Abstract

Background: Optimal surgical management of patients presenting with primary shunt failure in the era of neuroendoscopy remains complex. The value of replacing the entire shunt system as opposed to a single shunt component has not been assessed extensively.

Methods: In a retrospective study, the records of all patients who underwent their first shunt revision due to mechanical obstruction between September 2007 and December 2011 were reviewed. Shunt revisions were classified as total (entire shunt replaced) or partial (only malfunctioning component replaced). Patients having a minimum follow-up of 1 year after primary shunt revision were included in the study. Kaplan–Meier (shunt survival curves) and log-rank analysis were used to compare failure rates between partially and totally revised shunts.

Results: Records of 62 patients in whom cause of primary shunt failure was obstruction (proximal or distal) were analyzed retrospectively. At the end of follow-up period, 26 out of 28 partial revision group and 22 out of 34 total revision group had shunt failure. The median survival of the shunt in the partial revision and total revision groups was 60 and 270 days, respectively. The method (partial/total revision) related difference in shunt survival duration was statistically significant as shown by log-rank analysis (log-rank test value = 5.94 and P < 0.05).

Conclusion: Partial revision of shunt predisposes to accelerated shunt failure as compared with total revision in cases of obstructed ventriculoperitoneal shunt.

Key Words: Hydrocephalus, revision, ventriculoperitoneal shunt failure

INTRODUCTION

Ventriculoperitoneal (VP) shunting is a frequently performed procedure in neurosurgical practice. Mechanical obstruction is the most common cause of shunt failure requiring shunt revision. A subgroup of patients often requires dozens of shunt revision during their lifetime. One year failure rates as high as 40% underlying the abundance of shunt revisions performed. In most centers, the ratio of shunt revision to initial shunt surgery is 2:1. Several studies have examined the surgical technique, shunt hardware, and postoperative management of cerebrospinal fluid (CSF) shunting procedures in an attempt to improve...
shunt survival. However, only a few studies are available, which examine the consequences of replacing the entire shunt system versus a single component for the revision of a failed CSF shunt.[11,14] Keeping this in view, we retrospectively analyzed the records of patients who had undergone primary shunt revision at our institution from September 2007 to December 2011. We analyzed whether a total or partial replacement of failed CSF shunt was associated with prolonged shunt functioning. Our goal in this retrospective study was to examine our practice patterns to determine if intraoperative shunt revision decision making was accurate and maximized subsequent outcome of shunt.

MATERIALS AND METHODS

The records of all patients (N = 62) who had undergone shunt revision for primary shunt failure from September 2007 to December 2011 in Pt B. D. Sharma University of Health Sciences, Rohtak were reviewed [Table 1]. Only those patients in whom the cause of primary shunt failure was obstruction (whether proximal or distal) were included in the study. Patients requiring shunt revision due to disconnection, infection, slit ventricle syndrome, shunt over drainage, multicavitatory hydrocephalus, and complex shunt system were excluded from the study. In all these patients, a Chhabra’s shunt was used, which is made up of implant grade silastic material and has a ventricular end, a chamber, and a peritoneal end. The chamber has spring in slit valve through which the CSF flow is pressure regulated. There are around 40 holes along the radio-opaque ventricular end, which is 1.5 cm in length. The peritoneal end is also radio-opaque. It is a cost-effective shunt used widely in India and its neighboring countries. Patient age, sex, etiology of hydrocephalus, date of shunt placement, failed shunt component, date of primary shunt revision, and date of last follow-up were collected retrospectively from the patient’s records. All shunts were placed by a full time qualified neurosurgeon on the same day when patient reported as emergency basis to avoid any delay in relieving the raised intracranial pressure. Prior to shunt revision, all patients underwent a detailed clinical examination, computed tomography (CT) scan head, and blood chemistry to know the cause of obstruction. The site of obstruction was diagnosed intraoperatively. To determine the failed shunt component, the ventricular end of the shunt was explored and disconnected from the valve and a water column manometer was used to assess flow and pressure from the ventricular catheter. If there was no free flow or slow flow after disconnection of the ventricular catheter from the valve, the case was diagnosed as obstruction at the proximal end. After the valve was separated from the ventricular catheter, a manometer was attached, with the column filled to 50 mm water. Distal catheter function was considered obstructed if at least the closing pressure of the valve was not attained. The etiology of failure was classified as single-catheter obstruction only when the nonobstructed ventricular or peritoneal catheter clearly demonstrated adequate flow via manometry. If there was any concern of sluggish flow in the nonobstructed catheter, it was considered malfunctioning, classified as a total shunt obstruction and did not meet inclusion criteria for this study. The replacement of the entire shunt system was considered as total shunt revision and replacement of the malfunctioning component alone as partial revision. Valve was also replaced during partial revision of the distal shunt but not in partial revision of proximal shunt. CSF was collected in all patients and sent for gram staining and culture sensitivity. If culture or gram staining is positive, which is classified as shunt infection, it did not meet inclusion criteria for this study. All the patients received injection ceftrixone for initial 5 days in divided doses. Standard follow-up consisted of clinical examination at 1 week, 1 month, 3 months, 6 months, and annually thereafter. CT scan was performed only in patients exhibiting signs and symptoms of shunt malfunction. Only patients having a minimum follow-up of 1 year after primary shunt revision were included in the study.

The study focused on the functional life of each revised shunt. Infections necessitating shunt removal or shunt malfunction leading to subsequent revisions were considered as shunt failure. To compare failure rates between partially and totally revised shunts, univariate analysis using Kaplan–Meier estimates, Kaplan–Meier survival curves, and log-rank tests were conducted. Age and gender distribution of the subjects in both the groups were also analyzed statistically by applying two tailed unpaired ‘t’ tests for age and a Chi-square test for gender analysis.

RESULTS

Out of the total 62 patients of primary shunt failure, 28 underwent partial and 34 underwent total shunt

| Etiology                        | Total cases (n=62) | Partial replacement (n=28) | Total replacement (n=34) |
|---------------------------------|-------------------|---------------------------|-------------------------|
| Postmeningitis                  | 9                 | 5                         | 4                       |
| Meningomyelocele                | 9                 | 3                         | 6                       |
| Congenital                      | 7                 | 4                         | 3                       |
| Posterior fossa tumor           | 6                 | 2                         | 4                       |
| Intraventricular hemorrhage     | 4                 | 3                         | 1                       |
| Posttraumatic                   | 3                 | 3                         | 0                       |
| Encephlocele                    | 3                 | 0                         | 3                       |
| Subarachnoid hemorrhage         | 2                 | 0                         | 2                       |
| Central venous thrombosis       | 1                 | 0                         | 1                       |

Table 1: Patients of different etiology of hydrocephalus undergoing partial or total shunt revision
Revision surgeries [Table 1]. Age ($P = 0.490$) and sex ($P = 0.856$) distribution was nonsignificant in patients of both the groups. Patients in both the groups were also similar according to site of blockage of shunts [Table 2, $\chi^2$, $P = 0.283$]. At the end of the follow-up period, shunt failures were observed in 26 out of 28 patients of the partial revision group and 22 out of 34 patients of the total revision group. The median survival of the shunts in the partial and total revision groups were 60 and 270 days, respectively. The difference in survival of shunts was statistically significant between the two groups as shown by log-rank analysis, that is, log-rank test value = 5.94 and $P < 0.05$ [Table 3 and Figure 1]. The patients in the total revision group had a longer survival of shunts as compared with the partial revision group. There were no statistically significant differences among shunt survival in patients with partial revision having proximal or distal obstruction [Table 3 and Figure 2].

**DISCUSSION**

Mechanical obstruction is the most common cause of shunt failure requiring shunt revision. Proximal shunt obstruction due to occlusion of ventricular catheter is by far the most common cause of shunt obstruction and reported in 70-90% of cases. In present study, the ventricular catheter was blocked in 67.7% of cases. The ventricular catheters are most commonly blocked by ingrowth of the choroid plexus due to flow of CSF drawing the plexus in and by glial tissue from astrocyte proliferation. Less common causes of blocked ventricular catheters are connective tissue, lymphocytes, multinucleated giant cells, neutrophils, foreign material, or ingrowth of tumor cells around the catheter tip. Distal obstruction is seen due to entanglement of the omentum or placement in preperitoneal space. Low grade infections with intraabdominal loculations or pseudocyst formation, disconnection or withdrawal of the catheter tip from peritoneum are the other causes of distal obstruction. Valve obstructions can also be the cause of shunt obstruction and is seen in patients with ventriculitis.

### Table 2: Site of blockage in patients of partial vs. total shunt revision groups

| Type of shunt replacement | Partial (%) | Total (%) | Chi-square test | $P$ value |
|---------------------------|-------------|-----------|-----------------|-----------|
| Partial                   | 11 (39.3)   | 9 (26.5)  | 20 (32.3)       | 0.283     |
| Proximal                  | 17 (60.7)   | 25 (73.5) | 42 (67.7)       |           |
| Total                     | 28 (100)    | 34 (100)  | 62 (100)        |           |

Degree of freedom = 1

### Table 3: Survival of shunt in partial (Proximal and Distil) vs. total shunt revision group

| Type of shunt replacement | Median success estimate of shunts replacement | 95% Confidence interval | Log-rank test |
|---------------------------|---------------------------------------------|-------------------------|---------------|
|                           | Lower bound       | Upper bound             |               |
| Proximal shunt replacement | 60.000            |                         |               |
| Distal shunt replacement  | 68.000            |                         | (Proximal vs. distal) |
| Total shunt replacement   | 270.000           |                         | (Test value=0.781) |

$P<0.05$ significant
intraventricular hemorrhage (IVH), and cranial surgeries because the CSF of these patients contains high proportion of proteins and debris. Valve obstruction is usually indistinguishable from distal obstruction clinically. In the present study distal obstruction was seen in 32.3% of cases.

We report our experience with primary VP shunt failure due to single component obstruction in patients with different causes of hydrocephalus. Our goal in this retrospective study was to examine our practice pattern and to determine whether intraoperative shunt revision was accurate and maximized subsequent outcomes of shunt. Hence we examined whether reutilizing a shunt component that was assessed intraoperatively as fully functional affected subsequent shunt survival. Very few studies have examined the effect of partial versus total shunt revision on subsequent shunt survival.\(^{[11,14]}\) Hence, such a study offers a valuable observation that may provide insight into more effective operative management of patients with obstructed shunts. This observational study suggests that the partial replacement of shunts predisposes to accelerated shunt failure in cases of an obstructed VP shunt. In a retrospective analysis of 301 pediatric patients, McGirt et al.\(^ {[11]} \) showed that subsequent shunt survival was significantly lesser when the distal catheter was reutilized in the setting of proximal catheter malfunction while subsequent shunt survival was not affected by reutilization of proximal catheter. However, in our study there were no statistically significant differences among shunt survival in patients with partial revision having proximal or distal obstruction. This study also questions the accuracy of standard intraoperative manometry and subjective flow assessment to identify the specific shunt component dysfunction. The standard intraoperative manometry and subjective visualized flow assessment may not accurately represent shunt component function or its risk for subsequent failure. Reutilized component of shunt catheters determined to be adequately functional intraoperatively may have been mildly dysfunctional, due to cumulative deposit of proteinaceous intraluminal debris or minor infection, thus partly contributing to the subsequent shunt failure. There are differences in the etiology of hydrocephalus in two groups which could not be avoided due to the retrospective nature of the study but could potentially introduce bias. The partial group had more patients of posttraumatic and IVH while the total group had more patients of myelomeningoceles and posterior fossa tumor. We have not studied the relation of different etiological factor individually in relation to replacement of shunt because of the small number of cases. These observations establish an imperative operative question and establish several guidelines for future investigation. Nevertheless, a large controlled, randomized prospective trial is needed to definitely determine the independent benefit of partial versus total shunt revision.

REFERENCES

1. Bierbrauer KS, Storrts BB, Mccone DG, Tomita T, Dauer R. A prospective, randomized study of shunt function and infection as a function of shunt placement. Pediatr Neurosurg 1990;16:287-91.

2. Drake JM, Lantosca MR. Cerebrospinal fluid shunting and management of pediatric hydrocephalus. In: Schmidek HH, Roberts DW, editors. Schmidek and Sweet’s Operative Techniques in Neurosurgery. Philadelphia: Elsevier; 2005. p. 487-508.

3. Drake JM, Kestle JR, Milner R, Cinalli G, Boop F, Platt J Jr, et al. Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus. Neurosurgery 1998;43:294-305.

4. Drake JM, Kestle JR, Tuli S. CSF shunts 50 years on- past, present and future. Childs Nerv Syst 2000;16:600-4.

5. Geminberg HJ, Drake JM. Physiology of cerebrospinal fluid devices. In: Winn HR, Youman S, editors. Neurological Surgery. Philadelphia: Saunders; 2004. p. 3374-85.

6. Hudgin RJ, Boydston WR. Shunt revision by coagulation with retention of the ventricular catheter. Pediatr Neurosurg 1998;29:57-9.

7. Iskander BJ, Mclaughlin C, Mapstone TB, Grabb PA, Oakes WJ. Pitfall in the diagnosis of ventricular shunt dysfunction: Radiology reports and ventricular size. Pediatrics 1998;101:1031-6.

8. Iskander BJ, Tubbs S, Mapstone TB, Grabb PA, Bartolucci AA, Oakes WJ. Death in shunted hydrocephalic children in the 1990s. Pediatr Neurosurg 1998;28:173-6.

9. Kumar R, Singh V, Kumar MV. Shunt revision in hydrocephalus. Indian J Pediatr 2005;72:843-7.

10. Lazareff JA, Peacock W, Holfly L, Ver Halen J, Wong A, Olmstead C. Multiple shunt failures: An analysis of relevant factors. Childs Nerv Syst 1998;14:271-5.

11. McGirt MJ, Wellons JC, Nimjee SM, Bulsara KR, Fuchs HE, George TM. Comparison of total versus partial revision of initial ventriculoperitoneal shunt failures. Pediatr Neurosurg 2003;38:34-40.

12. Pattisapu JV, Trumble ER, Taylor KR, Howard PD, Kovach TM. Percutaneous endoscopic recalization of the catheter; a new technique of proximal shunt revision. Neurosurgery 1999;45:1361-7.

13. Platt JH Jr. Cerebrospinal shunt failure: Late is different from early. Pediatr Neurosurg 1995;23:133-9.

14. Platt JH Jr, Carlson CV. A search for determinants of cerebrospinal fluid shunt survival: Retrospective analysis of a 14-year institutional experience. Pediatr Neurosurg 1993;19:233-42.

15. Pollack IF, Albright AL, Adelson PD. A randomized, controlled study of a programmable shunt valve versus a conventional valve for patients with hydrocephalus. Hakim-Medos Investigator group. Neurosurgery 1998;43:139-411.

16. Relate HL. Shunt revision: Complications and their prevention. Pediatr Neurosurg 1991;17:155-62.

17. Sainte-Rose C, Platt JH, Renier D, Pierre-Kahn A, Hirsch JF, Hoffman HJ, et al. Mechanical complications in shunts. Pediatr Neurosurg 1991;17:541-44.

18. Tuli S, Drake J, Lawless J, Wigg M, Lamberti-Pasculli M. Risk factors for repeated cerebro-spinal shunt failure in pediatric patients with hydrocephalus. J Neurosurg 2000;92:31-8.

19. Ventureyra EC, Higgins MJ. A new ventricular catheter for the prevention and treatment of proximal obstruction in cerebrospinal fluid Shunts. Neurosurgery 1994;34:343-52.

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