Laparoscopic versus open insertion of the peritoneal catheter in ventriculoperitoneal shunt placement: review of 810 consecutive cases

Clinical article

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Object. Traditional ventriculoperitoneal (VP) shunt surgery involves insertion of the distal catheter by minilaparotomy. However, minilaparotomy may be a significant source of morbidity during shunt surgery. Laparoscopic insertion of the distal catheter is an alternative technique that may simplify and improve the safety of shunt surgery.

Methods. The authors performed a retrospective review of hospital records of all patients undergoing new VP shunt insertion at a tertiary care center between 2004 and 2009. Patient characteristics and outcomes were compared between patients undergoing open or laparoscopic insertion of the distal catheter. Independent variables in the analysis included age, sex, race, body mass index, surgical technique, previous VP shunt placement, previous abdominal procedures, American Society of Anesthesiology (ASA) score, and indication for shunt placement. Dependent variables included the occurrence of shunt failure, cause of shunt failure, complications, length of stay (LOS), LOS after shunt placement, estimated blood loss, and operative time.

Results. The authors identified 810 patients who met the inclusion criteria; open or laparoscopic distal catheter insertion was performed in 335 and 475 patients, respectively. There were no significant differences between the groups regarding age, race, ASA score, or indication for shunt placement. The most common indication was hydrocephalus due to subarachnoid hemorrhage, followed by tumor-associated hydrocephalus, normal pressure hydrocephalus (NPH), and hydrocephalus due to trauma. The incidence of shunt failure was not statistically different between cohorts, occurring in 20.0% of laparoscopic and 20.9% of open catheter placement cases (p = 0.791). With analysis of causes of shunt failure, shunt obstruction occurred significantly more often in the open surgery cohort (p = 0.012). In patients with a known cause shunt obstruction, distal obstruction occurred in 35.7% of the open cohort obstructions and 4.8% of the laparoscopic cohort obstructions (p = 0.014). The relative risk of distal obstruction in open cases compared with laparoscopic cases was 7.5. Infections occurred in 8.2% of laparoscopic cases compared with 6.6% of open cases (p = 0.419). Within the NPH subgroup, the laparoscopically treated patients had significantly more overdrainage (p = 0.040), whereas those in the open cohort experienced significantly more shunt obstructions (p = 0.034). Laparoscopically treated patients had shorter operative times (p < 0.0005), inpatient LOS (p < 0.001), and inpatient LOS after VP shunt placement (p = 0.01) as well as less blood loss (p = 0.058).

Conclusions. To our knowledge this is the largest reported comparison of distal VP shunt catheter insertion techniques. Compared with minilaparotomy, the laparoscopic approach was associated with decreased time in the operating room and a decreased LOS. Moreover, laparoscopy was associated with fewer distal shunt obstructions. Laparoscopic shunt surgery is a viable alternative to traditional shunt surgery. (DOI: 10.3171/2011.1.JNS101492)

Key Words • laparoscopy • minilaparotomy • shunt failure • complications • hydrocephalus • surgical technique • ventriculoperitoneal shunt

Abbreviations used in this paper: ASA = American Society of Anesthesiology; BMI = body mass index; LOS = length of stay; NPH = normal pressure hydrocephalus; SAH = subarachnoid hemorrhage; VP = ventriculoperitoneal.
the assistance of general surgeons. However, risks with this approach include infection, preperitoneal placement, adhesion formation, visceral injury, postoperative hernia formation, and increased postoperative pain.15, 27,38,40 In the early 1980s, laparoscopy was introduced for abdominal shunt revisions.15,27,38,40 In 1993, Armbruster et al.3 described the use of laparoscopy for primary insertion of VP shunt peritoneal catheters, and others have reported using this technique with good results.

Laparoscopic VP shunt insertion has become the standard method of shunt surgery in adults at our institution. An earlier study from this institution reported that laparoscopic surgery was associated with a significantly shorter average operative time, less blood loss, and a shorter LOS than minilaparotomy.7 The present study is an analysis of this technique with respect to surgical indication, and, based on a larger accumulated database, represents, to our knowledge, the largest laparoscopic shunt series to date.

Methods

Patient Population

This is a retrospective cohort study of all cases in which patients underwent insertion of a new VP shunt at the University of Alabama at Birmingham Hospital between January 2004 and April 2009. Medical records were reviewed to populate an IRB-approved database (x060331022). This database was divided into 2 cohorts based on surgical technique of distal VP shunt catheter insertion: open and laparoscopic.

The procedure was defined to include placement of the ventricular catheter, valve, and peritoneal catheter. Shunt revisions were excluded. Previously shunt-treated patients who underwent complete shunt removal (for infection or other indication), and then later underwent replacement with a new VP shunt were included. All shunts originating from a location other than the ventricle or with a terminus in a site other than the peritoneum were excluded. All distal catheters were placed either by minilaparotomy or laparoscopic technique. The decision to use laparoscopy was based on the neurosurgeon’s preference and on the availability of a laparoscopic surgeon. Over the course of this study, all of the neurosurgeons came to prefer laparoscopic insertion, and for this reason the techniques are not evenly distributed over time. During the early part of the analysis period, distal catheters were more likely to be inserted by minilaparotomy; later in the analysis period they were more likely to be inserted laparoscopically. No other changes in shunt insertion protocol over time have been identified.

Independent variables analyzed included age, sex, race, BMI, surgical technique, previous VP shunt placement, previous abdominal procedures, ASA score, and indication for shunt placement. Dependent variables included the occurrence of shunt failure, cause of shunt failure, complications, LOS, LOS after VP shunt placement, estimated blood loss, and operative time.

Shunt failure was defined as any return to surgery for management of a shunt-related problem. Causes of shunt failure were categorized as shunt infection, shunt obstruction, overdrainage, intracranial malposition, abdominal malposition, abdominal pain, and other. Shunt infection was defined as positive results of CSF or wound cultures, exposure of shunt hardware, or pseudocyst formation. Shunt obstruction was diagnosed upon intraoperative interrogation of the hardware. The proximal catheter was disconnected from the distal system and flow rate was observed. The distal system was assessed for obstruction using a manometer. Intracranial and abdominal malposition were radiographic diagnoses that were confirmed at surgery. Overdrainage was diagnosed by the presence of subdural fluid collections leading to revision. Often, patients with adjustable valves underwent valve adjustment before undergoing surgery. In this series, no patient was diagnosed with overdrainage unless surgical intervention was required. Additionally, overdrainage was not diagnosed on the basis of symptoms alone. Abdominal pain as a cause of shunt failure was diagnosed after persistent complaints following VP shunt placement that were not attributable to alternative diagnoses and were refractory to conservative management.

Other surgical complications such as hernia development, visceral injury, and conversion from a laparoscopic procedure to open surgery were queried. Secondary operative and hospital-related outcomes were defined as estimated blood loss, operative time, LOS, and LOS after VP shunt placement.

The length of the clinical follow-up period for each patient extended to either the time of shunt failure or, if there was no shunt failure, the last clinic or hospital visit. Additionally, shunt failure outcomes were compared between distal insertion techniques within the most prevalent indication subgroups.

Statistical Analysis

All statistical analyses were performed using SAS v9.1.3 (SAS Institute, Inc.). Categorical variables were compared using chi-square analysis unless group sizes were small enough to require use of the Fisher exact test. Continuous variables were compared using the Student t-test. When appropriate, groups were compared using an ANOVA with statistical significance set at p < 0.05. Multivariate analysis was performed using a best-fit backward stepwise logistic regression analysis.

Surgical Techniques

Our surgical technique for open and laparoscopic distal shunt catheter insertion has been previously described.2 In summary, all surgery was performed under general anesthesia, and the patient was positioned and prepared in standard fashion. The neurosurgeon made the bur hole and inserted the ventricular catheter. The distal system was tunneled to the abdomen, and distal flow was confirmed. A fully barium-impregnated peritoneal cath-
Laparoscopic versus open shunt insertion

er was used in all cases. In both techniques, the cranial
and abdominal procedures were performed concurrently.

If the distal catheter was inserted using the open
technique, the neurosurgery team performed a mini-lap-
arotomy. For laparoscopic cases, a general surgeon, ei-
ther an attending or fellow with laparoscopy expertise,
performed the abdominal portion of the procedure. The
general surgeons were comfortable with laparoscopic
insertion in most abdomens, including most previously
operated abdomens. In patients whose abdomens were
viewed as “hostile” (for example, patients with a large
ventral hernia that had been repaired with mesh, previous
peritonitis treated with multiple operations, or a “frozen
abdomen”), surgery was not performed laparoscopically
due to concern about adhesions.

The laparoscopic technique remained constant over
time with one exception. For most cases 2 small abdom-
inal incisions were made, one for introduction of the lap-
aroscope (Endo-Eye, Olympus America Inc.) and the other
for passage of the peritoneal catheter using the Seldinger
technique. The positioning of ports and the incision for
catheter tunneling can vary depending on previous ab-
dominal operations and body habitus. The distal catheter
was inserted into the peritoneum under direct visualiza-
tion. Shunt function was verified by observing CSF flow
from the distal catheter. In a small minority of cases, only
one small abdominal incision was made, and both the
scope and distal catheter were inserted through the same
incision. Although there was no additional morbidity due
to this technique, it was cumbersome and thus was aban-
doned. Additionally, the peritoneum was laparoscopically
explored, with any pathology or adhesions being noted. If
adhesions preventing catheter placement were present or
a previous shunt catheter had migrated into the peritoneal
cavity, a second port was placed to lyse adhesions and/or
remove the old catheter. The incisions were closed using a
4-0 absorbable subcuticular suture and a sterile adhesive
was applied for skin closure.

Results

Patient Characteristics

The demographic characteristics of the open surgery
and laparoscopic surgery groups were compared (Table
1). The groups were not significantly different with re-
spect to age, sex, race, indication for shunt placement, or
ASA score. The ages of the patients ranged from 15 to
87 in the laparoscopic cohort and 16 to 90 in the open
cohort. There were more female than male patients; the
most common indications for shunt placement were hy-
drocephalus related to SAH and intracranial tumors; most
patients were Caucasian. Characteristics that could
make abdominal surgery more technically challenging
were compared, and the cohorts were found to differ
significantly with respect to BMI and previous abdomi-
nal surgeries; more laparoscopically treated patients had
undergone previous abdominal surgery (p = 0.02), and
laparoscopically treated patients were significantly more
overweight (p < 0.001). Gastrostomy tubes were present
in 22 patients in the laparoscopic surgery group and 7

in the open surgery group. No patients had colostomies.
Additionally, more laparoscopically treated patients had
undergone previous VP shunt placement, although the
difference did not reach statistical significance (p = 0.06).
Follow-up was until shunt failure or, in cases in which
there was no shunt failure during the study period, un-
til most recent clinical follow-up; the mean duration of
follow-up was 12 months in the laparoscopic cohort and
21 months in the open cohort (p < 0.0005).

Shunt Failure and Complications

There was no statistically significant difference in the
incidence of VP shunt failure between cohorts, with
shunt failure occurring in 95 (20.0%) of 475 patients in
the laparoscopic cohort and 70 (20.9%) of 335 patients in
the open surgery cohort (p = 0.791). There was no dif-
ference in time to shunt failure, with failure occurring a
mean of 157 days after shunt placement in each cohort (p
= 1.00).

TABLE 1: Patient characteristics in 810 consecutive VP shunt
insertions categorized by distal surgical technique*  
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Laparoscopic (475 pts)</th>
<th>Open (335 pts)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean age (yrs)</td>
<td>52.0 ± 17.7</td>
<td>51.1 ± 17.1</td>
<td>0.43</td>
</tr>
<tr>
<td>sex</td>
<td></td>
<td></td>
<td>0.19</td>
</tr>
<tr>
<td>M</td>
<td>188 (39.6)</td>
<td>148 (44.2)</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>287 (60.4)</td>
<td>187 (55.8)</td>
<td></td>
</tr>
<tr>
<td>race</td>
<td></td>
<td></td>
<td>0.55</td>
</tr>
<tr>
<td>white</td>
<td>286 (60.2)</td>
<td>221 (66.0)</td>
<td></td>
</tr>
<tr>
<td>black</td>
<td>130 (27.4)</td>
<td>77 (23.0)</td>
<td></td>
</tr>
<tr>
<td>unknown</td>
<td>50 (10.5)</td>
<td>30 (9.0)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>4 (0.8)</td>
<td>2 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>3 (0.6)</td>
<td>4 (1.2)</td>
<td></td>
</tr>
<tr>
<td>other</td>
<td>2 (0.4)</td>
<td>1 (0.3)</td>
<td></td>
</tr>
</tbody>
</table>
| any previous abdominal opera-
| tion                        | 200 (42.1)             | 113 (33.7)     | 0.02    |
| previous VP shunt placement   | 74 (15.6)              | 37 (11.0)      | 0.06    |
| Indication for shunt placement|                        |                | 0.19    |
| hydrocephalus due to SAH      | 148 (31.2)             | 101 (30.1)     |         |
| hydrocephalus due to tumor    | 82 (17.3)              | 48 (14.3)      |         |
| normal pressure hydro-
| cephalus                   | 75 (15.8)              | 54 (16.1)      |         |
| hydrocephalus due to trauma   | 58 (12.2)              | 54 (16.2)      |         |
| other                         | 112 (23.6)             | 78 (23.3)      |         |
| ASA score                     |                        |                | 0.34    |
| 1–2                           | 25 (5.3)               | 17 (5.1)       |         |
| 3                             | 367 (77.3)             | 245 (73.1)     |         |
| 4–5                           | 83 (17.5)              | 73 (21.8)      |         |
| mean BMI (kg/m²)              | 28.9 ± 7.4             | 27.3 ± 5.9     | <0.001  |

* Values represent numbers of patients (%) unless otherwise indicated. Means are presented ± SDs. Pts = patients.
The cohorts were also compared according to cause of shunt failure (Table 2). The most prevalent cause of shunt failure was infection, occurring in 8.2% of laparoscopic cases and 6.6% of open cases; this difference was not statistically significant (p = 0.419). Shunt obstruction was the second most common cause of shunt failure, occurring significantly more often in the open cohort (in 9.9% of patients vs 5.1% of patients in the laparoscopic cohort, p = 0.012). This comparison included obstruction anywhere along the shunt, including proximal, valve, and distal failures. Shunt failure due to obstruction occurred in a total of 57 patients; although the site of obstruction was identified in most patients, it was not determined in 8 patients (5 in the open cohort and 3 in the laparoscopic cohort). In patients with a known location of obstruction, distal obstruction occurred in 35.7% (10/28) of the open cohort obstructions compared with 4.8% (1/21) of the laparoscopic cohort obstructions (p = 0.014). Therefore, the relative risk of distal obstruction in open cases compared with laparoscopic cases was 7.50.

On multivariate analysis in controlling for the independent variables, there was no difference in the incidence of shunt failure between open and laparoscopic techniques. Patients with previous shunts were at increased risk of failure (odds ratio 1.7, p = 0.03). Increased patient age was protective against failure (p = 0.02).

Overdrainage as a cause of shunt failure occurred in 2.3% of laparoscopic cases versus 0.6% of open cases, and this trend approached significance (p = 0.085). Abdominal preperitoneal malposition occurred in a small number of patients (1 in the laparoscopic group vs 3 in the open group), and interestingly, there was no statistically significant increase in the risk of malposition in the open cohort (p = 0.312). Analysis of other causes of shunt failure, including abdominal pain and intracranial malposition, showed no statistically significant difference between the cohorts.

Other complications included an intraparenchymal hemorrhage requiring a craniotomy for evacuation in 1 patient in the laparoscopic cohort. Two patients in the open cohort developed incisional hernias that necessitated operative repair.

Three laparoscopic procedures (0.6%) were converted to open procedures. Two of the 3 patients involved had previous abdominal surgery. None of these patients developed shunt failure or other negative outcome from this conversion. In another patient with a history of previous abdominal surgery who underwent laparoscopic insertion, a Veress needle punctured the liver, but no conversion to open surgery was required. This patient later developed an infection. No laparoscopic or open VP shunt placement was complicated by an enterotomy.

**Shunt Failure Within Surgical Indication Subgroups**

Shunt failure occurred in 16.9% of SAH cases, 20.8% of tumor cases, 17.1% of NPH cases, and 21.4% of trauma cases. Incidence of shunt failure within surgical-indication subgroups compared by distal technique is reported in Table 3. The 4 most common indication subgroups were analyzed separately and all others were grouped into an “other” category. Within the subgroups, there were no significant differences in overall shunt failure between laparoscopic and open cohorts. Analysis of the causes of shunt failure, however, showed that within the NPH subgroup the laparoscopic patients had significantly more overdrainage, while in the open cohort there were significantly more shunt obstructions.

**Operative and Hospital-Related Secondary Outcomes**

Outcomes reflecting resource utilization were compared between cohorts (Table 4). Laparoscopic VP shunt placement was found to involve shorter operative times (p < 0.0005), inpatient LOS (p < 0.001), and inpatient LOS after shunt placement (p = 0.01). Estimated blood loss was also noted to be less in the laparoscopic cases (p = 0.058).

**Discussion**

**Shunt Failure and Complications**

Negative outcomes after VP shunt placement are difficult to specifically categorize using the terms “shunt failure” or “complications.” Some types of shunt failure, such as infection or intracranial malposition, could be labeled as surgical complications rather than shunt failures. Likewise, shunt obstructions that occur years after shunt placement cannot be referred to as complications. This quandary is reflected by the inconsistent terminology used in the literature. On one end of the spectrum, in a study of laparoscopic shunt insertion, Handler and Callahan reported no perioperative complications but described infection and shunt revisions separately. On the other end of the spectrum, some authors refer to any shunt failure that occurs years after shunt placement as a “long-term complication.” With no consensus, these untoward events should be discussed together as a spectrum of negative outcomes after shunt insertion.

Several studies of laparoscopic shunt insertion have been reported; however, few studies have compared laparoscopy to other techniques. The most commonly investigated outcome measure is infection rate. Kast et al. proposed that laparoscopy increases the risk of infection. The infection rate after laparoscopic distal catheter insertion ranges from 1% to 13.5% with increased risk in patients who were previously shunted. Roth et

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**TABLE 2: Causes of VP shunt failure in 810 consecutive cases categorized by distal technique**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Laparoscopic (475 pts)</th>
<th>Open (335 pts)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>abdominal malposition</td>
<td>1 (0.2)</td>
<td>3 (0.9)</td>
<td>0.312</td>
</tr>
<tr>
<td>abdominal pain</td>
<td>9 (1.9)</td>
<td>3 (0.9)</td>
<td>0.377</td>
</tr>
<tr>
<td>intracranial malposition</td>
<td>10 (2.1)</td>
<td>6 (1.8)</td>
<td>0.804</td>
</tr>
<tr>
<td>overdrainage</td>
<td>11 (2.3)</td>
<td>2 (0.6)</td>
<td>0.085</td>
</tr>
<tr>
<td>shunt infection</td>
<td>39 (8.2)</td>
<td>22 (6.6)</td>
<td>0.419</td>
</tr>
<tr>
<td>shunt obstruction</td>
<td>24 (5.1)</td>
<td>33 (9.9)</td>
<td>0.012</td>
</tr>
<tr>
<td>other</td>
<td>1 (0.2)</td>
<td>1 (0.3)</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Laparoscopic versus open shunt insertion

al.34 reported an infection rate of 13.5% in laparoscopic cases versus 7.2% in cases in which other techniques were used. Additionally, Handler and Callahan16 noted a trend toward a lower infection rate if neurosurgeons performed the laparoscopy rather than the general surgeon. Neither of these studies found laparoscopy to significantly increase the infection rate. In our study, general surgeons performed all laparoscopic procedures, and there was a trend toward more infections in the laparoscopic group (8.2% vs 6.6%), although it did not reach statistical significance.

Shunt obstructions were significantly less common in our laparoscopic group than in the open group. Overall, the most common location of shunt obstruction is the ventricular catheter; less frequently, the obstruction occurs in the valve or peritoneal catheter.21 Roth et al. 34 noted more distal shunt obstructions in their non-laparoscopic cohort (10.3%) compared with the laparoscopic cohort (4%). This was attributed to the catheter being positioned in a previously untouched quadrant of the abdomen, adhesions being concurrently lysed, and peritoneal migration occurring less frequently since the peritoneal hole was smaller. Likewise, in a prospective comparison of laparoscopy versus open techniques, Schubert et al.36 noted a lower distal failure rate in laparoscopically inserted distal catheters. The findings in these two studies are in concordance with our findings and demonstrate a distinct advantage with laparoscopy.

There was a trend in our study toward an increased incidence of overdrainage in the laparoscopic cohort (p = 0.085). Overdrainage can cause cortical mantle collapse due to excessive CSF drainage from the ventricles.26 A potential explanation for the higher overdrainage rate in the laparoscopic group is that increased peritoneal adhesions in the open cohort caused increased resistance to distal flow, thus preventing overdrainage. Alternatively, different valves or a difference in clinical follow-up may have been factors.

One commonly discussed advantage of laparoscopy is the potential for decreased preperitoneal malposition or catheter migration into the preperitoneal space. This complication has been reported at rates as high as 8% with open shunt surgery.4 Unlike other authors, we did not find laparoscopy to significantly decrease abdominal malposition of the distal catheter (p = 0.312), possibly because the incidence was extremely low in both cohorts.

### Table 3: Causes of shunt failure in 810 consecutive VP shunts categorized by technique within indication subgroups

| Cause                      | Other (190 pts) | Laparoscopic (112 pts) | p Value | Open (78 pts) | Laparoscopic (54 pts) | p Value | Open (54 pts) | Laparoscopic (59 pts) | p Value | Open (54 pts) | Laparoscopic (48 pts) | p Value | Open (48 pts) | Laparoscopic (59 pts) | p Value | Open (54 pts) | Laparoscopic (54 pts) | p Value | Open (54 pts) | Laparoscopic (54 pts) | p Value | Open (54 pts) | Laparoscopic (54 pts) | p Value |
|---------------------------|----------------|------------------------|---------|---------------|--------------------|---------|---------------|--------------------|---------|---------------|--------------------|---------|---------------|--------------------|---------|---------------|--------------------|---------|---------------|--------------------|---------|---------------|--------------------|---------|---------------|--------------------|---------|
| abdominal malposition     | 0 (0)          | 2 (1.4)                | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   |
| abdominal pain            | 0 (0)          | 2 (1.2)                | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   | 0 (0)         | 2 (1.4)            | 0.002   |
| intracranial 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   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   |
| overdrainage              | 0 (0)          | 0 (0)                  | 1.000   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   |
| shunt infection           | 1 (0.7)        | 1 (0.7)                | 1.000   | 1 (0.7)       | 1 (0.7)            | 1.000   | 1 (0.7)       | 1 (0.7)            | 1.000   | 1 (0.7)       | 1 (0.7)            | 1.000   | 1 (0.7)       | 1 (0.7)            | 1.000   | 1 (0.7)       | 1 (0.7)            | 1.000   | 1 (0.7)       | 1 (0.7)            | 1.000   |
| shunt 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   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   | 0 (0)         | 0 (0)              | 1.000   |
| other                     | 26 (17.6)      | 16 (16.0)              | 0.735   | 26 (17.6)     | 16 (16.0)          | 0.735   | 26 (17.6)     | 16 (16.0)          | 0.735   | 26 (17.6)     | 16 (16.0)          | 0.735   | 26 (17.6)     | 16 (16.0)          | 0.735   | 26 (17.6)     | 16 (16.0)          | 0.735   | 26 (17.6)     | 16 (16.0)          | 0.735   |

* Values represent numbers of patients (%). Abbreviation: Lap = laparoscopic.

### Table 4: Secondary outcomes: hospital- and operation-related outcomes categorized by technique in 810 consecutive VP shunt procedures*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Laparoscopic (475 pts)</th>
<th>p Value</th>
<th>Open (335 pts)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>operative time (min)</td>
<td>43.5 ± 21.1</td>
<td>&lt;0.0005</td>
<td>55.6 ± 24.7</td>
<td>0.008</td>
</tr>
<tr>
<td>estimated blood loss (ml)</td>
<td>31.9 ± 28.9</td>
<td>0.058</td>
<td>44.9 ± 52.6</td>
<td>0.005</td>
</tr>
<tr>
<td>LOS (days)</td>
<td>17.6 ± 21.0</td>
<td>&lt;0.001</td>
<td>23.1 ± 27.7</td>
<td>0.001</td>
</tr>
<tr>
<td>LOS after VP shunt placement (days)</td>
<td>8.5 ± 15.6</td>
<td>0.01</td>
<td>11.9 ± 22.0</td>
<td>0.001</td>
</tr>
</tbody>
</table>

* Values represent means ± SDs.

J Neurosurg / Volume 115 / July 2011
Conversion From Laparoscopic to Open Surgery

Conversion to open surgery is a risk of any laparoscopic procedure. In 137 pediatric laparoscopic shunt catheter insertions, Handler and Callahan\textsuperscript{16} aborted 4 operations because of dense adhesions. This resulted in either conversion to an open procedure or a shunt with an alternative terminus. Roth et al.\textsuperscript{34} did not convert any case to an open procedure; however, 2 patients required additional abdominal incisions and one required externalization of the shunt. Ochalski et al.\textsuperscript{29} converted 9\% of minimal-access cases to open surgery and reported no visceral or vascular injuries. Yu et al.\textsuperscript{43} performed 17 distal shunt revisions in children using laparoscopy. Six (35\%) required conversion to open surgery because of extensive adhesions and one required conversion to a ventriculopleural shunt. Bani et al.\textsuperscript{4} reported that conversion to open surgery was required in one case due to peritoneal metastasis. Reimer et al.\textsuperscript{33} inserted VP shunts using laparoscopic guidance in 70 adult patients with diverse etiologies of hydrocephalus, and there was one enterotomy in a previously operated abdomen that required conversion to open to repair. It is our practice to convert to open surgery in situations in which significant peritoneal adhesions are present. Even with this threshold for conversion, we only converted to open surgery in 0.6\% of laparoscopic cases. In each case, conversion was required because of dense adhesions; 2 of the 3 patients had undergone previous abdominal surgery. There were no enterotomies in these patients and none experienced a negative outcome from conversion to open surgery.

Outcomes in Surgical-Indication Subgroups

The association between indication for shunt placement and shunt failure has interested many neurosurgeons, and this issue has been studied extensively, particularly in pediatric cases.\textsuperscript{12,25,28,41} To our knowledge, there has been no investigation of the relationship between indication for shunt placement (cause or type of hydrocephalus) and distal catheter insertion technique.

Results in NPH patients have been previously investigated. Turner et al.\textsuperscript{42} performed laparoscopic VP shunt insertion in 111 patients, most of whom had NPH. Shunt infection occurred in 12.5\% of patients with NPH compared with an infection rate of 1\% in the rest of their patient population. In our study, only 1 (1.3\%) of 75 NPH patients undergoing laparoscopic distal catheter insertion experienced an infection. In concordance with our findings, Bani et al.\textsuperscript{4} found no significant difference in infection rates between open and laparoscopic shunt insertion in NPH patients.

A relatively prevalent cause of shunt failure in NPH is overdrainage. Uniquely, in the NPH subgroup, patients undergoing laparoscopic distal catheter insertion were found to be at an increased risk of overdrainage. Additionally, the NPH patients undergoing open distal catheter insertion were at an increased risk of shunt obstruction. As discussed above, this may be due to the adhesion formation that occurs after an open abdominal procedure, and similarly, the lack of adhesion formation in laparoscopic cases.\textsuperscript{39}

Among patients undergoing VP shunt placement for hydrocephalus caused by SAH, tumor, or trauma, laparoscopic insertion of the shunt catheter did not provide any distinct advantage or disadvantage.

Operative and Hospital-Related Secondary Outcomes

Operative time is an important variable that affects healthcare resource utilization.\textsuperscript{39} Average reported operative times for laparoscopic VP shunt placement range from 40 to 81 minutes.\textsuperscript{4,12,16,22–24,33,36,42} In previous reports, there has been no consensus on whether laparoscopy saves time. Schubert et al.\textsuperscript{36} experienced the longest duration for laparoscopic cases. The reason for this was given as the time necessary for setting up the laparoscopic equipment and the additional time spent lysing adhesions in selected cases. Other authors have hypothesized that the operative time is longer in laparoscopic cases because of time lost waiting on the laparoscopic surgeon to complete the abdominal procedure.\textsuperscript{42} Handler and Callahan\textsuperscript{16} noted that after the period of familiarization laparoscopic technique did not increase operative time. At our institution, because of the high volume of laparoscopic VP shunt placement procedures performed, laparoscopic surgeons are accustomed to the schedule and are readily available. Therefore, no time is lost waiting for the general surgeon. A likely explanation for the reduced operative time in our study compared with other reports is that the high volume of laparoscopic shunt operations led to an economy of scale. That is, frequent use of the laparoscopic approach resulted in rapid and cohesive integration of the laparoscopic procedure with the neurosurgical portions of the operation. For the findings of this study to be generalizable to other centers, laparoscopy should be the routine method of shunt surgery in those centers rather than the exception. Whether decreased operative time with laparoscopy will reduce the costs of shunt surgery will have to be the topic of another investigation.

Additionally, our study found that LOS after VP shunt placement was significantly shorter in the laparoscopic cohort. However, LOS in our study appears longer than what has been reported in other studies. Turner et al.\textsuperscript{42} noted that about half of their patients were discharged within 24 hours and three-fourths were discharged within 2 days. In comparison, our mean LOS in the laparoscopic cohort was 17.6 days and 23.1 days in the open cohort (between-groups difference, p < 0.001). Moreover, LOS after VP shunt placement was 8.5 days in our laparoscopic cohort and 11.9 days in the open cohort (p = 0.01). The explanation for these longer lengths of stay is the cause or type of hydrocephalus in the patients that were being treated. The most common indication for shunt placement in our group was hydrocephalus due to SAH, followed by tumor-associated hydrocephalus. By their nature, SAH patients remain in the hospital for extended periods of time, being treated for aneurysms, undergoing attempted ventriculostomy weaning, and then often awaiting rehabilitation after shunt insertion. Likewise, tumor patients who develop hydrocephalus often have ventriculostomies from which they are weaned after tumor resection and most go on to require CSF shunting, and sometimes need rehabilitation after surgery. Therefore,
because of the types of patients undergoing shunt placement in this study, the LOS data are skewed.

Lastly, blood loss was found to be less in the laparoscopic cases (p = 0.058), although the absolute difference in blood loss (32 vs 45 ml), was relatively small. The incisions performed for the laparoscopic portion of the procedure are so small that essentially all blood loss reported in these cases originates from the cranial incisions.

**Study Limitations**

This is a retrospective study of VP shunt failure comparing 2 surgical techniques for peritoneal placement of the distal shunt catheter. The insertion technique was not evenly distributed over the study period, and while no other changes in the treatment protocol were identified, confounding factors may have affected outcomes over time. Additionally, surgeon preference was a source of selection bias in this study. Although surgeons did not knowingly discriminate against certain patients or conditions, patients in the laparoscopic cohort were found to have significantly higher BMIs and had undergone significantly more previous abdominal procedures. Additionally, the diagnosis of shunt failure was surgeon-dependent and subject to selection bias. Multivariate analysis was performed to control for the known variables, but we could not control for surgeon preference and other unidentified confounders.

A prospective study using a shunt insertion protocol would provide additional information that could potentially influence a change in practice. While an infection rate of 8.2% in the laparoscopic cohort is not outside the normal range, it is certainly higher than desired; a prospective protocol–based study design is needed to investigate factors affecting rate of infection. Additionally, this study only included new VP shunt insertions, and therefore, cannot be generalized to shunt revisions.

Lastly, no other distal techniques such as trocar use were employed. Many surgeons prefer the technique of trocar use and have had good results with it; however, this technique does not allow for preferentially placing the distal catheter in a specific location under direct visualization, direct in situ observation of shunt function, or lysing of adhesions.

**Conclusions**

Based on our study, laparoscopic VP shunt insertion is a safe, minimally invasive treatment option for insertion of distal peritoneal tubing. Laparoscopy offers reduced operative times, LOS, LOS after VP shunt placement, and blood loss. While not reducing the overall shunt failure rate, laparoscopy has the advantage of a decreased likelihood of distal shunt obstruction.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

This project was supported in part by Grant Number T32HS013852 from the Agency for Healthcare Research and Quality.

Author contributions to the study and manuscript preparation include the following. Conception and design: Argo, Clements, Harrigan. Acquisition of data: Naftel, Argo, Taylor. Analysis and interpretation of data: Naftel, Shannon, Tubbs, Harrigan. Drafting the article: Naftel. Critically revising the article: Tubbs, Harrigan. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: Naftel, Argo, Shannon. Administrative/technical/material support: Clements, Harrigan. Study supervision: Clements, Harrigan.

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Please include this information when citing this paper: published online February 11, 2011; DOI: 10.3171/2011.1.JNS101492. Address correspondence to: Robert P. Naftel, M.D., University of Alabama at Birmingham, Division of Neurosurgery, 510 20th Street South, FOT 1062, Birmingham, Alabama 35294-3410. email: naftel@uab.edu.