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Ventriculoperitoneal shunt entry points in patients undergoing shunt placement: A single-center study

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ABSTRACT

Background: The ventriculoperitoneal (VP) shunt redirects cerebrospinal fluid flow, with the selection of entry points crucial for optimal outcomes. Anatomical landmarks and specific entry points, such as Kocher's, Frazier's, Keen's, and Dandy's points, have been utilized for shunt catheter placement. This study investigates the impact of various entry points on outcomes, particularly the necessity for revision procedures, in patients undergoing VP shunt placement.
Methods: In this retrospective cohort study, we analyzed data from patients in our center's database, collected from October 2017 to October 2022. Participants were classified based on ventriculoperitoneal shunt entry points. The study followed STROBE guidelines. Continuous variables were presented as means with standard deviations (SD) and categorical variables as frequencies and percentages. Linear Model ANOVA and Pearson's Chi-squared tests were used for comparisons. Data analysis was conducted using Jamovi software.
Results: Our study included 94 patients who underwent shunt procedures. The patients were categorized into four treatment groups: Dandy point (10), Frazier point (21), Keen point (43), and Kocher point (20).
Conclusion: Our study found no significant differences in age, FOHR, and indication for shunt placement among catheter entry point subgroups. However, gender distribution, catheter length, and catheter tip location significantly varied. The proportion of patients requiring revision surgery varied among the groups, with the highest rate in the Dandy point group and the lowest in the Keen group; however, the difference among the entry groups was insignificant.

1. Introduction

Cerebrospinal fluid (CSF) flow is redirected via the ventriculoperitoneal (VP) shunt, which consists of a ventricular catheter attached to a valve and then to a distal catheter. The VP shunt's distal tip is inside the peritoneal cavity.[1] The right lateral ventricle can be used as the entry location for the ventricular catheter, with priority going to the larger ventricle in asymmetry cases. The distal catheter can also be inserted into the peritoneal cavity, the heart through a cervical venous entry, the pleura, or, in rare cases, the ureter or bladder if other locations are no longer suitable.[1]

Research investigations have been undertaken to compare the benefits of anterior and posterior entry points, aiming to determine the most favorable approach for achieving optimal outcomes.[2] Typically, the ventricular catheter primarily terminates in the peritoneal cavity, which is generally accessible and possesses ample absorptive capacity to accommodate the volume of CSF produced by an individual.[3] However, the hazards of thrombosis, endocarditis, myocardial damage, nephritis, and arrhythmias make the right atrium of the heart a second-choice but tolerable distal site.[3]

Anatomical landmarks like the medial canthus of the ipsilateral eye and the tragus of the ipsilateral ear are essential for inserting a frontal catheter. Kocher's point, which is 1–2 cm anterior to the coronal suture and 3 cm lateral from the midline, is used to put burr holes. The anterior fontanelle's corner is a good entrance point for infants. A retro-auricular skip incision is frequently needed for frontal shunts.[1,3,4] An alternative approach to estimate burr-hole placement for an occipital catheter involves positioning the burr hole at the midpoint of a line drawn between

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the inion and the mastoid process.[1,3,4] The Frazier point, which is 6 cm above the inion and 3 cm off midline with the catheter approaching from a superior lateral to inferior midline direction, the Keen point, which is 3 cm above and 3 cm behind with the catheter aiming perpendicular to the cortex and slightly cephalic, the Dandy point, which is 2 cm lateral to the midline and 3 cm above, were other common cranial catheter entry points that have been mentioned in the prior literature.[5,6]

In addition to catheter entry points' importance in ventricular shunting, throughout several years, clinical observations have yielded evidence suggesting that ventricular catheter tips situated in particular regions, including the frontal horn, occipital horn, and locations distant from the choroid plexus, demonstrate prolonged durability when contrasted with catheters positioned in alternative areas.[7–11] Nonetheless, despite these findings, the exact specification and substantiation of these preferable targets have yet to be established, resulting in uncertainty surrounding the precise whereabouts of the most advantageous target site.

Although the literature did not explicitly mention complications associated with using specific entry catheter points for ventricular access, it is crucial to acknowledge that selecting an entry point is contingent upon the patient's unique anatomy and the surgeon's personal preference and expertise. Nevertheless, comprehensive knowledge regarding these access points, encompassing their background, external anatomical landmarks, trajectories, and indications, will aid in effectively managing all cases necessitating ventricular drainage.[5,6] Our study aims to present the results of our investigation concerning the utilization of various entry points in our patients and the impact of these points on our assessed outcome, particularly the necessity for revision procedures.

2. Methods

2.1. Study design

We retrieved the data of 94 patients from our center database from October 2017 to October 2022 and classified them according to the ventriculoperitoneal shunt entry points. Our retrospective cohort study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[12]

2.2. Participants and inclusion criteria

The study included a total of 94 patients who met the inclusion criteria that were as follows: age <3 years old; patients who have any of the following entry points for their catheter: Frazier, Koche, Keen, and Dandy points. The exact anatomical landmarks for these points were defined previously in the previous literature.[5,6] Also, the following outcomes had to be available to be included in our study: Patient revision status, Frontal Occipital and Frontal Temporal Horn Ratios (FOHR), catheter tip location, catheter length, and the indication for shunt placement. Ethical considerations were taken into account throughout the design and implementation of this study.

2.3. Ethical considerations

The study protocol was reviewed and approved by the ethics committee of our institution prior to data collection. The ethics committee waived informed consent due to the study's retrospective nature and the use of de-identified patient data. The study did not involve any interventions or modifications to the standard clinical procedures. The data analysis or reporting included no patient identifiers or personal information to ensure anonymity and privacy.

2.4. Data analysis

Descriptive statistics were used to summarize the characteristics of the patients within each group. Continuous variables were reported as means with standard deviations (SD), while categorical variables were presented as frequencies and percentages. The Linear Model ANOVA test was employed to compare the means between the four groups for continuous outcomes. Pearson's Chi-squared test was used to examine the association between the outcome variables among the four catheter entry groups for categorical outcomes. All statistical analyses were performed using Jamovi software.[13]

3. Results

3.1. Patient characteristics

This retrospective cohort study included 94 patients who underwent shunt procedures. The patients were divided into four treatment groups: Dandy point ($n = 10$), Frazier point ($n = 21$), Keen point ($n = 43$), and Kocher point ($n = 20$). The associations between various patient characteristics and treatment outcomes were assessed using appropriate statistical tests. The mean age of the participants was 41.2 years (SD = 15.2), with a range of 3.0–86.0 years. However, the difference in age among the treatment groups was not statistically significant ($p = 0.2551$). Gender distribution showed a significant association with the treatment groups ($p = 0.0042$). Among the total participants, 75.5% were male. The Frazier point group had the highest proportion of male patients (85.7%), followed by the Keen point group (76.7%) and the Kocher point group (85.0%). Table 1 summarizes the descriptive and inferential statistics for our study participants.

3.2. Assessed outcomes

3.2.1. Revision

The need for revision surgery did not show a significant association with the treatment groups ($p = 0.3982$). Among the total participants, 13.8% required revision surgery. The proportion of patients requiring revision surgery was 30.0% in the Dandy point group, 14.3% in the Frazier point group, 9.3% in the Keen point group, and 15.0% in the Kocher point group (Fig. 1). Additionally, when we applied the analysis for catheter tip location, we didn't find any significant difference between any group ($p = 0.80$).

3.2.2. Catheter tip

The catheter tip locations significantly differed among the studied groups ($p = 0.0082$). Most patients (76.6%) had the catheter tip placed in the ipsilateral lateral ventricle. However, the distribution of catheter tips differed among the treatment groups. The Dandy point group had 90.0% of catheter tips placed in the ipsilateral lateral ventricle, while the Frazier point, Keen point, and Kocher point groups had 85.7%, 76.7%, and 60.0%, respectively. The Dandy point group had 10.0% catheter tips placed in the contralateral lateral ventricle, compared to 4.8% in the Frazier point group, 16.3% in the Keen point group, and 10.0% in the Kocher point group. Additionally, 25.0% of the catheter tips in the Kocher point group were placed in the third ventricle, compared to 0.0% in the other groups. The brain parenchyma had 2.3% catheter tips in the Frazier point group, 7.0% in the Keen point group, and 5.0% in the Kocher point group.

3.2.3. Catheter length and FOHR

The mean catheter length was 3.7 cm (SD = 1.6) for all treatment groups, ranging from 1.0 to 10.0 cm. The difference in catheter length among the treatment groups was significantly different ($p > 0.001$). Conversely, all entry groups had a mean frontal occipital horn ratio (FOHR) of 0.4 (SD = 0.1). The FOHR did not differ significantly among the treatment groups ($p = 0.8841$).

3.2.4. Shunt indication

The indication for the shunt procedure did not show a significant

Table 1
Summarizes descriptive and inferential statistics of the studied population based on the catheter entry points for Ventriculoperitoneal shunt placement.

	Dandy point ($n = 10$)	Frazier point ($n = 21$)	Keen point ($n = 43$)	Kocher point ($n = 20$)	Total ($n = 94$)	*p*-value
Age						0.255[a]
Mean (SD)	41.3 (19.2)	37.7 (14.7)	40.2 (15.7)	46.9 (11.7)	41.2 (15.2)	
Range	20.0–86.0	3.0–72.0	16.0–71.0	23.0–71.0	3.0–86.0	
GENDER						0.004[b]
Males	3.0 (30.0%)	18.0 (85.7%)	33.0 (76.7%)	17.0 (85.0%)	71.0 (75.5%)	
Revision						0.398[b]
Yes	3.0 (30.0%)	3.0 (14.3%)	4.0 (9.3%)	3.0 (15.0%)	13.0 (13.8%)	
FOHR						0.884[a]
Mean (SD)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)	0.4 (0.1)	
Range	0.3–0.5	0.2–0.6	0.2–0.6	0.3–0.6	0.2–0.6	
Catheter tip						0.008[b]
Ipsilateral lateral ventricle	9.0 (90.0%)	18.0 (85.7%)	33.0 (76.7%)	12.0 (60.0%)	72.0 (76.6%)	
Contralateral lateral ventricle	1.0 (10.0%)	1.0 (4.8%)	7.0 (16.3%)	2.0 (10.0%)	11.0 (11.7%)	
3rd ventricle	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	5.0 (25.0%)	5.0 (5.3%)	
Brain parenchyma	0.0 (0.0%)	2.0 (9.5%)	3.0 (7.0%)	1.0 (5.0%)	6.0 (6.4%)	
Catheter length						>0.001[a]
Mean (SD)	4.0 (1.5)	4.3 (1.5)	3.9 (1.6)	2.4 (1.0)	3.7 (1.6)	
Range	1.5–6.2	1.5–6.0	1.7–10.0	1.0–4.5	1.0–10.0	
Indication						0.338[b]
Aqueductal stenos	1.0 (10.0%)	0.0 (0.0%)	3.0 (7.0%)	0.0 (0.0%)	4.0 (4.3%)	
CONGENITAL	0.0 (0.0%)	1.0 (4.8%)	4.0 (9.3%)	0.0 (0.0%)	5.0 (5.3%)	
DW	0.0 (0.0%)	1.0 (4.8%)	0.0 (0.0%)	0.0 (0.0%)	1.0 (1.1%)	
IIH	2.0 (20.0%)	1.0 (4.8%)	3.0 (7.0%)	1.0 (5.0%)	7.0 (7.4%)	
INFECTION	1.0 (10.0%)	2.0 (9.5%)	4.0 (9.3%)	3.0 (15.0%)	10.0 (10.6%)	
IVH	1.0 (10.0%)	0.0 (0.0%)	2.0 (4.7%)	3.0 (15.0%)	6.0 (6.4%)	
IVH/AVM	0.0 (0.0%)	2.0 (9.5%)	0.0 (0.0%)	0.0 (0.0%)	2.0 (2.1%)	
MMC	0.0 (0.0%)	0.0 (0.0%)	1.0 (2.3%)	0.0 (0.0%)	1.0 (1.1%)	
NPH	1.0 (10.0%)	1.0 (4.8%)	5.0 (11.6%)	2.0 (10.0%)	9.0 (9.6%)	
SAH	0.0 (0.0%)	1.0 (4.8%)	1.0 (2.3%)	4.0 (20.0%)	6.0 (6.4%)	
TRAUMATIC	2.0 (20.0%)	4.0 (19.0%)	10.0 (23.3%)	2.0 (10.0%)	18.0 (19.1%)	
TUMOR	2.0 (20.0%)	8.0 (38.1%)	10.0 (23.3%)	5.0 (25.0%)	25.0 (26.6%)	

•MMC: meningomyelocele; DW: dandy walker; IHH: idiopathic intracranial hypertension. IVH: inter-ventricular hemorrhage; NPH: normal pressure hydrocephalus; SAH: sub-arachnoid hemorrhage; AVM: arteriovenous malformation.

[a] Linear Model ANOVA.

[b] Pearson's Chi-squared test.

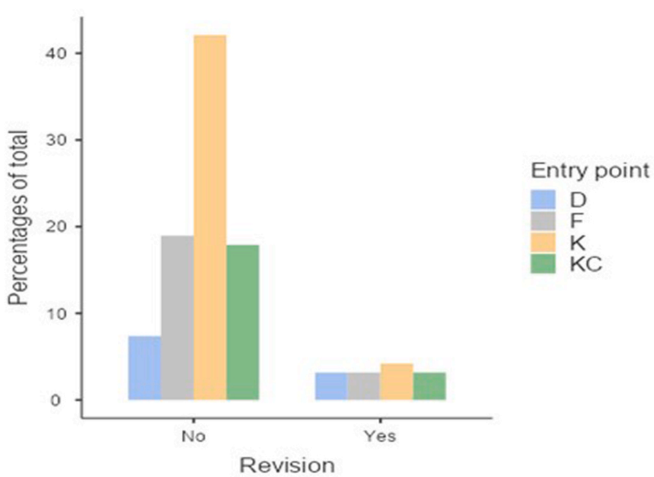

Fig. 1. Illustrates different entry points stratified according to revision status D: Dandy, F: Frazier, K: Keen, and KC: Kocher's points.

association with the treatment groups ($p = 0.3382$). Traumatic (19.1%) and tumor-related (26.6%) conditions were the most common indications for shunt placement. The Dandy, Frazier, Keen, and Kocher point groups had proportions of 20.0%, 38.1%, 23.3%, and 25%, respectively, for tumor-related indications. The proportions for traumatic indications were 20.0%, 19.0%, 23.3%, and 10.0% for the respective treatment groups.

4. Discussion

Our retrospective cohort study found no significant differences in age, FOHR, and indication for shunt placement among the subgroups according to Catheter entry points. Also, we did not find significant differences in revision groups regarding catheter tip location. However, significant differences were observed in gender distribution, catheter length, and catheter tip location. Among the total participants, 13.8% required revision surgery. The proportion of patients requiring revision surgery was 30.0% in the Dandy point group, 14.3% in the Frazier point group, 9.3% in the Keen point group, and 15.0% in the Kocher point group.

The brain trauma foundation guidelines and the CLEAR (Clot Lysis Evaluating Accelerated Resolution of Intraventricular Hemorrhage) trial have highlighted the importance of emergency ventriculostomy and determination of entry points, even in patients without hydrocephalus.[14–16] This procedure has become more demanding, especially in cases of traumatic brain injury, where frontal contusions with effacement of the frontal horn are common, making frontal horn cannulation challenging. In such cases, posterior cannulation through the Frazier point is a preferred option due to the relatively lower incidence of occipital injuries/incisions.[15] Despite the availability of easier shunt sites, some preferred Frazier point because they offered a long intraventricular trajectory and a lower risk of choroid plexus blocking the shunt holes, along with a relatively safe entry zone. This explains the continued use of this shunt method despite the challenges of occipital insertion and the need for a higher level of surgical expertise.[14,15]

Furthermore, we need to study these entry points because the shape of the occiput plays a significant role in determining which point would be suitable for shunt placement.[16] Racial differences influence skull shapes, with variations in dolichocephalic, brachycephalic, and mesocephalic shapes.[16] In a study including a series of 50 cases, they found that entry points varied based on skull shape, with specific distances from the inion. Group 1 (flat and little round shapes) had an average distance of 5.3 cm from the inion, while group 2 (round and very round types) had a 5.1 cm distance.[16]

The most well-described ventricular access points include Kocher's, Keen's, Frazier's, and Dandy's points.[6] Kocher's point is commonly described as the site for external ventricular drain placement during sudden CSF diversion. It has been utilized for various clinical procedures, including inserting ventriculoperitoneal shunt catheters, endoscopic third ventriculostomies, removing colloid cysts, and intraventricular hemorrhage.[17–23] The catheter's tip should be placed close to the foramen of Monro to maximize CSF drainage. Since the patient's right side typically correlates to the nondominant hemisphere, inserting the catheter is generally thought to be safer. However, a left-sided approach may also be used, depending on the disease and the surgical objectives.[17–23] Despite its widespread use, ventricular cannulation through Kocher's point is still inaccurate, with reported miss rates ranging from 4 to 40%; in our study, it was 15%.[17–23] So, we had an acceptable failure rate compared to previous literature.

Regarding Keen's point, it is generally used for the emergency diversion of CSF fluid during posterior fossa surgery and is frequently included in the surgical field. In addition, it is frequently used to implant a proximal ventriculoperitoneal shunt catheter.[6,24,25] Although several reports have described successful ventricular cannulation using Keen's point, no clinical trials have determined its accuracy.[6,24,25] Notably, we had a success rate of approximately 91%; however, the population in this group was only 43 patients.

Frazier's point was initially employed as a surface marking during trigeminal nerve transaction in trigeminal neuralgia.[26] It is used during posterior fossa surgery when rapid cerebrospinal fluid diversion is required to relieve increased intracranial pressure.[24] Using magnetic resonance imaging data, Lee et al demonstrated a 100% simulated ventricular cannulation rate in 10 individuals with this craniometrics.[15] We had an approximately 85% success rate in the Frazier group of 21 real patients. Consequently, our success rate without revision is acceptable when compared to the Lee et al simulation study.

Regarding Dandy's point, it was first utilized to perform ventriculography via an occipital approach.[27] Currently, this technique is performed when cerebrospinal fluid diversion is necessary for a patient already positioned for an occipital or retromastoid craniotomy.[24] It can be performed as a planned procedure just before initiating the formal craniotomy or, more commonly, in an emergent situation where rapid and unplanned cerebrospinal fluid diversion is required for a patient exhibiting intraoperative signs of elevated intracranial pressure requiring immediate interference.[24] Lee et al also simulated the ventricular trajectories of 10 patients and achieved a cannulation rate of 100%.[15] However, we considered one of the earliest studies to include real patients with a success rate of approximately 70%. It is important to note that due to the catheter's trajectory close to or through the optic radiations, potential damage to the visual fields is a theoretical concern when performing this technique.

As to the importance of various catheter tip locations versus entrance points, Whitehead et al demonstrate that the choice of entry site has a substantially greater impact on shunt survival than catheter tip placement.[11] In other words, the site where the catheter enters the brain on route to the ventricle is of greater significance than the catheter's precise position within the ventricle. This does not imply that the target site is insignificant (as any catheter tip embedded in the brain from any entry site will ultimately fail). Nonetheless, it suggests that catheter orientation within the ventricle may significantly prevent catheter occlusion. When catheters are implanted anteriorly, entering the frontal horn or body of the ventricle through the roof and hanging like a chandelier, they are less likely to touch the ventricular walls, floor, and choroid plexus. This decreased contact may result in a decreased incidence of blockage and increased survival times.[11]

In contrast, catheters implanted using a posterior approach, entering the ventricle through the walls, are more likely to rest on the ventricular floor or choroid plexus, perhaps leading to a higher incidence of obstruction.[11] Whitehead et al concurred with the current popularity of anterior entrance points like Kocher's point[11]; nonetheless, our findings did not reveal a statistically significant difference in revision rate between implanted catheters. In addition, we need larger, high-quality trials to generate solid evidence for selecting the entry point with the lowest risk of complications or revisions.

To our knowledge, we are the first study to compare these different catheter entry points with each other regarding revision, FOHR, and catheter tip location. Additionally, our results give promising approaches that could imply different situations without strict adherence to one approach. However, our study was not free of limitations that were as follows: We had a relatively small sample size (94 patients in the four compared groups), which attributes our results to type 2 error and could hinder the results' generalizability. Additionally, the different indications in each group and between groups, as we illustrated earlier in Table 1, could be a major confounder for our results. Furthermore, the study's retrospective nature includes other potential biases due to the study design, reliance on existing medical records, and the possibility of missing or incomplete data. However, efforts were made to minimize these limitations through careful data collection and analysis procedures.

5. Conclusion

Our retrospective cohort did not identify any significant disparities in age, FOHR, and indication for shunt placement across the various subgroups defined by Catheter entry points. However, notable distinctions were observed in gender distribution, catheter length, and catheter tip location. Furthermore, the proportion of patients necessitating revision surgery varied across the different Catheter entry point groups, with the Dandy point group having the higher rate and the Keen group having the lowest. However, the difference among groups was not statistically significant. These results highlight the need for further research to investigate the underlying factors driving these differences and explore their potential implications for clinical practice.

CRediT authorship contribution statement

Younis Baregzai: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mohammed Maan Al-Salihi:** Software, Methodology, Formal analysis. **Amro Al Hajali:** Project administration, Methodology. **Firas Hammadi:** Validation, Investigation, Data curation. **Ali Ayyad:** Writing – review & editing, Methodology.

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.

References

1. Fowler JB, De Jesus OMF. *Ventriculoperitoneal Shunt. StatPearls [Internet]. Treasure Island (FL).* StatPearls Publishing; 2023, 2023.
2. Duong J, Elia C, Miulli D, Dong F, Sumida A. An approach using the occipital parietal point for placement of ventriculoperitoneal catheters in adults. *Surg Neurol Int.* 2019;10:21. https://doi.org/10.4103/sni.sni_3_18.
3. Bakhaidar M, Wilcox JT, Sinclair DS, Diaz RJ. Ventriculoatrial shunts: review of technical aspects and complications. *World Neurosurg.* 2022;158:158–164. https://doi.org/10.1016/j.wneu.2021.11.025.
4. Lind CRP, Tsai AMC, Law AJJ, Lau H, Muthiah K. Ventricular catheter trajectories from traditional shunt approaches: a morphometric study in adults with

hydrocephalus. *J Neurosurg*. 2008;108:930–933. https://doi.org/10.3171/JNS/2008/108/5/0930.
5. Roka YB. A review of trajectories for external cranial ventricular access. *Nepal J Neurosci*. 2021;18:2–8. https://doi.org/10.3126/njn.v18i2.36276.
6. Morone PJ, Dewan MC, Zuckerman SL, Shane Tubbs R, Singer RJ. Craniometrics and ventricular access: a review of kocher's, kaufman's, paine's, menovksy's, tubbs', keen's, frazier's, dandy's, and sanchez's points. *Oper Neurosurg*. 2020;18:461–469. https://doi.org/10.1093/ons/opz194.
7. Becker DP, Nulsen FE. Control of hydrocephalus by valve-regulated venous shunt: avoidance of complications in prolonged shunt maintenance. *J Neurosurg*. 1968;28: 215–226. https://doi.org/10.3171/jns.1968.28.3.0215.
8. Kestle JRW, Drake JM, Cochrane DD, et al. Lack of benefit of endoscopic ventriculoperitoneal shunt insertion: a multicenter randomized trial. *J Neurosurg*. 2003;98:284–290. https://doi.org/10.3171/jns.2003.98.2.0284.
9. Pang D, Grabb PA. Accurate placement of coronal ventricular catheter using stereotactic coordinate-guided free-hand passage. *J Neurosurg*. 1994;80:750–755. https://doi.org/10.3171/jns.1994.80.4.0750.
10. Tuli S, O'Hayon B, Drake J, Clarke M, Kestle J. Change in ventricular size and effect of ventricular catheter placement in pediatric patients with shunted hydrocephalus. *Neurosurgery*. 1999;45:1329–1335. https://doi.org/10.1097/00006123-199912000-00012.
11. Whitehead WE, Riva-Cambrin J, Kulkarni AV, et al. Ventricular catheter entry site and not catheter tip location predicts shunt survival: a secondary analysis of 3 large pediatric hydrocephalus studies. *J Neurosurg Pediatr*. 2017;19:157–167. https://doi.org/10.3171/2016.8.PEDS16229.
12. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. *STROBE eigen doc (from Equator)*. 2008;12–3.
13. Https://www.jamovi.org. T jamovi project (2022). jamovi. (Version 2. 3. [Computer SR from. The jamovi project (2022). jamovi. (Version 2.3) [Computer Software]. Retrieved from https://www.jamovi.org. n.d. https://doi.org/The jamovi project (2022). jamovi. (Version 2.3) [Computer Software]. Retrieved from https://www.jamovi.org.
14. Hydrocephalus Fact Sheet; 2008. Available at: www.ninds.nih.gov/disorders/hydrocephalus/detail _hydrocephalus.htm Accessed November 5, 2023.
15. Lee CK, Tay LL, Ng WH, Ng I, Ang BT. Optimization of ventricular catheter placement via posterior approaches. *Surg Neurol*. 2008;70:274–277. https://doi.org/10.1016/j.surneu.2007.07.020.
16. Deora H, Pruthi N, Rao KVLN, Saini J, Dikshit P. Predicting the ideal ventricular freehand pass trajectory using osirix software and the role of occipital shape variations. *World Neurosurg*. 2020;141:e341–e357. https://doi.org/10.1016/j.wneu.2020.05.146.
17. Woo H, Kang D-H, Park J. Preoperative determination of ventriculostomy trajectory in ventriculoperitoneal shunt surgery using a simple modification of the standard coronal MRI. *J Clin Neurosci*. 2013;20:1754–1758. https://doi.org/10.1016/j.jocn.2013.01.025.
18. Jones RF, Stening WA, Brydon M. Endoscopic third ventriculostomy. *Neurosurgery*. 1990;86. https://doi.org/10.1097/00006123-199001000-00012.
19. Zohdi A, Kheshin S. Endoscopic approach to colloid cysts. *Min - Minim Invasive Neurosurg*. 2006;49:263–268. https://doi.org/10.1055/s-2006-950385.
20. Wang W-H, Hung Y-C, Hsu SPC, et al. Endoscopic hematoma evacuation in patients with spontaneous supratentorial intracerebral hemorrhage. *J Chinese Med Assoc*. 2015;78:101–107. https://doi.org/10.1016/j.jcma.2014.08.013.
21. Abdoh MG, Bekaert O, Hodel J, et al. Accuracy of external ventricular drainage catheter placement. *Acta Neurochir*. 2012;154:153–159. https://doi.org/10.1007/s00701-011-1136-9.
22. Rehman T, Rehman A ur, Ali R, et al. A radiographic analysis of ventricular trajectories. *World Neurosurg*. 2013;80:173–178. https://doi.org/10.1016/j.wneu.2012.12.012.
23. Toma AK, Camp S, Watkins LD, Grieve J, Kitchen ND. External ventricular drain insertion accuracy. *Neurosurgery*. 2009;65:1197–1201. https://doi.org/10.1227/01.NEU.0000356973.39913.0B.
24. Mortazavi MM, Adeeb N, Griessenauer CJ, et al. The ventricular system of the brain: a comprehensive review of its history, anatomy, histology, embryology, and surgical considerations. *Child's Nerv Syst*. 2014;30:19–35. https://doi.org/10.1007/s00381-013-2321-3.
25. Chen C-C, Lin H-L, Cho D-Y. Endoscopic surgery for thalamic hemorrhage: a technical note. *Surg Neurol*. 2007;68:438–442. https://doi.org/10.1016/j.surneu.2006.11.054.
26. Frazier CH. Analysis of five hundred casesb. *Ann Surg*. 1928;88:534–547. https://doi.org/10.1097/00000658-192809000-00021.
27. Dandy WE. Ventriculography following the injection of air into the cerebral ventricles. *Ann Surg*. 1918;68:5–11. https://doi.org/10.1097/00000658-191807000-00002.

Abbreviations

VP: ventriculoperitoneal
SD: standard deviations
FOHR: frontal occipital horn ratio
CSF: Cerebrospinal fluid