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ORIGINAL ARTICLE

Peritoneal insertion of shunts in children: comparison between trocar and laparoscopically guided insertion

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Abstract

Purpose Ventriculo-peritoneal shunts are commonly used for treating hydrocephalus for all age groups. There are 3 main methods for shunt placement into the peritoneum: mini laparotomy, laparoscopically guided, or percutaneously with a trocar. There is limited literature comparing between these techniques in the pediatric population, and specifically—the trocar has not been compared with laparoscopy. The goal of this study is to compare trocar and laparoscopy use, with respect to safety and potential need for future shunt revisions.

Methods Data was retrospectively collected from 2 centers for children (< 18 years old) who underwent a *primary* insertion of a CSF shunt to the peritoneum, and had no prior abdominal surgery or significant abdominal disease. One center used a trocar, and the other laparoscopic guidance. Demographics, surgical time, and shunt complications were analyzed. Primary endpoint was distal shunt malfunction, either technique-related or non-technique-related.

Results Two hundred fifty-seven children (220 trocar, 37 laparoscopy) were included. The groups were similar with regard to age at surgery and etiology of hydrocephalus. Trocar use was associated with a slightly higher, although statistically insignificant, rate of technique-related distal complications (4.1% vs 0, $p = 0.37$). Following propensity score matching, there was no statistically significant difference in any shunt complication between both groups. Trocar use was associated with shorter surgery, and less surgical personnel.

Conclusions In primary shunt surgery in children, abdominal placement of the catheter using a trocar or laparoscopic guidance is safe, and associated with a low distal malfunction rate, with no statistically significant differences between both techniques.

Keywords Hydrocephalus · Shunt · Trocar · Laparoscopy · Distal malfunction

Marga Serafimova and Jehuda Soleman contributed equally to this work.

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Introduction

Ventriculoperitoneal (VP) shunts remain the most common method for treating hydrocephalus of all etiologies and for all age groups [1]. Since it was initially described, many advances in techniques and technology of shunt insertion have been introduced. However, surgical complications and shunt failure still pose a significant medical, social, and economic burden [2, 3].

The peritoneum is the most common, effective target for distal shunt insertion. Nevertheless, distal obstructions are a common cause of shunt malfunction [4]. Several methods for shunt placement into the peritoneum are practiced: mini laparotomy, laparoscopically guided, or percutaneously with a trocar [5–12]. Each method has been studied individually, and is associated with good outcomes and low morbidity; however, there is limited literature comparing these techniques in general, and specifically in the pediatric population [13].

The aim of this study was to compare two pediatric centers' experience, one routinely using percutaneous trocar, and another using laparoscopy to aid shunt insertion. We compare the technique-associated complications, as well as malfunction rates between the two groups.

Methods

Two centers participated in this study. Surgeon preference in one center was trocar-assisted insertion of shunts, whereas in the other center laparoscopic-assisted distal insertion was preferred. Therefore, all shunts inserted via trocar-assisted technique were collected from the patients in one center, and patients whose shunts were inserted via laparoscopic-assisted technique were collected in the other center.

We conducted this study following an institutional review board approval from both institutes. Both ethics committees, due to the retrospective nature of the study, waived patient and parental consents. All patients under the age of 18 years who underwent surgery for primary CSF shunt placement (including ventriculoperitoneal, subduro-peritoneal, subgaleo-peritoneal, and cysto-peritoneal), between the years 2010–2018 (in the trocar group) and 2013–2019 (in the laparoscopy group), were included. Other shunt systems that were not placed into the peritoneum (such as ventriculo-atrial or pleural shunts) were excluded, as well as lumbo-peritoneal shunts. Patients with a prior peritoneal shunt, patients with prior abdominal surgery, and patients with acute or chronic abdominal diseases were also excluded. Patients with PEG (percutaneous endoscopic gastrostomy) were included.

Data was collected retrospectively, including demographics, surgical data such as peritoneal shunt insertion technique, intraoperative findings, and outcome, including complications and need for shunt revisions (immediate and long-term at follow-up). Data relied on patient files and on imaging captures from the PACS system.

When analyzing the data, we focused on complications of the distal placement of the shunt, both acute (perioperatively < 30 days from surgery) and chronic (> 30 days). We classified the distal complications into two groups: insertion-technique-related complications and unrelated complications.

Technique-related distal complications included:

- Early (< 3 months from surgery) visceral perforation
- Misplacement of the tip in extraperitoneal locations
- Distal obstruction
- Pseudocysts

Non-technique-related distal complications included:

- Distal tubing disconnections
- Migration of distal catheters
- Late (> 3 months from surgery) visceral complications

We recognize that distal obstruction, as well as pseudocysts, may be unrelated to the technique of insertion; however, we considered them technique related, since potentially during laparoscopy loculations and adhesions may be identified and freed, consequently avoiding these complications.

Statistical analysis

Contingency tests were done using Fisher's exact test or χ^2 test, while all other calculations were done using the Mann-Whitney *U* test. Since the two groups showed differences in some of the baseline characteristics, which might skew our results, a propensity score matching was applied, in order to reduce this bias to a minimum. After propensity matching in a 1:1 fashion, 37 patients from each group were matched and analyzed. The outcome measures were then re-analyzed. The baseline characteristics of the matched groups are shown in supplementary Table 1. Unfortunately, even after matching the groups through propensity score, the number of surgeons, operation time, and catheter type were unevenly distributed between the groups. Finally, a log-rank test for 30-day and the complete follow-up time of the cumulative complication-free rate in each group were performed and presented as Kaplan–Meier curves. All statistical analyses were done using SPSS Statistics Version 21.0 (IBM Corp, 2012), while propensity score matching was done using R (Comprehensive R Archive Network (CRAN), R Foundation for Statistical Computing, Vienna, Austria, Version 3.2.2). A p value of < 0.05 was considered significant.

Results

Patient groups

A total of 257 patients fulfilled the inclusion criteria, 220 undergoing trocar insertion (trocar group, TG), and 37 laparoscopic-guided insertion (laparoscopy group, LG). Table 1 summarizes the basic group demographic and medical history characteristics. The groups were balanced for history of prematurity, weight at surgery, age at surgery, underlying cause of hydrocephalus, age at shunt insertion, and presence of a PEG. Four statistically significant characteristics were identified:

- The TG had a significantly higher rate of using antibiotic impregnated shunts (AIS).

Table 1 Baseline characteristics of the whole cohort as well as the trocar and laparoscopic cohort

	Total (*n* = 257)	Trocar group (*n* = 220)	Laparoscopic group (*n* = 37)	*p* value
Gender (female), *n* (%)	113 (44.0)	91 (41.4)	22 (59.5)	0.04
Premature born (yes), *n* (%)	98 (48.5)	82 (49.7)	16 (43.2)	0.48
Weight at surgery (≤ 5 kg), *n* (%)	119 (47.0)	99 (45.8)	20 (54.1)	0.36
Weight at surgery (kg, mean ± SD)	10.57 (14.37)	10.45 (14.38)	11.21 (14.51)	0.80
Age at surgery (≤ 1 year), *n* (%)	192 (74.7)	166 (75.5)	26 (70.3)	0.50
Age at surgery (≤ 1/2 year), *n* (%)	150 (58.4)	129 (58.6)	21 (56.8)	0.83
Age at surgery (months, mean ± SD)	29.3 (98.1)	29.6 (104.6)	26.9 (44.0)	0.97
Underlying cause, *n* (%)				
• Congenital	29 (11.3)	23 (10.5)	6 (16.2)	0.40
• IVH	86 (33.5)	79 (35.9)	7 (18.9)	0.05
• Post-infectious	16 (6.2)	14 (6.4)	2 (5.4)	1
• Post MMC	23 (8.9)	18 (8.2)	5 (13.5)	0.35
• Syndromic	7 (2.7)	7 (3.2)	0	0.60
• Cyst/tumor	63 (24.5)	55 (25.0)	8 (21.6)	0.84
• Posttraumatic	1 (0.4)	0	1 (2.7)	0.14
• AS	15 (5.8)	11 (5.0)	4 (10.8)	0.24
• Other	13 (5.1)	11 (5.0)	2 (5.4)	1
• Multiple	4 (1.6)	2 (0.9)	2 (5.4)	0.10
PEG (yes), *n* (%)	5 (1.9)	3 (1.4)	2 (5.4)	0.10
Catheter type (impregnated), *n* (%)	207 (90.4)	192 (100)	15 (40.5)	< 0.001
OR time, mean (± SD)	42.6 (18.3)	40.8 (18.6)	53.1 (11.3)	< 0.001
Number of surgeons, mean (± SD)	2.3 (0.8)	2.1 (0.4)	3.5 (1.3)	< 0.001
Follow-up time, days mean (± SD)	1030.0 (873.4)	1091.6 (880.9)	670.3 (740.7)	0.002

IVH intraventricular hemorrhage, *MMC* myelomeningocele, *AS* aqueductal stenosis, *PEG* percutaneous enterogastrostomy

- Surgeries in the TG were shorter by 25% compared with the LG.
- Surgeries in the TG included less surgeons (2 vs 3.5).
- Follow-up after surgery in the TG was longer by more than 60%.

Outcomes and complications

Table 2 summarizes the various complication rates. Intraoperative complications were rare (0.45% in the TG, 0 in the LP). Postoperative complications were more common in the LG, although the TG had significantly more cases with multiple complications. The TG had more distal complications than the LG (both technique related and non-technique related), although this difference did not reach statistical significance. The TG had significantly more proximal malfunctions. Early (< 30 days) complications were significantly more common in the LG (Figs. 1 and 2), while the overall time to first complication was significantly longer in the TG. The overall rate of infections was comparable in both groups, but the infection rate per patient (not counting multiple infections for one patient) was significantly higher in the LG compared with the TG.

After propensity score matching (supplement Tables 1 and 2):

- The increased infection rate per patient in the LG and increased rate of multiple complications in the TG did not indicate statistically significant differences ($p = 0.19$ and 0.06 respectively)
- The overall rate of complications was comparable between the groups (approximately 40% per group).
- All other results did not significantly change.

Technique-related complications

Nine patients in the TG (4.1%) had a technique-related distal complication, compared with no distal complications in the LG. Table 3 summarizes the clinical data and treatment of these cases.

Discussion

The current study is the largest to date to evaluate the safety and efficacy of the minimally invasive trocar-assisted shunt

Table 2 Outcome measurements trocar group vs laparoscopic group

	Total (*n* = 257)	Trocar group (*n* = 220)	Laparoscopic group (*n* = 37)	*p* value
Intraoperative complication, *n* (%)	1 (0.39-%)	1 (0.45%)	0 (0)	0.86
Total patients with *postop* complications (yes), *n* (%)	87 (33.8-5%)	72 (32.7%)	16 (43.2)	0.21
Total patients with *postop infections* (yes), *n* (%)	24 (9.3)	16 (7.2)	8 (21.6)	0.01
Patients with multiple *postop* complications, *n* (%)	37 (14.4-%)	36 (16.4%)	1 (0.3)	0.001
• No complication, *n* (%)	169 (65.8)	148 (67.3)	21 (56.8)	0.26
• 1 complication, *n* (%)	50 (19.5)	35 (15.9)	15 (40.5)	0.001
• 2 complications, *n* (%)	20 (7.8)	20 (9.1)	0 (0)	0.09
• 3 complications, *n* (%)	14 (5.4)	13 (5.9)	1 (2.7)	0.70
• 4 complications, *n* (%)	2 (0.8)	2 (0.9)	0 (0)	1
• 5 complications, *n* (%)	2 (0.8)	2 (0.9)	0 (0)	1
Number of *complications/per patient*, mean (± SD)	0.6 (± 1.0)	0.6 (± 1.0)	0.5 (0.7)	0.53
Distal complication (all, *n* (%))	16 (6.2)	16 (7.3)	0 (0)	0.14
Distal complication (technique-related, *n* (%))	9 (3.5)	9 (4.1)	0 (0)	0.37
Distal complication (non-technique-related, *n* (%))	7 (2.2)	7 (2.5)	0 (0)	0.60
Total number of *postop* complications, *n*	150	132	18	0.06
Type of Complication, *n* (number of complication) (% of total number of postop complications)				
• Abdominal perforation, *n* (%)	1 (0.7)	1 (0.8)	0 (0)	0.88
• Abdominal pseudocyst, *n* (%)	1 (0.7)	1 (0.8)	0 (0)	0.88
• Distal obstruction, *n* (%)	5 (3.3)	5 (3.8)	0 (0)	0.52
• Distal disconnection, *n* (%)	1 (0.7)	1 (0.8)	0 (0)	0.88
• Distal misplacement, *n* (%)	2 (1.3)	2 (1.5)	0 (0)	0.77
• Distal catheter migration, *n* (%)	6 (4.0)	6 (4.5)	0 (0)	0.61
• Proximal obstruction, *n* (%)	57 (38.0)	54 (40.9)	3 (16.7)	0.04
• Proximal disconnection, *n* (%)	1 (0.7)	1 (0.8)	0 (0)	0.88
• Proximal misplacement, *n* (%)	6 (4.0)	4 (3.0)	2 (11.1)	0.15
• Infection, *n* (%)	43 (28.7)	35 (26.5)	8 (44.4)	0.12
• Wound dehiscence, *n* (%)	10 (6.7)	8 (6.1)	2 (11.1)	0.61
• Slit ventricle syndrome, *n* (%)	6 (4.0)	6 (4.5)	0 (0)	0.61
• Shunt overdrainage/underdrainage, *n* (%)	6 (4.0)	6 (4.5)	0 (0)	0.61
• Other, *n* (%)	5 (3.3)	2 (1.5)	3 (16.7)	0.02
Early (≤ 30 days) complication, *n* (%)	31 (20.7)	23 (17.4)	8 (44.4)	0.008
Time to complication (days), mean (± SD)	397.1 (± 623.7)	427.6 (± 649.7)	173.3 (± 311.2.0)	0.02
Time to complication late (days), mean (± SD)	497.4 (± 664.9)	514.8 (± 684.0)	371.0 (± 664.9)	0.69
Time to complication early (days), mean (± SD)	12.1 (± 9.4)	14.6 (± 9.3)	5.1 (± 5.7)	0.009

insertion in children, comparing it with a laparoscopic-guided technique. Our results suggest that although trocar was associated with higher distal malfunction and complication rates compared with laparoscopy, the difference between the two techniques was not statistically significantly different, and both techniques were safe. Our results also suggest that trocar surgery was faster than the laparoscopy method, using less surgical personnel and instrumentation, and with a tendency

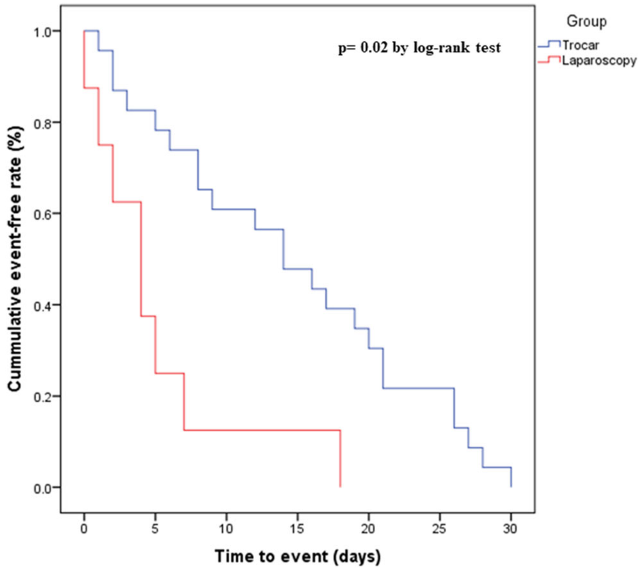

Fig. 1 Kaplan-Meier curve showing the cumulative event-free rate of early (≤ 30 days) complications for the two groups (trocar and laparoscopic). $p = 0.02$ by log-rank test

towards fewer shunt infections. These results may also potentially be translated into lower cost, although this was not directly evaluated. The results hold true for all pediatric ages, including infants younger than 1 year of age. It is important to state that children with prior abdominal diseases (such as necrotizing enterocolitis (NEC) associated with prematurity) or prior shunts were excluded; thus, these results cannot be extrapolated to patients with an "abdominal history" or to shunt revisions.

Abdominal visceral injury has been described following shunt insertion. It is usually delayed and not associated with

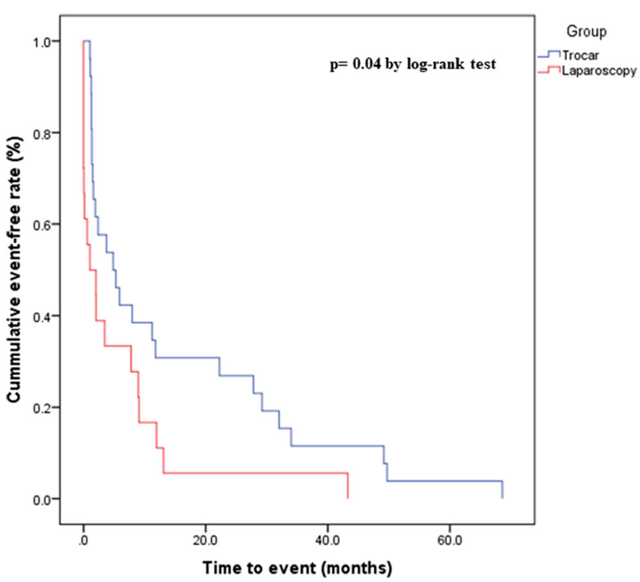

Fig. 2 Kaplan-Meier curve showing the cumulative event-free rate of all complications for the two groups (trocar and laparoscopic) after propensity score matching. $p = 0.04$ by log-rank test

a specific shunt placement technique [14–19]. Risk factors for visceral perforation are younger age and myelomeningocele. However, immediate visceral complications may occur [5, 7]. The main approaches that have been described for shunt placement into the peritoneum are mini-laparotomy, trocar, and laparoscopic guided. Each approach has its advantages and disadvantages (Table 4). It is important to acknowledge that each technique has its own characteristics and learning curve. For example, laparoscopy is usually performed by a general surgical team experienced in this technique, while mini-laparotomy and trocar-assisted are performed by individual neurosurgeons. The trocar approach has its own learning curve and technical nuances: where to locate the entry point to the abdomen, what trocar to use, where to aim the tip of the trocar, how forcefully to use the trocar, how to verify intraperitoneal location, etc. Understanding and experience with these nuances are crucial to reduce the rate of trocar technique-related complications.

Laparoscopy has been associated with an extremely low (although not 0) rate of distal misplacement and visceral perforation [6, 7, 9, 20–22]. Several studies have compared laparoscopy with mini-laparotomy and demonstrated the advantages of laparoscopy in terms of procedure length and complication rate [5, 7, 23]. Generally, the laparoscopic approach is associated with a shorter operative time and decreased distal shunt malfunction compared with mini-laparotomy [7, 22–27]. In obese patients, laparoscopy is associated with smaller incisions, thus reducing the risk of migration of the shunt to subcutaneous tissue [28]. A recent meta-analysis has also shown a significantly reduced distal shunt failure rate in the laparoscopy group compared with the mini-laparotomy group [25, 26]. Nevertheless, the literature is not unanimous—at least one other study in children has found a longer time of surgery in the laparoscopy group compared with the open approach, with no added value in reducing complications [13].

Laparoscopic-assisted shunt insertion carries the advantage of catheter insertion under vision, with minimal scarring and the ability to address abdominal adhesions. Often, the laparoscopic introduction to the peritoneum is performed concurrently with the cranial part of surgery, speeding up the entire procedure [6, 7, 20, 21, 29, 30]. As reflected in the results of this study, the laparoscopy time was significantly longer than for the trocar. However, since 2018, we have found that laparoscopy time has shortened significantly, since both cranial and abdominal surgical procedures are performed in parallel, and the laparoscopy team has gained experience in the introduction of the catheter through a peel away sheet (data not presented). In some centers, the neurosurgical team does the laparoscopic technique too [5, 10]. Laparoscopy has been described in infants and babies, and associated with very low rates of complications [20, 31].

Table 3 Clinical and treatment data of technique-related distal complications in the *trocar group*

Type of complication	Age at shunt insertion (days)	Weight at shunt insertion (kg)	Time from shunt insertion to revision (days)	Treatment	Outcome
Obstruction	72	2.6	14	Repositioning	Uneventful
Obstruction	60	2.5	337	Repositioning	Uneventful
Obstruction	4570 (12.5 years old)	50	2	Repositioning	Uneventful
Obstruction	4	3.1	1521	Repositioning	Uneventful
Obstruction	4	N/S	764	Repositioning	Uneventful
Misplacement	173	6	238	Migration into scrotum, repositioning + hydrocele closure	Uneventful
Misplacement	4679 (12.8 years old)	38	1	Rolled in abdominal wall, repositioned	Uneventful
Perforation	2553 (7 years old)	28	3	Exploratory laparotomy and primary suturing of perforation	Uneventful
Pseudocyst	79	2.5	515	Distal revision	Uneventful

Trocar-assisted shunt insertion is widely practiced and has also been associated with shorter surgical time compared with mini-laparotomy [12, 32]. The reported risk of vascular injury (which may be fatal) from trocar-assisted shunt insertion in adults is about 0.18% [33]. A thin abdominal wall is suspected to be a risk factor. In comparison with mini-laparotomy, trocar-assisted shunt placement is faster, and associated with fewer distal shunt complications [34]. However, we are not aware of any study comparing a trocar approach with a laparoscopic approach in children.

Table 4 Potential advantages and disadvantages of various peritoneal shunt insertion techniques

	Potential advantages	Potential disadvantages
Mini-laparotomy	Open access, with verified peritoneal opening	Time consuming Larger incision than other approaches In overweight patients, may increase risk of distal migration of shunt into subcutaneous space Risk of postoperative incisional hernia
Laparoscopic guided	Minimal invasive Entry of distal shunt tip under vision Location of distal end verified in peritoneum Ability to address peritoneal adhesions Reduced risk of postoperative incisional hernia In preemies, often can repair hernia in the same session Reduced risk of distal complications	Time consuming Need for laparoscopic equipment and experienced personnel (usually a general pediatric surgeon)
Trocar	Fast Minimal invasive Reduced risk of postoperative incisional hernia Lower cost	Potential risk of abdominal organ and vascular injury Potential risk of misplacement of distal end of shunt in preperitoneal tissue Learning curve essential

When looking into the technique-related distal complications in our study, there was no significant difference between the trocar-assisted and laparoscopically inserted shunts. Nine technique-related complications were observed in the trocar group, but only 4 (1.8%) were clearly related to the technique and occurred within 2 weeks of surgery, while the remaining 5 occurred more than 8 months later. Interestingly, in our trocar group, only 1 infant (< 1 year of age) (0.6%) had a technique-related complication. On the other hand, in the laparoscopically assisted insertions, no distal complication occurred in any age.

The infection rate with trocar-assisted shunt insertions was about 7% (16 patients had a total of 35 infections) and with laparoscopically guided insertions the infection rate was 21% (8 patients). The 7% infectious rate of the TG is comparable with the current literature of 5–11% shunt infection rate [35, 36]. In a recent study, we reported our overall shunt infectious rate to be about 4% [37]. A reason for the relatively high infection rate in the LG might be the type of catheter used. In all 8 patients suffering a shunt infection, a non-impregnated catheter was used. This is also supported by the recent literature, where antibiotic-impregnated catheters showed a strong association with lower infection rates [38]. The LG have altered their routine and are currently inserting only antibiotic impregnated shunts. Other explanations for the higher infection rate in the LG as opposed to the TG might be the longer surgical duration, as well as the need for additional surgical equipment and surgical personnel.

As observed by Roth et al. in adult patients, laparoscopically aided shunt insertions could benefit obese patients, patients with previous abdominal surgery, or chronic abdominal pathologies; hence, the method of insertion should be based on patient selection [29]. These variables have not been evaluated in children. However, for children with a history of necrotizing enterocolitis (NEC), or any other prior abdominal surgery or infection, or even for patients with a percutaneous gastrostomy (PEG), there seems to be an advantage to laparoscopic guidance of shunt insertion.

Limitations

As with any retrospective study, data collection and selection bias may affect the results. Additionally, we did not include patients with an "abdominal history" nor patients with shunt revisions. Extrapolating our results to these patients is incorrect. The protocol in both hospitals is to use a laparoscopic-guided approach for any case with an "abdominal history," especially if it entails a significant abdominal disease or previous abdominal surgery [13, 39, 40]. Additionally, antibiotic impregnated shunts were more common in the trocar group, possibly explaining the difference in infectious complications. Although not accounted for in this study, most shunts in the trocar group were placed in the parietal region, while the laparoscopic ones were frontal, possibly accounting for additional surgical time in the laparoscopy group.

Conclusion

Trocar-assisted placement of shunts in children of all ages is associated with a non-statistically significant higher rate of distal malfunction and distal complications compared with laparoscopic-guided shunt placement. Both techniques were safe with a very low technique-related complication rate. Surgical time and number of surgeons are both reduced when using trocar vs laparoscopy. These results should not be extrapolated to children with a history of abdominal disease or previous abdominal surgeries.

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Compliance with ethical standards We conducted this study following an institutional review board approval from both institutes. Both ethics committees, due to the retrospective nature of the study, waived patient and parental consents.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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