CSF flow diversion, which was in accord with the existing literature.³

The present study is subject to several important limitations. One important limitation is the retrospective nature of the study that explores the long-term management of hydrocephalus in patients with meningioma. Although uniform technique for VP shunt insertion was practiced, the surgeries were performed by different neurosurgeons.

Taken together, with lower percentage of shunt revision, the results of our series revealed that VP shunting is a good option for the management of hydrocephalus in patients with meningioma. However, prospective clinical studies with a large volume of patients are warranted to identify the revision-free shunt survival rate in hydrocephalus patients with meningioma. Factors regarding the proximal shunt complication need to be identified and resolved, since the major cause of shunt revision was obstruction in the proximal shunt. Recent studies are focused on improving shunts by developing material such as antibiotic impregnation in the shunt and valve mechanisms.^{47,48} In

addition, other treatment modalities including endoscopic ventriculostomy or use of neuronavigation for shunt placement need to be compared with the regular VP shunt procedure to avoid shunt-related complication in meningioma patients.

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