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# Outcomes of ventriculoperitoneal shunt placement with or without laparoscopic assistance: An analysis of the national inpatient sample

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ABSTRACT

*Background:* Ventriculoperitoneal shunt (VPS) can be placed solely by a neurosurgeon often via an open-laparotomy approach, or laparoscopically as a collaborative effort between a neurosurgeon and a general surgeon. Prior studies have shown conflicting results when examining outcomes regarding infection, revision rate, hospital charges, length of stay, and mortality between the open mini-laparotomy and the laparoscopic approaches.

*Objective:* The current study uses the National Inpatient Sample (NIS) to compare outcomes of open mini-laparotomy vs. laparoscopic collaborative approach in VPS placement.

*Methods:* We performed a retrospective database study of the NIS from October 2015-December 2017 utilizing International Classification of Diseases, 10th Revision coding to identify all cases of VPS placement. All analyses accounted for the sampling design of the NIS.

*Results:* A total of 6580 cases (4969 with open mini-laparotomy approach and 1611 with laparoscopic collaborative approach) met inclusion criteria. Hospital charges, infection rates, and revision rates were similar between approaches. There were no significant differences in length of stay, mortality, or complication rates between the two approaches.

*Conclusion:* The collaborative, laparoscopic approach to VPS placement has similar outcomes and is non-inferior to the traditional open mini-laparotomy approach.

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## 1. Introduction

Hydrocephalus is a multifactorial neurological disorder with different etiologies. It is defined as an active distension of the ventricular system of the brain resulting from inadequate passage of cerebrospinal fluid from its point of production within the cerebral ventricles to its point of absorption into the systemic circulation.[1] The most common treatment of hydrocephalus is CSF diversion from the ventricular space to a body cavity.[2] Ventricular shunts can terminate in the peritoneum, heart, pleural space, gallbladder, stomach, and urinary bladder. The ventriculoperitoneal shunt (VPS) procedure has become the most common surgical treatment since the late 1950s due to its reduced risk of complications.[2–4]

Traditionally, placement of the distal portion of the VPS was performed solely by a neurosurgeon via an open mini-laparotomy. In 1993, Basauri et al introduced laparoscopy-assisted visualization and placement of the distal end as a collaboration between neurosurgery and general surgery.[5] Multiple studies have attempted to investigate outcomes from an open mini-laparotomy approach and a laparoscopic approach, and they have shown conflicting results.[6–11] A recent large Medicare database study mostly included patients older than 64 years of age with a large proportion of normal pressure hydrocephalus.[12] To the best of our knowledge, there has not been a large national database

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study addressing outcomes between the two approaches in the general population. By using the National Inpatient Sample (NIS) database, we aim to address whether there are any differences in mortality, shunt revision rates, length of stay, hospital charges, and complications between open mini-laparotomy and laparoscopic approaches for VPS placement.

## 2. Methods

### 2.1. Data acquisition

This is a retrospective database study of the NIS data set (see Supplementary Methods for detailed description) from October 2015-December 2017, utilizing International Classification of Diseases, 10th Revision (ICD-10) procedure codes. Adult patients $\geq$ 18 years old were included. Encounters with diagnosis codes for hydrocephalus and VPS procedure were selected. We only included ventriculo-peritoneal shunts and therefore, ventriculo-atrial and ventriculo-pleural shunts were excluded. This cohort of patients was further characterized based on whether a general surgery diagnostic laparoscopy procedure was coded for the patient on the same date as the VPS. The cohort group was divided into two distinct groups: those with hydrocephalus and VPS placement performed by neurosurgery via an open mini-laparotomy and those performed collaboratively by neurosurgery and general surgery with laparoscopic assistance. When a VPS was coded on multiple days, the procedure from the earliest date of admission was used to define the respective groups. Relevant ICD-10 codes are included in Supplementary Table 1. A total of 6580 cases were identified meeting inclusion criteria: 4969 having the open mini-laparotomy approach and 1611 the laparoscopic approach. Rutgers' Institutional Review Board review was not necessary since the NIS data are de-identified and publicly available.

### 2.2. Outcomes and variables

Patient and treatment characteristics including age, race, sex, hospital charges, mortality, length of stay (LOS), comorbidities, and complications were extracted. Revision surgery was based on ICD-10 procedure codes (Supplementary Table 1) which occurred after the date of the initial VPS. LOS is measured from the date of VPS to discharge. Patients who died while inpatient were excluded from LOS. Patient comorbidities were assessed using the Elixhauser comorbidity definitions, with the overall score representing the cumulative comorbidity burden for each subject.[13,14] Complications were analyzed based on ICD-10 diagnosis codes (see Supplementary Table 1 for list of complications).

The primary aim of this study was to determine whether or not there were differences in outcomes (mortality, shunt revision rates, length of stay, hospital charges, and complications) between patients undergoing an open mini-laparotomy v. laparoscopic collaborative approach in VPS placement.

### 2.3. Statistical analysis

Differences in patient and treatment characteristics between open mini-laparotomy and laparoscopic approaches were assessed using either the Wilcoxon Rank-Sum or Chi-Squared test. Logistic and Poisson regression models were used to assess the impact of patient and treatment characteristics on mortality and length of stay, respectively. Yearly estimates for 2015 were based on increasing the observed counts by a factor of 4 in order to account for the lack of Quarter 1 – Quarter 3 data. All analyses were completed in R 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org).

## 3. Results

Table 1 highlights the distribution of patient demographics between the open mini-laparotomy and laparoscopic groups. The cohort examined in this analysis represents roughly 20 % of the national prevalence of VPS cases. In this analyzed cohort, the overall number of VPS cases increased slightly over time, with 2708 in 2015 to 3028 in 2017. The proportion of open mini-laparotomy and laparoscopic cases was similar across years ($p = 0.777$), as was the distribution of sex ($p = 0.551$). Patients in the open mini-laparotomy group tended to be younger (median age 63 v. 65 years; $p = 0.054$), and more likely to be non-white (29.4 % v. 26.1 %, $p = 0.025$). We included multiple races in our study that did not lead to statistically significant results. Obese patients were much more likely to undergo the laparoscopic approach compared to the open mini-laparotomy approach ($p = 0.007$).

**Table 1**
Demographics.

| Variable | Category | Procedure Approach | | Univariate Analysis *p*-value |
|---|---|---|---|---|
| | | Open Mini-Laparotomy | Laparoscopic | |
| Year | | | | 0.777 |
| | 2015 | 508 (10.2) | 169 (10.5) | |
| | 2016 | 2189 (44.1) | 686 (42.6) | |
| | 2017 | 2272 (45.7) | 756 (46.9) | |
| Sex | | | | 0.551 |
| | female | 2344 (47.2) | 774 (48.0) | |
| | male | 2625 (52.8) | 837 (52.0) | |
| Age (continuous) | | 63.0 (18.0, 90.0) | 65.0 (18.0, 90.0) | 0.054 |
| Age (quartile) | | | | 0.201 |
| | [18,48] | 1255 (25.3) | 396 (24.6) | |
| | (48,64] | 1317 (26.5) | 394 (24.5) | |
| | (64,74] | 1220 (24.6) | 403 (25.0) | |
| | (74,90] | 1177 (23.7) | 418 (25.9) | |
| Race | | | | 0.025 |
| | White | 3339 (70.6) | 1146 (73.9) | |
| | Non-white | 1392 (29.4) | 405 (26.1) | |
| | (Missing) | 238 | 60 | |
| Race | | | | 0.269 |
| | White | 3339 (70.6) | 1146 (73.9) | |
| | Black | 553 (11.7) | 153 (9.9) | |
| | Hispanic | 485 (10.3) | 143 (9.2) | |
| | Asian/ Pacific Islander | 147 (3.1) | 43 (2.8) | |
| | Native American | 12 (0.3) | 4 (0.3) | |
| | Other | 195 (4.1) | 62 (4.0) | |
| | (Missing) | 238 | 60 | |
| Median Income Percentile | | | | 0.457 |
| | [0, 25] | 1249 (25.5) | 389 (24.4) | |
| | [26, 50] | 1198 (24.5) | 366 (23.0) | |
| | [51, 75] | 1212 (24.8) | 419 (26.3) | |
| | [76, 100] | 1233 (25.2) | 418 (26.3) | |
| | (Missing) | 77 | 19 | |

Table 2 displays the distribution of additional characteristics between the open mini-laparotomy and laparoscopic groups. Cases booked as elective were more likely to have the laparoscopic approach (44.0 % open mini-laparotomy v. 51.3 % laparoscopic); whereas non-elective procedures were more likely to have the open mini-laparotomy approach (56.0 % v. 48.7 %; $p < 0.001$). A greater proportion of laparoscopic cases were performed at urban/teaching hospitals (87.0 % v. 89.9 %) relative to urban/non-teaching (11.7 % v. 9.4 %) and rural hospitals (1.3 % v. 0.7 %, overall $p = 0.017$). There was no association between procedure approach and geographic region, median income, discharge disposition, or payer.

### 3.1. Primary aims

In univariate analysis, shunt revision rates following initial VPS

**Table 2**
Additional baseline demographic data.

| Variable | Category | Procedure Approach | | Univariate Analysis *p*-value |
|---|---|---|---|---|
| | | Open Mini-Laparotomy | Laparoscopic | |
| Day | | | | 0.004 |
| | Mon-Fri | 4292 (86.4) | 1435 (89.1) | |
| | Sat/Sun | 677 (13.6) | 176 (10.9) | |
| Admission Day [same as procedure] | | | | 0.011 |
| | Mon-Fri | 2115 (97.1) | 764 (98.7) | |
| | Sat/Sun | 64 (2.9) | 10 (1.3) | |
| | (Missing) | 2790 | 837 | |
| Admission Type | | | | <0.001 |
| | elective | 2187 (44.0) | 826 (51.3) | |
| | non-elective | 2782 (56.0) | 785 (48.7) | |
| Discharge Disposition | | | | 0.293 |
| | routine | 1966 (40.2) | 671 (42.1) | |
| | short-term hospital | 83 (1.7) | 29 (1.8) | |
| | SNF/ICF/other facility | 2183 (44.6) | 663 (41.6) | |
| | HHC | 658 (13.5) | 232 (14.5) | |
| | AMA | 2 (0.0) | 0 | |
| | (Missing) | 77 | 16 | |
| Payer | | | | 0.062 |
| | medicare | 2519 (50.7) | 874 (54.3) | |
| | medicaid | 750 (15.1) | 216 (13.4) | |
| | private insurance | 1411 (28.4) | 446 (27.7) | |
| | self-pay | 135 (2.7) | 28 (1.7) | |
| | no charge | 10 (0.2) | 2 (0.1) | |
| | other | 140 (2.8) | 43 (2.7) | |
| | (Missing) | 4 | 2 | |
| Hospital Type | | | | 0.017 |
| | urban/teaching | 4322 (87.0) | 1449 (89.9) | |
| | urban/non-teaching | 581 (11.7) | 151 (9.4) | |
| | rural | 66 (1.3) | 11 (0.7) | |
| Hospital Region | | | | 0.973 |
| | northeast | 1002 (20.2) | 340 (21.1) | |
| | midwest | 1012 (20.4) | 328 (20.4) | |
| | south | 1869 (37.6) | 599 (37.2) | |
| | west | 1086 (21.9) | 344 (21.4) | |
| Revision | | | | 0.796 |
| | no | 4808 (96.8) | 1561 (96.9) | |
| | yes | 161 (3.2) | 50 (3.1) | |
| Length of Stay (days) | | 3.0 (0.0, 252.0) | 3.0 (0.0, 302.0) | 0.056 |
| Died | | | | 0.038 |
| | no | 4892 (98.5) | 1595 (99.1) | |
| | yes | 77 (1.5) | 14 (0.9) | |
| | (Missing) | 0 | 2 | |
| Charges (thousands) | | 91.9 (0.3, 6161.5) | 84.4 (1.5, 2557.7) | 0.231 |

placement were similar between groups (3.2 % open mini-laparotomy v. 3.1 % laparoscopic; $p = 0.796$); as were infection rates (0.2 % open mini-laparotomy v. 0.2 % laparoscopic; $p = 0.843$) and hospital charges ($91, 900 open mini-laparotomy v. $84, 400 laparoscopic; $p = 0.231$) (Table 2 and Supplementary Table 3). LOS trended toward being shorter among the laparoscopic group (mean 5.7 days v. 6.5 days; $p = 0.056$) and mortality was significantly higher in the open mini-laparotomy group (1.5 % v. 0.9 %, $p = 0.038$).

In multivariate analysis, procedure approach (open min-laparotomy v. laparoscopic) was not significantly associated with mortality (Table 3). Factors significantly associated with mortality included: race,

**Table 3**
Univariate and multivariate analysis of mortality.

| Variable | Category | Univariate Analysis | | Multivariate Analysis | |
|---|---|---|---|---|---|
| | | OR (95 % CI) | *p*-value | OR (95 % CI) | *p*-value |
| Procedure Group | | | 0.041 | | |
| | Open Mini-Laparotomy | reference | | | |
| | Laparoscopic | 0.56 (0.32, 0.98) | | | |
| Year | | | 0.408 | | |
| | 2015 | reference | | | |
| | 2016 | 1.21 (0.54, 2.73) | | | |
| | 2017 | 1.54 (0.70, 3.42) | | | |
| Sex | | | 0.392 | | |
| | female | reference | | | |
| | male | 1.20 (0.79, 1.84) | | | |
| Age | | | 0.18 | | |
| | [18,48] | reference | | | |
| | (48,64] | 1.35 (0.79, 2.30) | | | |
| | (64,74] | 0.79 (0.42, 1.49) | | | |
| | (74,90] | 0.81 (0.44, 1.49) | | | |
| Race | | | 0.002 | | 0.038 |
| | White | reference | | reference | |
| | Non-white | 2.00 (1.29, 3.09) | | 1.60 (1.03, 2.49) | |
| Median Income Percentile | | | 0.149 | | |
| | [0, 25] | reference | | | |
| | [26, 50] | 0.71 (0.41, 1.23) | | | |
| | [51, 75] | 0.61 (0.35, 1.06) | | | |
| | [76, 100] | 0.54 (0.29, 0.99) | | | |
| Admission Day | | | 0.316 | | |
| | Mon-Fri | reference | | | |
| | Sat/Sun | 1.33 (0.76, 2.32) | | | |
| Admission Type | | | <0.001 | | <0.001 |
| | elective | reference | | reference | |
| | non-elective | 4.35 (2.48, 7.63) | | 3.12 (1.66, 5.87) | |
| Hospital Type | | | 0.118 | | |
| | urban/teaching | reference | | | |
| | urban/non-teaching | 0.68 (0.31, 1.46) | | | |
| | rural | 2.85 (0.89, 9.14) | | | |
| Hospital Region | | | 0.366 | | |
| | northeast | reference | | | |
| | midwest | 0.59 (0.29, 1.18) | | | |
| | south | 0.79 (0.45, 1.37) | | | |
| | west | 1.02 (0.57, 1.84) | | | |
| Elixhauser Score Group | | | <0.001 | | <0.001 |
| | 0–1 | reference | | reference | |

(*continued on next page*)

**Table 3** (*continued*)

| Variable | Category | Univariate Analysis OR (95 % CI) | Univariate Analysis *p*-value | Multivariate Analysis OR (95 % CI) | Multivariate Analysis *p*-value |
|---|---|---|---|---|---|
| | 2–3 | 3.73 (1.26, 11.01) | | 3.22 (1.08, 9.58) | |
| | 4+ | 13.18 (4.77, 36.42) | | 9.34 (3.28, 26.58) | |

case status (elective or non-elective), and medical comorbidities (Table 3). Non-white patients had increased mortality risk following VPS placement (OR [95 % CI]1.60 [1.03, 2.49]; $p = 0.038$). Cases booked as non-elective had increased risk of mortality following VPS placement (3.12 [1.66, 5.87]; $p < 0.001$). Individuals with more comorbidities were also at an increased risk of mortality following VPS placement ($p < 0.001$) (Table 3).

Similarly, in multivariate analysis, procedure approach was not significantly associated with LOS (Table 4). Factors significantly associated with length of stay included: case status, patient comorbidities, race, patient age, hospital type, hospital regional location (Table 4). Cases booked as non-elective tended to have a greater LOS (1.86 [1.68, 2.07], $p < 0.001$). A greater comorbidity burden as well as non-white race (1.34 [1.22, 1.48], $p < 0.001$) was associated with a greater LOS. Older patients ($p < 0.001$) and those treated in rural hospitals ($p = 0.005$) had a shorter LOS. Patients treated in hospitals in Southern states had the greatest LOS, while patients treated in hospitals in the Midwest had the shortest LOS ($p < 0.001$).

Of the commonly analyzed Elixhauser patient comorbidities, only obesity was significantly associated with the laparoscopic procedure approach ($p = 0.007$) (Supplementary Table 2). Complications following surgical procedure were not associated with either approach (Supplementary Table 3).

## 4. Discussion

VPS placement is the standard of care for treatment of hydrocephalus in the world. Traditionally, an open mini-laparotomy approach is performed by the neurosurgeon for inserting the distal catheter. However, laparoscopy has been increasingly gaining popularity due to its minimal invasiveness and its excellent visualization of the peritoneal cavity.[10,11] Numerous studies exist analyzing various measured outcomes following VPS via open mini-laparotomy approach v. laparoscopic approach.[7,8,10,11,15–21] To the best of our knowledge, our study is the first large national database study addressing outcomes between the two approaches.

In our retrospective database study of the NIS, a total of 6580 cases (4969 with open mini-laparotomy approach and 1611 with laparoscopic collaborative approach) met inclusion criteria. Our goal was to examine whether there are differences between the two surgical approaches in terms of mortality, shunt revision rates, length of stay, hospital charges, and complications.

Our study showed that approximately 25 % of all initial VPS placements were performed with the laparoscopic approach. Patients who underwent the laparoscopic approach had a statistically significant older median age (65 years) compared to those who underwent the open mini-laparotomy approach (63 years). This difference in age is unlikely of clinical significance as there was no appreciable trend for one approach or another based on age quartile.

Our multivariate analysis of the NIS data shows that the different surgical approaches were not associated with differences in mortality or LOS. Outcome measures of mortality and LOS are gaining increasing importance as benchmarks for quality of care and hospital efficiency. Longer LOS is associated with increased risk of hospital acquired

**Table 4**
Univariate and multivariate analysis of length of stay.

| Variable | Category | Univariate Analysis OR (95 % CI) | Univariate Analysis *p*-value | Multivariate Analysis OR (95 % CI) | Multivariate Analysis *p*-value |
|---|---|---|---|---|---|
| Procedure Group | | | 0.008 | | |
| | Open Mini-Laparotomy | reference | | | |
| | Laparoscopic | 0.87 (0.78, 0.96) | | | |
| Year | | | 0.132 | | |
| | 2015 | reference | | | |
| | 2016 | 1.01 (0.87, 1.17) | | | |
| | 2017 | 0.91 (0.79, 1.04) | | | |
| Sex | | | 0.353 | | |
| | female | reference | | | |
| | male | 1.05 (0.95, 1.15) | | | |
| Age | | | <0.001 | | <0.001 |
| | [18,48] | reference | | reference | |
| | (48,64] | 1.16 (1.00, 1.33) | | 1.02 (0.88, 1.18) | |
| | (64,74] | 0.68 (0.60, 0.77) | | 0.73 (0.64, 0.83) | |
| | (74,90] | 0.53 (0.46, 0.61) | | 0.66 (0.58, 0.76) | |
| Race | | | <0.001 | | <0.001 |
| | white | reference | | reference | |
| | non-white | 1.75 (1.58, 1.93) | | 1.34 (1.22, 1.48) | |
| Median Income Percentile | | | <0.001 | | |
| | [0, 25] | reference | | | |
| | [26, 50] | 0.76 (0.67, 0.87) | | | |
| | [51, 75] | 0.81 (0.71, 0.93) | | | |
| | [76, 100] | 0.79 (0.69, 0.89) | | | |
| Admission Day | | | <0.001 | | 0.022 |
| | Mon-Fri | reference | | reference | |
| | Sat/Sun | 1.74 (1.52, 1.99) | | 1.19 (1.03, 1.37) | |
| Admission Type | | | <0.001 | | <0.001 |
| | elective | reference | | reference | |
| | non-elective | 2.74 (2.50, 3.00) | | 1.86 (1.68, 2.07) | |
| Hospital Type | | | <0.001 | | 0.005 |
| | urban/ teaching | reference | | reference | |
| | urban/non-teaching | 0.91 (0.79, 1.04) | | 0.93 (0.83, 1.05) | |
| | rural | 0.53 (0.44, 0.65) | | 0.68 (0.54, 0.86) | |

(*continued on next page*)

**Table 4** (*continued*)

| Variable | Category | Univariate Analysis | | Multivariate Analysis | |
|---|---|---|---|---|---|
| | | OR (95 % CI) | *p*-value | OR (95 % CI) | *p*-value |
| Hospital Region | | | <0.001 | | <0.001 |
| | northeast | reference | | reference | |
| | midwest | 0.88 (0.78, 0.99) | | 0.83 (0.74, 0.93) | |
| | south | 1.18 (1.02, 1.36) | | 1.18 (1.02, 1.36) | |
| | west | 1.08 (0.94, 1.25) | | 1.00 (0.87, 1.16) | |
| Elixhauser Score Group | | | <0.001 | | <0.001 |
| | 0–1 | reference | | reference | |
| | 2–3 | 1.74 (1.54, 1.96) | | 1.70 (1.50, 1.92) | |
| | 4+ | 3.16 (2.86, 3.49) | | 2.74 (2.45, 3.06) | |

infection (HAI).[22] Argo et al showed a statistically shorter hospital stay post-operatively in their laparoscopic group compared to open.[7] Comparatively, Schucht et al showed no difference in LOS between the mini-laparotomy group and the laparoscopic group.[21] Few studies within the scope of this topic have reported mortality rates, presumably because patient death following VPS placement is low.[15]

VPS is a commonly performed procedure; therefore, it is important from both an economic and healthcare utilization standpoint to lower the incidence of shunt failure and subsequent revisions.[2,4,23] The literature has shown conflicting results on the question of shunt failure and revision rates. In a single-center study of 810 consecutive patients, there was no difference in shunt failure rates between laparoscopic and open cases.[8] However, Catapano et al demonstrated more distal shunt revisions in the non-laparoscopic group.[11] Consistent with prior studies' conclusions, our analysis shows a revision rate in both groups of approximately 3 % ($p = 0.796$), thereby demonstrating in a large national database cohort there is not a difference in the revision rate between the laparoscopic and open approaches.

Phan et al presented a meta-analysis and systematic review of a mix of 10 prospective and retrospective studies which showed no significant difference in infection or other complications between open mini-laparotomy v. laparoscopic VPS distal end placement.[19] Similarly, in our study, none of the most frequently post-operative complications evaluated within the broad categories of infectious, cardiac, digestive, respiratory, or shock were significantly associated with either procedure group approach.

Our analysis of Elixhauser comorbidities aligns with other studies showing that obese patients have a greater likelihood of undergoing laparoscopic guidance v. open approach (Supplementary Table 2).[20] Reasons for this likely include a general surgeon's familiarity with the obese abdomen and the reliable visualization of the peritoneal cavity with laparoscopy. Also, distal catheter complications including migrations and incorrect placements are associated with obesity and can be potentially mitigated by the laparoscopic approach.[15,20,21,24,25]

We found that cases booked on a non-elective basis had a longer LOS and higher overall mortality rate. They were more likely performed with the traditional open mini-laparotomy approach as compared to elective procedures more commonly done with laparoscopic approach. Cases performed laparoscopically have traditionally been found to have a shorter LOS presumably due to operative technique providing more manageable post-operative pain, quicker return of bowel function, and lower frequency of abdominal surgical complication (perforation, incisional hernia formation, wound infection).[7,24] Mortality rate is likely higher in non-elective cases due to their urgent or emergent nature requiring CSF diversion and are inherently associated with higher morbidity and mortality.[26,27]

Interestingly, our study showed that older patients tended to have shorter LOS following VPS placement. Elderly patients may have certain shunt indications unique to their patient population (e.g. normal pressure hydrocephalus), and may even be accompanied by protocoled discharge timing as shown in one study which analyzed patients aged >80 years.[28] Thus, preoperative health optimization in preparation for elective cases and protocoled discharge amongst elderly patients may factor into a shorter post-operative stay.

In our demographic analysis, non-white patients were more likely to undergo the open mini-laparotomy approach as compared to white patients. Furthermore, in multivariate analysis, non-white patients had a higher mortality following VPS placement. It is difficult to interpret this finding, which could be confounded. We have shown that non-elective cases carry a higher mortality rate and non-white patients, particularly black patients, are more likely to undergo procedures on a non-elective basis compared to white patients.[29] In non-elective cases, the open mini-laparotomy approach is often chosen due to logistical factors.[30] Prior studies have failed to show an independent link between race and complication or mortality following surgery.[27,31] Additional work on social and socioeconomic disparities in the management of hydrocephalus is needed.

Two retrospective, single-center studies published within the same year have shown conflicting data regarding the price differential between VPS distal end insertion approaches. Catapano et al showed in a subset of patients with normal-pressure hydrocephalus that laparoscopic VPS is more cost-effective compared to traditional mini-laparotomy.[11] Gravbrot et al showed that the laparoscopic VPS approach represented a statistically significant mean increase of >$1200 per patient in direct cost (costs attributed to the surgical procedure exclusively) compared to mini-laparotomy approach.[10] Although a cost comparison was not the focus of this study, analyzing the large dataset's total inpatient charge data suggests no financial advantage to either approach. Mean charge for the open mini-laparotomy approach was $91, 900 compared to $84, 400 for the laparoscopic approach ($p = 0.231$).

## 5. Limitations

Limitations of this study include those associated with any large database study. The data source relies on self-reporting of ICD-10 codes on individuals from a multitude of hospitals and hence the data are only as robust as the quality of the coding. We acknowledge that the infection rates reported in our manuscript were lower than the literature. This could be due to inaccurate self-reporting within the database. The timeframe of interest for this study began just as the ICD-10 period began (October 2015). This time represented a dramatic shift in coding and billing procedures for providers throughout the nation. Because the NIS database does not include duration of surgery, we were not able to evaluate the operative time in our study, as some studies have suggested that the laparoscopic approach has shorter operative time compared to the open approach.[8,11,21] Additionally, the NIS database does not provide longitudinal data on the same patient. We were unable to gather follow-up information. Future studies should continue to examine this population of patients and outcomes between both procedure approaches. Of particular interest, a granular investigation of cases involving VPS revision should be examined for differences in reason for revision depending on what initial VPS approach they had.

## 6. Conclusion

We present the first analysis of a weighted, nationally collected coded dataset to examine baseline characteristics and outcomes in

patients with hydrocephalus who undergo VPS insertion with distal end placement by the traditional open mini-laparotomy approach v. the more contemporary laparoscopic approach. Prior studies have emphasized incidence of distal shunt obstruction but showed conflicting evidence addressing factors such as overall hospital charges, mortality, LOS, and shunt revision rates. Our study is the first to approach this question using the NIS dataset in the ICD-10 period. There was no statistically significant difference in hospital charges, rates of shunt revision, LOS, mortality, or complications between the two approaches. We believe the laparoscopic approach is non-inferior and therefore, the decision of a neurosurgeon to operate alone or in collaboration with general surgery should be based on the neurosurgeon's own experience and preference.

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None.

## CRediT authorship contribution statement

**Monica Maloney:** Investigation, Writing - original draft, Conceptualization, Methodology, Writing - review & editing, Investigation, Conceptualization, Methodology. **Kevin Zhao:** Investigation, Conceptualization, Writing - review & editing. **Patrick Hilden:** Investigation, Software, Formal analysis, Data curation. **Amber L. Turner:** Writing - review & editing, Methodology. **Aziz Merchant:** Conceptualization, Methodology, Investigation, Writing - review & editing. **Pankaj K. Agarwalla:** Conceptualization, Methodology, Investigation, Writing - review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wnsx.2023.100266.

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## Abbreviations

*CSF –*: cerebrospinal fluid
*VPS –*: ventriculoperitoneal shunt
*NIS –*: National Inpatient Sample
*ICD -10 –*: International Classification of Diseases, 10th Revision
*LOS –*: length of stay