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Ventriculoperitoneal shunting: Laparoscopically assisted versus conventional open surgical approaches

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ABSTRACT

Objectives: Ventriculoperitoneal shunting (VPS) is a mainstay of hydrocephalus therapy, but carries a significant risk of device malfunctioning. This study aims to compare the outcomes of laparoscopic ventriculoperitoneal shunting versus open ventriculoperitoneal shunting (OVPS) VPS-placement and reviews our findings in the pertinent context of the literature from 1993 to 2012.

Materials and Methods: Between 2003 and 2012, a total of 232 patients underwent first time VPS placement at Beth Israel Deaconess Medical Center. Of those, 155 were laparoscopically guided and 77 were done conventionally. We analyzed independent variables (age, gender, medical history, clinical presentation, indication for surgery and surgical technique) and dependent variables (operative time, post-operative complications, length of stay in the hospital) and occurrence of shunt failure.

Results: Mean operative time was 43.7 min (18.0-102.0) in the laparoscopic group versus 63.0 min (30.0-151.0) in the open group, ($P < 0.05$). Length of stay was similar, 5 days in the laparoscopic and in the open group, ($P = 0.945$). The incidence of shunt failure during the entire follow-up period was not statistically different between the two groups, occurring in 14.1% in the laparoscopic group and 16.9% in the open group, ($P = 0.601$). Kaplan-Meier analysis demonstrated no difference in shunt survival between the two groups ($P = 0.868$), with functionality in 85% at 6-months and 78.5% at 1-year.

Conclusion: According to our study, LVPS-placement results compare similarly to OVPS placement in most aspects. Since laparoscopic placement is not routinely indicated, we suggest a prospective study to assess its value as an alternate technique especially suitable in obese patients and patients with previous abdominal operations.

Key words: Hydrocephalus, laparoscopy, ventriculoperitoneal shunting

Introduction

Ventriculoperitoneal shunt (VPS) placement remains a mainstay of surgical therapy for non-obstructive hydrocephalus since it was described in 1908.[1] Over time different methods and devices have been developed to control cerebrospinal fluid (CSF) drainage and advances in design and materials of catheters as well as valves and tubes have been achieved.

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Despite its common use in neurosurgery, complications are frequent and often cannot be avoided. Typical complications include: Infection, bleeding, wound healing difficulties and hardware failure. Shunt malfunction from malpositioning and mechanical failure is frequent and 1-year failure rates can be as high as 40%.[2] Distal failures account for as much as 30% of all failures requiring revision.[3] According to Patwardhan and Nanda (2005) the overall annual health care costs associated with VPS in the U.S. exceeded $1.1 billion.[4] Given the enormous volume and gross economic impact of this neurosurgical problem, with ancillary costs well in excess of the health care associated financial volume, any improvement in management strategies and outcome for VPS patients will translate directly into a significant economic benefit.

The introduction of laparoscopic techniques into neurosurgery was initially described for the retrieval of disconnected peritoneal shunts in pediatric patients.[5,6] Subsequently, Armbruster, *et al.* Basauri *et al.* and Schievink, *et al.* have described the use of laparoscopic techniques in guiding the insertion of the peritoneal catheter portion during VPS placement as an alternative to the traditional open techniques. This approach seems especially suited for obese patients and those with previous abdominal operations.[7-9] The laparoscopic technique offers many advantages-including direct visualization of the peritoneal cavity, intraoperative confirmation of shunt position and patency (by observing the CSF outflow from the distal catheter end) and the opportunity to perform direct lysis of adhesions in patients with a history of previous abdominal surgery. Beyond this, it is assumed that it can shorten the operative time, lessen the incidence of post-operative adhesions and requires a smaller incision which in itself reduces the incidence of complications such as post-operative herniation. In addition, it may accelerate post-operative recovery by decreasing post-operative pain with less prescription medications used (which should translate into a lower ileus rate in cases of narcotics) and allow for early mobilization resulting in a shorter length of stay in the hospital, which lessens the risk of pneumonia and deep venous thrombosis.[10-13]

In this study, we performed an extensive cohort analysis of a prospectively collected data set from our tertiary care center and compared the clinical parameters and outcomes of 232 patients who underwent VPS placement either by conventional open or laparoscopic technique.

Materials and Methods

This is an institutional review board (IRB #2011P-000101/4 and 2013P-000253/1) approved retrospective cohort study of prospective data set of all consecutive adult patients, who underwent 1st time insertion of a VPS at Beth Israel Deaconess Medical Center between December 2003 and September 2012.

New VPS placement was strictly defined as insertion of a proximal cerebral catheter, a new valve and distal placement of a peritoneal catheter. To avoid contamination of data, any shunt revisions and previously shunt-treated patients, who underwent complete shunt removal (for infection or other indication) and who later underwent placement of a new VPS, were also excluded. All shunts originating from a location other than the lateral ventricle or with a distal terminus in a site other than the peritoneal cavity were also excluded. Distal catheters were placed either through a standard small open laparotomy (at the right subcostal margin or at the rectus sheath near the midline) or via a laparoscopic technique using either 2or 3-access ports.

The decision to use laparoscopy was based on (1) past medical history of the individual patient (e.g., prior abdominal surgery with possible adhesions) (2) patients body habitus or (3) the neurosurgeon's preference and experience with both techniques. During the early part of the study period, distal catheters were more likely to be inserted by the open technique, whereas later in the study period they were more likely to be inserted laparoscopically as teams became more familiar with improved work flow.

Demographic, clinical and operative data of the patient cohort were collected by reviewing all medical records of the individual patients and included (a) manual chart review, (b) examination of all operative notes and (c) extraction of records from electronic hospital databases including all radiographic examinations. Independent variables investigated in this study included: Demographics (e.g., age, gender), indication for surgery and past medical history (e.g., comorbidities and previous abdominal operations). For all patients, we carefully examined the pre-operative imaging (head computed tomography [CT] and/or magnetic resonance imaging scan when available), the description of the operative technique (open or laparoscopic as well as intraoperative findings) and the specifics of the implanted valve type as well as clinical notes and radiographic studies during the follow-up period. Dependent variables analyzed included: Operative time, length of hospital stay, findings on post-operative head CT scan (obtained immediately and 4-8 weeks after surgery and annually thereafter to assess early as well as delayed post-operative complications), occurrence of any shunt failure, cause of shunt failure and any other complications.

A post-operative complication was defined as: Any complication related to surgery that occurred before the date of discharge and were categorized by type (e.g., hemorrhage, infection), or location (intracranial and abdominal obstruction or malpositioning). Complications were categorized as proximal to the valve, at the level of the valve and distally. Clinical relevant shunt failure was defined as any return to surgery for management of a shunt-related problem. Causes of shunt failure were categorized as over-drainage, proximal shunt malposition, obstruction or infection, distal shunt malposition, obstruction or infection and valve malfunction. Shunt infection was broadly defined as a positive CSF culture or increase in white blood cell from the shunt tap or revision in a symptomatic patient with a positive wound culture at the time of revision surgery. Shunt obstruction was diagnosed preoperatively or intraoperatively by testing the implanted hardware. To this end, the intraventricular catheter was disconnected proximal to the shunt valve and checked for flow. The distal catheter was then accessed with a Marx needle and flushed with saline. If proper flow was in doubt, VPS was further assessed via a manometer to determine the run-off pressure. Intracranial or abdominal catheter malposition were radiographically diagnosed and then confirmed at surgery. Over-drainage was diagnosed by (1) the presence of symptomatic slit ventricles or (2) the presence of new significant subdural fluid collections requiring surgical revision. Patients with adjustable valves (e.g., NPH patients) sometimes underwent multiple valve setting adjustments before undergoing a revision surgery. Abdominal pain complication or shunt failure was diagnosed if symptoms persisted following catheter placement and if complaints were not attributable to alternative diagnoses and remained refractory to conservative management.

The most recent patient encounter (clinic visit or hospital discharge) was taken as the end point for the radiographic follow-up period. For the purpose of the study, we assume that patients who did not present to this or any other hospital or office for any shunt related problems had a functioning shunt for the interim period. Other end points of the study were any occurrence of shunt revision, timing of shunt revision or shunt removal, or patient death.

Results

Between December 2003 and September 2012, a total of 232 patients underwent 1st time placement of a VPS. For this cohort, the mean age was 59.6 years (age range: 19.2-88.3). There were 121 (52.2%) men and 111 (47.8%) women. Of these 232 patients, 60 (25.8%) had a history of previous abdominal operation. In 77 (33.2%) cases, the distal shunt was placed by open technique and in 155 (66.8%) cases the placement of the distal catheter was laparoscopically. None of the laparoscopic cases required conversion to open. Both groups were similar in term of gender, mean age, previous abdominal operation and indication for surgery [Table 1].

Operative time was considered the surgical time from skin incision to skin closure. The mean Operative time in all shunts was 50.0 (range, 18.0-151.0) min, but in the laparoscopic group the mean operative time was significantly shorter, with 43.7 (range, 18 - 102) min when compared with the time spent on open cases requiring 63.0 (range, 30- 151) min, ($P < 0.05$). The overall number of post-operative complications was 9/232 (3.8%) and there was no significant difference between the open and the laparoscopic group, with 4 cases (5.1%) versus 5 cases (3.2%), ($P = 0.5$).

In the open group, two patients had minimal intracranial parenchymal hemorrhage (<5 mm) along the proximal catheter trajectory detected on CT after the operation, (one was in a patient with hydrocephalus due to metastatic disease from melanoma and the other one was in a patient with low grade astrocytoma). Neither of them required shunt revision or catheter replacement. One patient with initial hydrocephalus due to subarachnoid hemorrhage underwent repositioning of proximal catheter for malposition detected by a post-operative CT scan; Finally one patient with hydrocephalus due to metastatic disease from acute myelocytic lymphoma with a history of multiple abdominal operations developed erythema surrounding the abdominal incision after surgery without signs of distal shunt obstruction or malposition, which also improved prior the discharge.

In the laparoscopic group, an infection of the proximal catheter occurred in two patients: One was infection caused by *Cryptococcus neoformans* in a human immunodeficiency virus patient with Chiari I malformation, who had obstructive hydrocephalus. In this patient, the shunt was removed for persistence of fever and positive *Cryptococcus* CSF cultures. The other infection was in a patient with hydrocephalus from subarachnoid hemorrhage, developing a skin infection with *staphylococcus aureus*. The latter was treated successfully with vancomycin. There were two other patients who required proximal catheter revision due to malposition; finally there was one patient with obstructive hydrocephalus in the setting of a pituitary adenoma. This patient had proximal catheter obstruction due to intraventricular bleeding and the shunt had to be substituted with an external ventricular drainage (EVD). There was no further complication in those patients after their discharge. Noteworthy, there were no post-operative distal complications in the laparoscopic group of patients [Table 2].

Table 1: Demographic data and etiology of hydrocephalus

Demographics	All shunts (*n*=232)	Open (*n*=77)	Laparoscopic (*n*=155)	*P* value
Mean age (years)	59.6±16.6 (61.9, 19.2-88.3)	58.3±17.2 (58.9, 19.2-87.4)	60.2±16.2 (62.6, 20.0-88.3)	0.422
Gender (%)				
Male	121 (52.2)	44 (57.1)	77 (49.6)	0.284
Female	111 (47.8)	33 (42.9)	78 (50.4)	
Indication for surgery (%)				
Subarachnoid hemorrhage	74 (31.9)	19 (24.7)	55 (35.5)	0.086
Normal pressure hydrocephalus	67 (28.9)	23 (29.8)	44 (28.3)	0.816
Metastatic disease	40 (17.2)	16 (21.0)	24 (15.5)	0.335
Hydrocephalus sec. CNS tumor	19 (8.2)	9 (11.6)	10 (6.5)	0.211
Other	30 (13.8)	10 (12.9)	22 (14.2)	0.8
Previous abdominal operation	60 (25.8)	23 (29.8)	37 (23.2)	0.289

CNS – Central nervous system

The mean length of stay in the hospital in all shunt patients was 5 days (range, 1-30), which is a difficult measure to assess in this cohort since patients had various medical conditions for with they were treated. Of note, patients with normal pressure hydrocephalus were discharged usually within 24 h after surgery and for those there was no significant difference between the open and the laparoscopic group, (5 vs. 5 days, $P = 0.945$). In general, patients with hydrocephalus due to metastatic disease or CNS tumor stayed longer in the hospital since they were scheduled to have other procedures after VPS-surgery (such as biopsy, radiotherapy, chemotherapy etc.) and in our study out of the 232 patients, 59 patients had hydrocephalus from metastatic disease and CNS tumor who required VPS placement. Patients were routinely followed for a minimum of 1 year after VPS placement and then instructed to return only for signs of malfunctioning. The mean follow-up time in our cohort was 32.6 months (range, 0.0-107.3, median 22.1 months) and was slightly longer in the open group when compared with the laparoscopic group as open cases were performed more frequent initially [Table 2].

Shunt failure was defined as any return of the patient to the hospital with symptoms related to shunt failure-requiring surgery. Causes of shunt failure have been categorized in proximal (infection, malposition and obstruction), distal (infection, malposition and obstruction), valve revision and over-drainage. The overall number of shunt failures in all VPS patients of this cohort was 35 (15.0%) and of those 18 (51.4%) shunts failed in the first 3 months of the follow-up period [Figure 1]. The most frequent cause was shunt infection (proximal or distal), followed by proximal and distal catheter malfunction and finally valve malfunction [Figure 2]. There was no statistically significant difference between the open and the laparoscopic group in term of shunt failure rate, ($n = 13$/or 16.9% vs. $n = 22$/or 14.1%, $P = 0.601$) [Table 2].

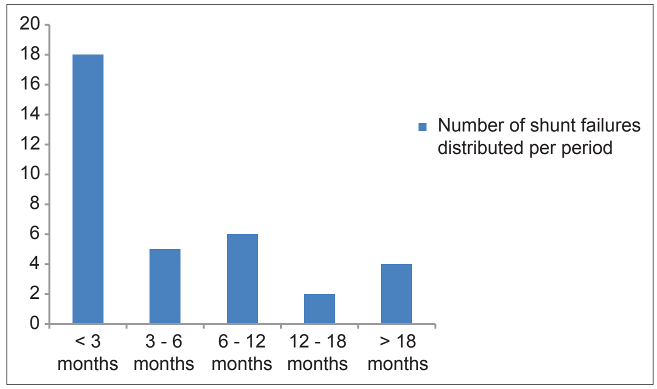

Figure 1: Number of shunt failure distributed per period

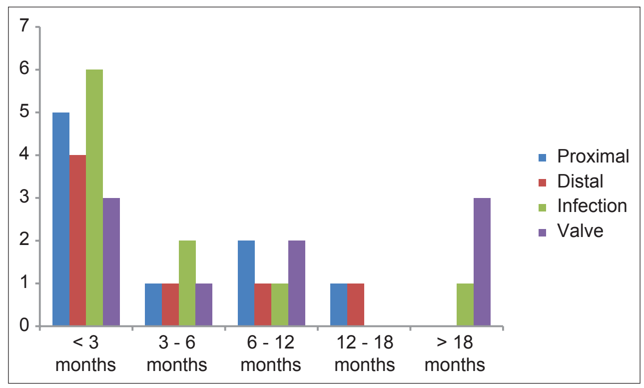

Figure 2: Location of shunt failure distributed per period

Table 2: Outcomes

Outcomes	All shunts (n=232)	Open (n=77)	Laparoscopic (n=155)	P value
Operative time (min)	50.0±20.3 (46.5, 18.0-151.0)	63.0±23.4 (58.0, 30.0-151.0)	43.7±15.6 (41.0, 18.0-102.0)	<0.05
Tot. Post-operative complications (%)	9 (3.8)	4 (5.2)	5 (3.2)	0.5
Intracranial (%)				
Hemorrhage	2 (0.8)	2 (2.6)	0 (0)	0.155
Infection	2 (0.8)	0 (0)	2 (1.3)	0.157
Catheter malposition	3 (1.2)	1 (1.3)	2 (1.3)	0.995
Catheter obstruction	1 (0.43)	0 (0)	1 (0.6)	0.318
Abdominal (%)				
Hemorrhage	0 (0)	0 (0)	0 (0)	1.000
Infection	1 (0.43)	1 (1.3)	0 (0)	0.318
Catheter malposition	0 (0)	0 (0)	0 (0)	1.000
Catheter obstruction	0 (0)	0 (0)	0 (0)	1.000
Length of stay (days)	5.0±5.0 (3.0, 1.0-50.0)	5.0±3.5 (3.0, 1.0-30.0)	5.0±5.0 (3.0, 1.0-50.0)	0.945
Tot. Shunt failures (%)	35 (15.0)	13 (16.9)	22 (14.1)	0.601
Proximal	17 (7.3)	6 (7.8)	11 (7.0)	0.851
Distal	8 (3.4)	4 (5.2)	4 (2.5)	0.359
Valve	9 (3.9)	3 (3.9)	6 (3.8)	0.992
Over-drainage	1 (0.43)	0 (0)	1 (0.64)	0.318
Follow-up (months)	32.6±29.8 (22.1, 0.0-107.3)	43.4±38.0 (29.8, 0.0-107.3)	27.2±23.1 (20.8, 0.0-81.8)	<0.05

Analysis was performed based on the location where complications occurred and was categorized by technique and related to indications for surgery and time of shunt failure. We then compared the demographic data between the patients who had shunt failure and those who did not have shunt failure during our observation period. To our surprise, we found the mean age of the patients who had shunt failure to be slightly lower than the other patients and this difference was statistically significant, (54.6 vs. 60.5, $P < 0.05$), without any obvious cause for it, except that mean operative time in the group of patients who had complication was longer than those who did not have a complication though this difference was not statistically significant (56.2 vs. 50.0 min, $P = 0.081$) [Table 3]. Proximal catheter malposition or obstruction was the most common cause for shunt revision in both groups and occurred in 17 (7.3%) patients. There was no significant difference between the open and the laparoscopic group (7.8% vs. 7.0%, $P = 0.851$) [Table 2]. We did not find any specific pattern in shunt failures among the different etiologies of hydrocephalus leading to VPS placement, but we noted that infection of the proximal catheter was more common in-patient with subarachnoid hemorrhage [Table 4], which is consistent with the literature on EVD infections.[14-17]

The second most common cause of shunt failure in our study was that of valve malfunction. It occurred in 9 (3.9%) patients and as expected without any significant difference between the open and the laparoscopic group (3.8% vs. 3.9%, $P = 0.992$) [Table 2]. Distal shunt revision for malposition, obstruction, or infection was reported in 8 (3.4%) patients among the total number of shunt failures, but there was no significant difference between the open and the laparoscopic group (4 vs. 4, $P = 0.359$) [Table 2]. Malposition of the distal catheter (clinically presenting with abdominal pain) was reported in both groups in low numbers: 2 cases in the open group and 4 cases in the laparoscopic group [Table 4]. This pain resolved after shunt revision in all affected patients. We did not have cases that required shunt removal for refractory abdominal pain in any patient from either group. Infection of the distal catheter occurred in 2 cases from the open group and in none in the laparoscopic group [Table 4]. We did not have any case of obstruction in the distal catheter. Over-drainage from a defective valve required valve revision

Table 3: Shunt failures required surgery categorized by technique within indication

Cause of shunt failure failure	SAH (*n*=74)			NPH (*n*=67)			Tumors (*n*=59)			Other (*n*=32)		
	Open (*n*=19) (%)	Lap (*n*=55) (%)	*P* value	Open (*n*=23) (%)	Lap (*n*=44) (%)	*P* value	Open (*n*=25) (%)	Lap (*n*=34) (%)	*P* value	Open (*n*=10) (%)	Lap (*n*=22) (%)	*P* value
Proximal catheter												
Obstruction	0 (0)	1 (1.8)	0.318	0 (0)	2 (4.5)	0.183	0 (0)	2 (5.8)	0.152	2 (20.0)	1 (4.5)	0.273
Malposition	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000
Infection	2 (10.5)	3 (5.4)	0.519	1 (4.3)	1 (2.2)	0.672	0 (0)	1 (2.9)	0.318	1 (10.0)	0 (0)	0.318
Distal catheter												
Obstruction	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000
Malposition	0 (0)	0 (0)	1.000	2 (8.7)	1 (2.2)	0.318	0 (0)	0 (0)	1.000	0 (0)	3 (13.6)	0.069
Infection	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	2 (8.3)	0 (0)	1.000	0 (0)	0 (0)	0.000
Over-drainage	0 (0)	1 (1.8)	0.318	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000
Valve revision	1 (5.2)	1 (1.8)	0.536	0 (0)	4 (9.0)	0.039	0 (0)	0 (0)	1.000	2 (20.0)	1 (4.5)	0.273

SAH – Subarachnoid haemorrhage; NPH – Normal pressure hydrocephalus

Table 4: Comparison in the demographic data in patients who had shunt failures during the follow-up and the rest of the group

Demographics and outcomes	Shunts without failure (*n*=197)	Shunts failure (*n*=35)	*P* value
Mean age (years)	60.5±16.5 (61.9, 19.2-88.3)	54.6±16.6 (60.3, 24-78.5)	<0.05
Gender (%)			
Male	102 (51.7)	19 (54.2)	0.786
Female	95 (48.3)	16 (45.8)	0.685
Indication for surgery (%)			
Subarachnoid hemorrhage	65 (33.0)	9 (25.7)	0.376
Normal pressure hydrocephalus	56 (28.4)	11 (31.5)	0.727
Tumors	54 (27.4)	5 (14.3)	0.054
Other	22 (11.2)	10 (28.5)	<0.05
Previous abdominal operation	49 (25.0)	11 (30.5)	0.408
Operative time (min)	50.0±20.3 (46.5, 18.0-151.0)	56.2±25.3 (52.0, 26.0-143.0)	0.081
Length of stay (days)	5.0±5.7 (3.0, 1.0-32.0)	6.0±8.0 (3.0, 1.0-50.0)	0.645

occurred in one case among the laparoscopic group of patients and in none in the open group, this difference was not significant ($P = 0.318$) [Table 4]. There was no significant difference in the length of stay in the hospital between the patients who sustained a shunt failure and those who did not have shunt failure (6.0 vs. 5.0 days, $P = 0.645$) [Table 3]. Kaplan-Meier survival analysis demonstrated no significant difference in survival between shunts placed by open versus laparoscopic technique ($P = 0.868$) as both groups' contained mixed indications for placement. The overall functional patency or "shunt survival" for all shunts was estimated to be 85.0% at 6 months and 78.5% at 1 year [Figure 3].

Discussion

Several studies have reported on the benefits and advantages of the laparoscopic insertion of the distal catheter in VPS placement since it was first introduced[7-10,16,18-29] and a few studies have compared aspects of the outcome and its impact on shunt survival in patients, who underwent VPS through laparoscopic technique and other traditional techniques used for distal catheter placement.[3,14,15,17,30-35]

In this study, we the report the outcomes of 232 patients who underwent 1st time VPS placement for a number of different indications either laparoscopically or by open technique; beyond this we review complications of the pertinent literature during the period between 1993 and 2012 [Table 5].

In our cohort, mean operative time differed between the two surgical groups: It was 32.2% shorter in the laparoscopic group versus the open group, (43.7 vs. 63.0, $P < 0.05$) [Table 2]. Other series study reported mean operative time for the open shunt placement ranging from 40 to 130 min[3,14,17,21,30-33,36] and for the laparoscopic technique 30-115 min,[3,14,-17,19,20,22,25,30-36] but the definitions of surgical time differ somewhat in those reports. Certainly the operative time depends on patient and surgeon factors; obese patients, patients with a history of previous abdominal operation, or distorted abdominal anatomy require extra time when compared with other patients, since the abdominal surgeon often has to lyse adhesions in order to avoid malposition or obstruction of the distal catheter. Furthermore, obese patients have a higher risk of shunt malpositioning due to more abundant preperitoneal fat that can be mistaken for omentum.[3] We also noticed that the mean operative time has decreased over time in our center and this is likely due to growing experience as well as efforts to improve efficiency by coordinating the 2 surgeon's timing as well as intraoperative workflow to ensure that appropriate supplies are readily available when needed during the case.

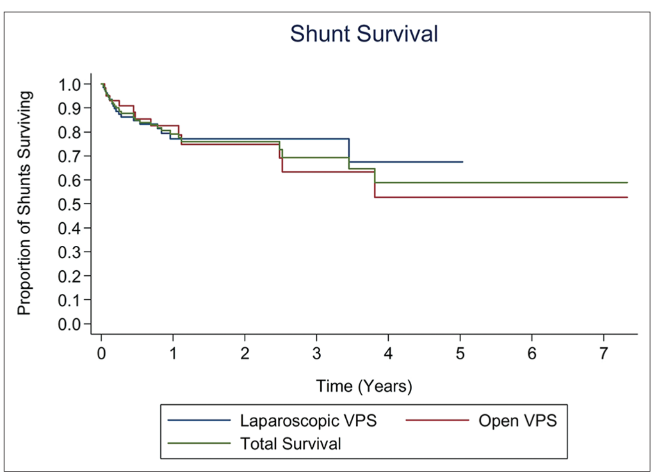

Figure 3: Overall shunt survival during the observation period

The mean length of stay in the hospital was 5 days for both groups; it was shorter than other studies published previously,[14,34] but is largely dependent on patient selection and indications for VPS placement. Naftel *et al*.[17] in their study have reported a mean length of stay of 11.9 and 8.5 days in the open and laparoscopic groups respectively; in their study the main etiologies of hydrocephalus were post-subarachnoid hemorrhage and tumor-associated hydrocephalus. Since these patient populations differ significantly in the clinical course and outcomes as well as discharge destinations and level of care requirements (home vs. rehabilitation etc.) we are not sure of the meaning of this difference, since other groups[19,22] have reported that half of their patients were discharged within 24 h and three-fourths were discharged within 2 days. Certainly the etiology of hydrocephalus plays a major role in the post-operative recovery of the patient. In fact in our study, the most common indication was subarachnoid hemorrhage and tumor associated hydrocephalus [Table 1] and these groups of patients did stay in the hospital for extended periods of time, due to the nature of their underlying disease; often they are scheduled for other procedures and diagnostic tests and cannot be discharged from the neurosurgery service. In our series of patients, group of patients with most elective VPS placement (67 individuals with normal pressure hydrocephalus patients) was usually discharged within 24 h.

The overall rate of shunt failure in our cohort was 15.0% over the mean observation period of 32.6 months [Table 2]. And this is consistent with similar studies reported previously.[15-17,22] There was no significant difference in the overall complication rate between the two groups of patients and our results are consistent with previous similar studies.[14,17,22,30] However, some authors have reported a lower complication rate with the laparoscopic technique, especially with respect to distal shunt failures,[15,31-33] which is consistent with our results showing a low distal failure rate. The etiology of hydrocephalus did not seem to influence the overall rate of shunt failure [Table 4]; consistent with other studies.[22,37,38] In our experience, patient's age was correlated to shunt failures, confirming other studies [Table 3].[14,39,40] Among the rather low number of cases of shunt failure we have seen, 17 (48.5%) were located in the proximal catheter, followed by 9 (25.8%) at the valve, 8 (22.8%)

Table 5: Review of the literature

Authors	Journal	No. of patients	Primary operations	No. of complications
Armbruster *et al.*[7]	J Laparoendosc Surg 1993	3	3	0
Basauri *et al.*[8]	Pediatric Neurosurg	6	6	0
Schievink *et al.*[9]	Mayo Clin Proc 1993	10 (aged 40-81 years)	10	1 bilateral subdural Hygromas 1 superficial infection in the subumbelical wound 2 deaths (unrelated to the shunt)
Cuatico and Vannix[46]	J Laparoendosc Surg 1995	11 (aged 18-72 years)	11	1 death (unrelated to the shunt)
Box *et al.*[26]	Surgical Endoscopy 1996	6 (aged 15-75 years)	4	1 hemothorax unrelated to intraabdominal portion
Esposito *et al.*[18]	Pediatr Surg Int 2003	10 (aged 1-14 years)	0	0
Reimer *et al.*[25]	J Am Coll Surg 1998	53 (aged 19-82 years)	53	14 deaths (unrelated to the shunt) 1 bilateral subdural hygromas 1 superficial infection of the subumbelical wound
Rolle *et al.*[47]	Eur J Pediatric Surg 1998	20 (aged 2-15 years)	0	1 distal catheter malposition
Khosrovi *et al.*[3]	Surg Neurol 1998	13 (aged 9-73 years)	2	1 wound infection
Khaitan and Brennan[19]	Surg Endosc 1999	10 (aged 22-81 years)	10	0
Roth *et al.*[27]	Surg Endosc 2000	27 (aged 4-81 years)	17	0
Acharya *et al.*[41]	J Laparoendosc Adv Surg Tech A 2001	28 (aged 28-58 years)	0	0
Kubo *et al.*[24]	J Neurosurg 2001	8 (age not reported)	8	0
Kirshtein *et al.*[11]	Surg Lapasc Endosc Percutan Tech 2004	24 (aged 6-80 years)	15	3 proximal malfunctions 1 infection 1 distal malfunction
Schubert *et al.*[31]	Surg Endoscop 2005	50 (aged 1-85 years)	37	2 distal catheter obstructions 1 infection
Tepetes *et al.*[34]	Clinical Neurology and Neurosurgery 2006	10 (aged 44-80 years)	10	0
Bani *et al.*[30]	J Neurosurg 2006	151 (aged 19-85 years)	151	2 infections
Bani and Hassler[48]	Pediatric Neurosurg 2006	39 (aged 3 months-18 years)	25	0
Goitein *et al.*[23]	J Laparoendosc Adv Surg Tech A 2006	10 (aged 30-76 years)	6	0
Yu *et al.*[49]	JSCLS 2006	11 (aged 9 months-19 years)	1	0
Li *et al.*[50]	Minim Invasive Ther Allied Technol 2007	56 (aged 17-65 years)	39	4 distal obstructions 1 infection
Jea *et al.*[10]	J Neurosurg 2007	11 (aged 1 month-15 years)	1	1 reducible incisional hernia
Kavic *et al.*[35]	JSCLS 2007	10 (aged 29-74 years)	0	2 distal shunt malfunction 1 lumbar CSF leak
Konstantinidis *et al.*[51]	Minim Invasive Neurosurg 2007	12 (not reported)	12	0
Roth *et al.*[15]	Surg Neurol 2007	59 (aged 19-74 years)	43	8 infections 7 proximal malfunctions 4 distal malfunctions 1 death (unrelated to the shunt 2 other causes
Turner *et al.*[22]	Neurosurgery 2007	111 (aged 9-87 years)	95	3 infections 9 proximal malfunctions 3 other causes
Handler and Callaham *et al.*[16]	J Neurosurg Pediatrics 2008	126 (aged 1-20 years) for 137 procedures	58 of 137 procedures	9 infections 13 distal malfunctions 3 proximal malfunctions 2 distal malposition
Nfonsam *et al.*[21]	Surg Endosc 2008	13 (aged 18-79 years)	0	0
Argo *et al.*[14]	Surg Endosc 2009	258 (aged 15.7-87.8 years)	258	24 shunt infections 10 shunt obstructions 5 shunt malposition 4 abdominal pain 14 other causes

Contd...

Table 5: Contd...

Authors	Journal	No. of patients	Primary operations	No. of complications
Sekula *et al.*[20]	Br J Neurosurg 2009	76 (aged 19-80 years)	76	2 distal catheter malposition
Park *et al.*[32]	J Korean Neurosurg Soc 2010	155 (not reported)	155	4 infection 2 shunt malfunction 1 organ injury
Raysi Dehcordi *et al.*[33]	Neurosurg Rev 2011	60 (aged 24-85 years)	48	2 valve revision 1 distal malfunction 3 distal malposition 1 distal obstruction 9 death (unrelated to the shunt) 5 proximal malfunction 1 organ perforation
Naftel *et al.*[17]	J Neurosurg 2011	810 (aged 15-90 years)	810	4 distal malposition 12 abdominal pain 16 proximal malposition 13 overdrainage 61 infections 57 shunt obstruction 2 other causes
Tormenti *et al.*[29]	J Neurosurg Pediatrics 2011	6 (aged 1 day-16 years)	5	1 proximal obstruction 1 infection 1 death (unrelated to the shunt)
Shao *et al.*[28]	Minim Invas Neurosurg 2011	10 (aged 19-71 years)	10	1 migration of distal catheter
Reddy *et al.*	2012	105 (aged 17.3-56.7 years)	105	141 obstruction 33 infection 18 overdrainage 87 proximal shunt complication 50 distal shunt complication 62 valve replacement 73 shunt system replacement 49 shunt system removal 28 externalization 17 shunt adjustment 73 other causes
Reddy *et al.*[39]	J Neurooncol 2011	187 (not reported)	187	16 infection 45 obstruction 4 overdrainage 43 proximal shunt complication 16 distal shunt complication 29 shunt system replacement 17 valve replacement 14 externalization of shunt 41 other causes
Reddy[40]	Clinical Neurology and Neurosurgery 2012	133 (aged 21.1-90.4 years)	133	9 infection 19 overdrainage 12 obstruction 19 proximal shunt complication 9 distal shunt complication 17 old shunt dysfunction 25 valve dysfunction 30 shunt complication 9 externalization 6 shunt adjustment 54 shunt replacement 41 other causes

CSF – Cerebrospinal fluid

in the distal catheter and one case of over-drainage [Table 2]. Lazareff *et al.* and Kast *et al.*[37,38] have analyzed relevant factors and the timing patterns of ventricular shunt failure. They found that the most frequent cause of shunt failure was proximal catheter malfunction, though CSF protein concentration, white blood cells (lymphocyte or eosinophil) did not seem to influence the rate of shunt failure in their study. Peritoneal catheter malfunction and valve failure are less common causes of shunt malfunction. These tend to be late causes of shunt failure as they are often due to fibrosis and calcification along the shunt tract or mechanical failure of the valve.[37,38] The anatomical integrity of the lateral ventricles seems to be one principal factor in the success of shunt survival. In fact, patients with hydrocephalus due to subarachnoid hemorrhage showed a higher rate of proximal catheter infection requiring revision than patients with other causes of hydrocephalus [Table 4] and maybe partially explained by the fact that many had an EVD placement prior to the definitive VPS. In our series, there were 9 proximal catheter infections [Table 4], 5 (55.5%) of which were associated with an external ventricular placement prior the placement of the definitive VPS.

According to the literature, the frequency of distal catheter malfunction requiring a shunt revision varies from 5% to 47%, with the most common causes being: Obstruction, catheter disconnection or loss, abdominal perforation, intestinal occlusion, bowel perforation, CSF ascites, pseudo-cysts, inguinal hernia, infection and peritonitis.[3,15,16,18,19,21,31,32,37,38,41-43] Nevertheless, obesity, previous abdominal operation and distorted abdominal anatomy seem to correlate straightly with the rate of distal mechanical shunt failure due to adhesions, calcification and fibrosis causing distal catheter obstruction, malposition and migration. In our study, distal catheter malfunction which resulted in shunt failure occurred only in 8 (3.5%) of cases, without significant difference between the two groups [Table 2]. Several studies have confirmed the correlation between previous abdominal operation and distal shunt failure.[3,15,18,19,25,30,31,37,41] We also analyzed whether there is a correlation between distal shunt failure and history of previous abdominal operation, but in our cohort previous abdominal surgery was not a good predictor for shunt failure for distal catheter malfunction. This is consistent with the study of 111 patients reported by Turner *et al*.[22]

Infection along the catheter tract was the most common cause of shunt failure in the first 3 months following placement [Figure 2]. We encountered a total of 11/232 (4.7%) cases of infection requiring a shunt revision, without any difference between open and the laparoscopic group of patients [Table 4]. In comparison to the literature our rate of infection is lower than in other previous studies.[14-17] Some authors have reported a higher infection rate with the laparoscopic technique[15,17] but we cannot confirm that observation in our cohort. Previous studies have shown that the number of surgeons, circulating personnel, start time and duration of the operation all increase the infection rate,[38,25] which are all factors we have tried to minimize, but when assessed, we did not find that those factors influenced the rate of infection in our cohort.

When compared with traditional laparotomy, the laparoscopic technique offers several significant advantages: Firstly, the ability of the surgeon to inspect the entire abdominal cavity and perform adhesiolysis as needed. This avoids placement of the distal catheter in a pocket of adhesions or in a kinked position especially in obese patients and in patients with previous abdominal surgeries.[15,18,16,22,25,30,31,35] Secondly, laparoscopy also reduces abdominal wall trauma and post-operative morbidity, since it requires smaller incision with smaller peritoneal and fascia openings and fewer formed secondary adhesions, less post-operative pain, a decrease in the incidence of post-operative ileus, less risk of perforating abdominal organs and a decrease in the frequency of incisional herniation.[13,18,44,45] We are currently studying these aspects prospectively.

We are aware of the fact that our study also has some limitations: First of all, the study is a retrospective study. Secondly, non-unified selection criteria were employed for utilizing the laparoscopic technique and may skew the results in those patients with higher risk who were often selected to this technique. Third, patient's body mass index (BMI) was not always reported and hence we could not correlate the patient selection or outcome parameters to obesity. A prospective study in which variables such BMI, history of abdominal operation, American Society of Anesthesiologists score, post-operative pain, need of pain medication, 1st day defecation and indication for operative technique used reported in detail is currently being conducted at our center.

Conclusion

Based on our experience, we can confidently conclude that VPS placement with the laparoscopic technique is a safe approach, which has many advantages over the traditional minilaparotomy. It shortens the operative time, allows the surgeon to explore the abdominal cavity, lyse adhesions if necessary and allows to assess incidental abdominal pathology and it finally ensures an optimal position of the distal catheter. We strongly suggest the laparoscopic technique as an alternative technique in obese patients and patients with previous abdominal operations.

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