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Study of Relationship between Location of Ventricular Catheter Tip and Function of the Ventriculoperitoneal (VP) Shunt in Hydrocephalus in Children

Swapan Kumar Paul[1*], Rakibul Islam[2], Prosanto Kumar Biswas[3], Ashim Kumar Sarker[4], Md. Ayub Ali[5], Md. Aminur Rashid[6]

[1]Associate Professor and Head, Department of Paediatric Neurosurgery, Bangladesh Shishu Hospital & Institute (BSH&I), Dhaka, Bangladesh
[2]Registrar In-charge, Department of Paediatric Neurosurgery, Bangladesh Shishu Hospital & Institute (BSH&I), Dhaka, Bangladesh
[3]Registrar In-charge, Department of Paediactric Burn & Reconstruction, Bangladesh Shishu Hospital & Institute (BSH&I), Dhaka, Bangladesh
[4]Phase B Resident Department of Paediatric Surgery, Bangladesh Shishu Hospital & Institute (BSH&I), Dhaka, Bangladesh
[5]Associate Professor, Department of Paediatric Urology, Bangladesh Shishu Hospital & Institute (BSH&I), Dhaka, Bangladesh
[6]Professor & Head, Faculty of Paediatric Surgery, Bangladesh Shishu Hospital & Institute (BSH&I), Dhaka, Bangladesh

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***Corresponding author:** Swapan Kumar Paul
Associate Professor and Head, Department of Paediatric Neurosurgery, Bangladesh Shishu Hospital & Institute (BSH&I), Dhaka, Bangladesh

Abstract | **Original Research Article**

Objective: To determine the relationship between location of the ventricular catheter tip and functional status of the ventriculo-peritoneal (VP) shunt in children. ***Methods:*** This prospective observational study was conducted in Faculty of Paediatric Surgery under the Department of Paediatric Neurosurgery in Bangladesh Shishu Hospital and Institute (BSH&I) from January 2017 to December 2021. The study included 140 patients who underwent ventriculo-peritoneal shunt using free hand technique. Data obtained for each patient included age, sex, diagnosis including site and side of ventricular catheter placement. Postoperative CT scan of brain were done in all cases and followed up over 2½ to 4½ years. Sixty-three patients were available for follow up. The relationship of location of ventricular catheter tip and function of the ventriculo-peritoneal shunt was analyzed in all 63 patients. ***Results:*** Number of the patients included in the study was 140. Accuracy of ventricular catheter tip placement were 55(39.28%) using freehand technique. VP shunts function well in 43(68.25%) patients. Among the 43 patients with well-functioning shunts, 19 were in accurate group, 7 were in suboptimal group and 17 were in inaccurate group. Twenty-six (41.27%) patients had good outcome with normal development. ***Conclusion:*** Mechanical malfunction and infection are the most significant problems associated with VP shunts for the treatment of hydrocephalus. A significant proportion of shunt failure is due to inaccurate placement of the ventricular catheter tip. Accurate placement of the catheter tip is highly important to reduce the incidence of shunt malfunction.

Keywords: Hydrocephalus, ventriculoperitoneal shunt, accurate ventricular catheter placement, the function of VP shunt.

INTRODUCTION

Ventriculoperitoneal shunt surgery is the most standard and commonly performed CSF drainage procedure in children for hydrocephalus. Their remains a high rate of shunt failure despite in advances of shunt materials used. Approximately 30% to 50% of shunt surgeries for hydrocephalus require shunt revision within the first 12 months [1]. Mechanical complication remains the most common cause of shunt failure [2]. Common reason for proximal catheter failure is believed to be obstruction of the catheter by the choroid plexus and by debris from choroid plexus and ependymal layer [3]. Optimal catheter placement reduces this risk of shunt failure. Ventricular catheters are placed using anatomical landmarks in freehand method, although adjuncts are available including stereotactic neuronavigation and intra-operative ultrasonography. Correct placement of the catheter tip is essential for long term VP shunt function. This study evaluated the correlation of the ventricular catheter tip and long-term function of VP shunt. Ventricular catheter placed into the frontal born or trigone, away from the choroids plexus and ventricular wall, result in a significant improvement in shunt survival [4]. If reliable surgical techniques for accurate placement of ventricular catheters can be developed, shunt survival may improve. Conventional shunt insertion techniques rely on anatomical landmarks to determine catheter trajectory into the ventricle. The depth of catheter insertion is determined by a veriety of methods including preoperative imaging endoscopy and flow of CSF from the catheter. These techniques result in favorable catheter placement in approximately one-third to two-third of cases [5-10]. The target was defined as the ipsilateral frontal born or trigone. Proximal catheter obstruction is known to be the most common cause of malfunctioning of ventriculoperitoneal (VP) shunt followed by infection. Thus, the main concern is to precisely insert the ventricular catheter tip placement. Optimal position of the ventricular catheter tip was focused to reduce potential occlusion of proximal catheter by parenchyma of choroidal tissues. Tuli *et al.*, like others have shown that a ventricular catheter tip surrounded by cerebrospinal fluid (CSF) could decrease the risk of shunt failure.

METHODOLOGY & MATERIALS

A prospective observational study was conducted on paediatric hydrocephalus patient's upto 10 years undergoing first time ventriculoperitoneal shunt placement for hydrocephalus from January 2017 to December 2021. All the patients (CT Scan of Brain proven) of hydrocephalus were managed prospectively in the Department of Paediatric Neurosurgery of Bangladesh Shishu Hospital & Institute (BSH&I). Specific variables including age, sex, causes of hydrocephalus were documented (Table 1). All patients had undergone postoperative CT scan of brain to reveal the accuracy of shunt placement (Figure 1a & b).

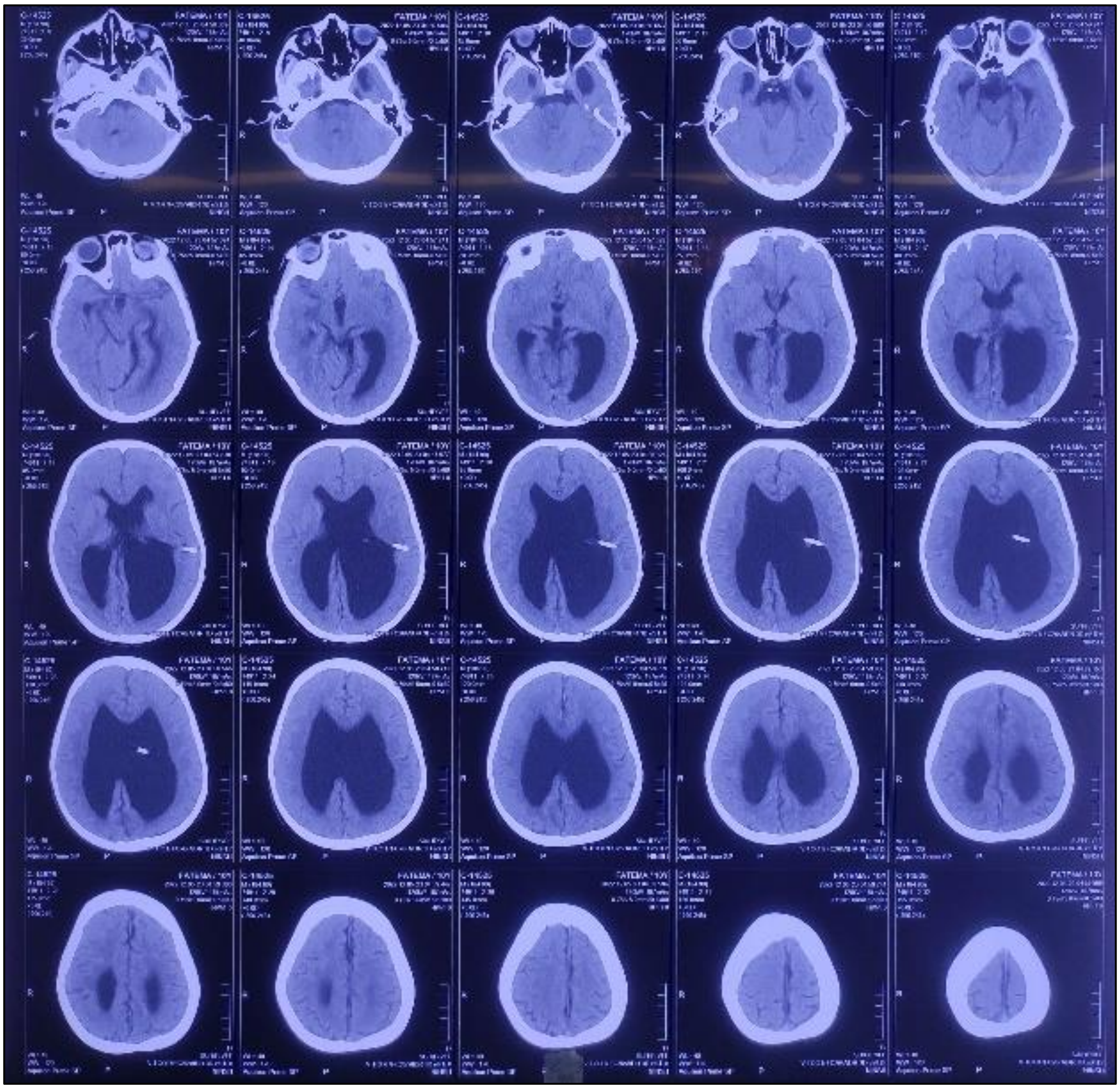

Figure 1a: Postoperative CT scan of the brain showing the accurate location of the ventricular catheter tip

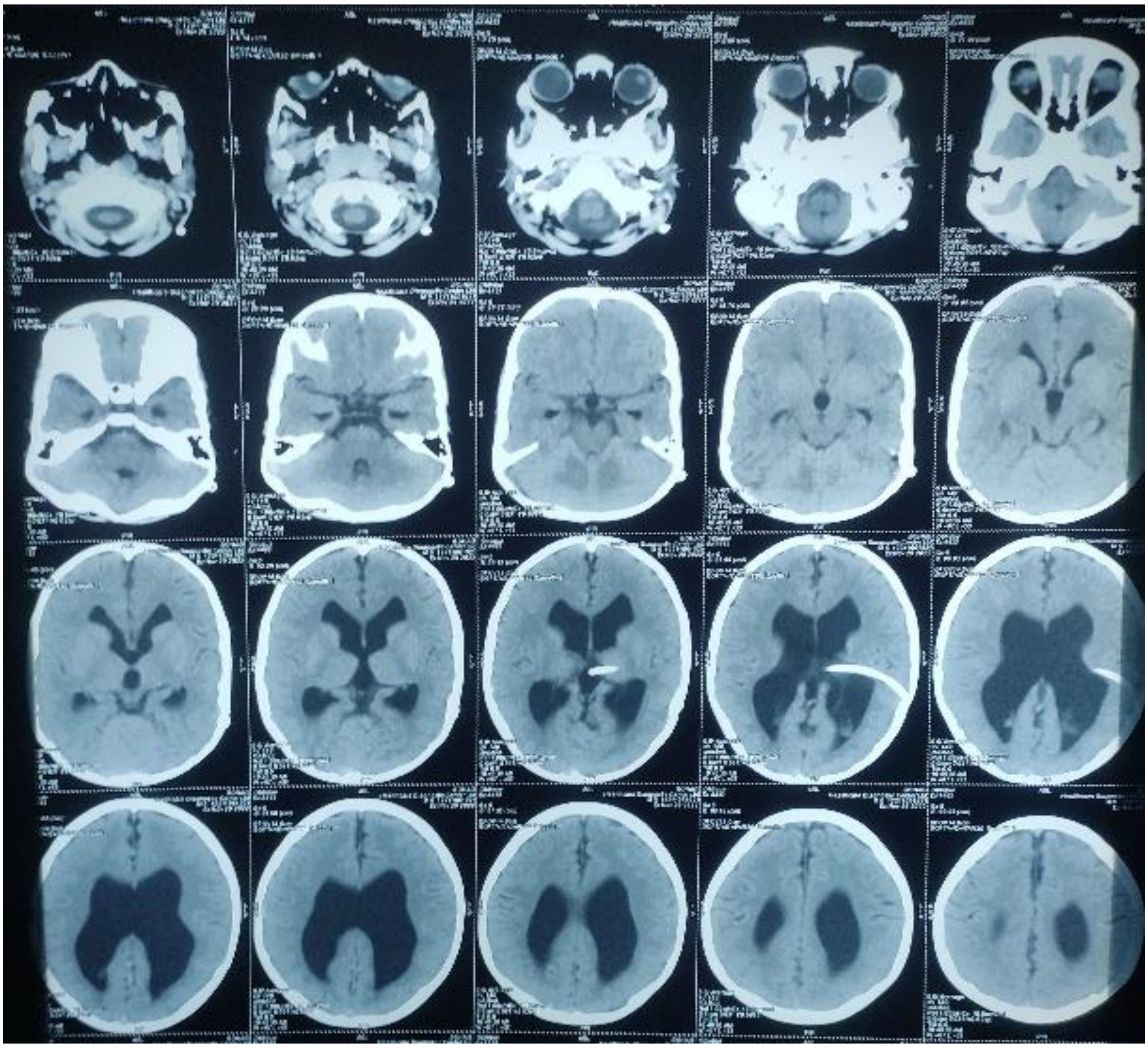

Figure 1b: Postoperative CT scan of the brain showing the inaccurate location of the ventricular catheter tip

The primary outcome was location of the ventricular catheter of the first postoperative imaging study. Patients were followed up over 2½ to 4½ years. 63 patients were available for followed up. The relationship of the location of the ventricular catheter tip and function of the ventriculoperitoneal shunt was analyzed in 63 patients. Functional status of VP shunt was assessed clinically and recorded.

RESULT

A total of 180 first time VP shunt placement were performed in the Department of Paediatric Neurosurgery of Bangladesh Shishu Hospital & Institute (BSH&I). All patients underwent follow-up CT scan of brain to determine ventricular catheter location. Female children were predominant: 74(52.85%) were male and female were 66(47.15%) (Table 2). The most common causes of hydrocephalus were congenital aqueductal stenosis 60 (42.86%), posterior fossa tumour 20(14.29%), post meningitis Hydrocephalus 18(12.86%) and myelomeningocele 21(15.0%). Most of the hydrocephalus was obstructive 112 (80%). Communicating hydrocephalus were 18(12.86%) (Table 3). On first postoperative CT scan image 55 (39.28%) ventricular catheter tip resided in frontal horn, 18 (12.85%) ventricular catheter tip resided in body. 12 (8.57%) ventricular catheter tip resided in trigone, 15(10.71%) ventricular tip resided in 3rd ventricle. 15 (10.71%) ventricular catheter tip resided in brain parenchyma and 39(27.86%) ventricular catheter tip crossed the midline (Table 4). 140 ventricular catheters were freehand passed based on standard surface 55 (39.28%) of 140 freehand passed catheters were placed accuracy (Table 5, 6). Ventricular catheter tip placement in body of ventricle, trigone and 3rd ventricle was considered suboptimal and acceptable 31(22.14%) Ventricular catheter tip placement in brain parenchyma and contralateral side were considered inaccurate. In our study 54 (38.57%) ventricular tip placement was inaccurate (Table 5). Patients were followed up over 2½ to 4½ years. 63 patients were available for follow up. We lost communication with rest of the patients. The relationship of the location of the ventricular catheter tip and function of the ventriculoperitoneal shunt were analyzed in 63 patients. Table 7 & 8 showed the number patients according to catheter tip location and VP shunt function. VP shunt location was well maintained in 43 patients (68.25%) of whom 19 were in accurate group. 7 were in suboptimal group and 17 were 1 inaccurate group demonstrating and odds ratio (OR) of 1.80 (p<0.05). Two patients developed shunt malfunction, one were in suboptimal group and 1 were in inaccurate group, underwent revision surgery later. 19 patients (30.16%) died during follow up period among them 8(12.70%) patients had brain tumour (Craniopharyngioma-5, Posterior fossa tumour-3). In the rest 11(17.46%) patients 5 were suboptimal group and 6 were in inaccurate group. No patient without brain tumor died in accurate group. Table 9 showed complications during postoperative follow up period. 10 patients developed walking difficulties, usually gait. 6 patients with myelomeningocele persisted lower limb weakness and urinary incontinence. VP shunt infection shunt infection was developed in 2 patients (3.17%). Chronic subdural effusion was developed in one patient. One patient developed transanal migration of shunt. 5 patients developed occasional seizure. 3 patients had gross developmental delay.

Table 1: Side and location of burr hole

Side and Location	Frequency	Percentage
Side		
Right	137	97.86%
Left	3	2.14%
Location of burr hole		
Frontal	1	0.71%
Parieto-occipital	139	99.29%

Table 2: Age distribution of the patient

Age Group (Month)	Number of patients	Percentage
0-1	13	9.28%
> 1-6	61	43.57%
> 6-12	20	14.28%
> 12-24	13	9.28%
> 24-60	8	5.71%
> 60-120	25	17.85%
Total	**140**	**100.0%**

Table 3: Sex distribution of patient with Hydrocephalus

Sex	Number of patients	Percentage
Male	66	47.15%
Female	74	52.85%
Total	**140**	**100.0%**

Table 4: Etiology of Hydrocephalus

Cause of Hydrocephalus	Number of patients	Percentage
Congenital Hydrocephalus Aqueductal stenosis	60	42.86%
Post meningitis	18	12.86%
Hydrencephaly	19	13.57%
Myelomeningocele	21	15.00%
Posterior fossa tumour	20	14.29%
Supratentorial tumour	11	7.86%
Dundy walker malformation	9	6.43%
Occipital encephalocele	2	1.43%
Arachnoid cyst	1	0.71%

Table 5: Location ventricular catheter tip in first Postoperative CT scan image

Location Ventricular Catheter Tip	Frequency	Percentage
Frontal horn	55	39.28%
Body	18	12.85%
Trigone	12	8.57%
3^{rd} ventricle	1	0.71%
Brain parenchyma	15	10.71%
Tip crosses midline	39	27.86%

Table 6: Freehand ventricular catheter placement

Freehand Placement	Number of patients	Percentage
Accurate	55	39.28%
Suboptimal	31	22.14%
Inaccurate	54	38.57%

Table 7: Location of ventricular catheter tip and VP shunt function

Group	Well-functioning VP shunt	VP shunt malfunction	Revision	Death (Hydrocephalus without brain tumour)	Death (Hydrocephalus with brain tumour)
Accurate	19	0	0	0	6
Suboptimal	7	1	1	5	1
Inaccurate	17	1	1	6	1
Total	**43 (68.25%)**	**2**	**2**	**11 (17.46%)**	**8 Craniopharyngioma-5 Post. fossa tumour-3)**

Table 8: Comparison between VP shunt locations according to shunt function

Shunt location	Well-functioning shunt (OR=1.86, p<0.05)	
	Yes	No
Accurate	19	6
Sub optimal and Inaccurate	24	14

Figure 2a: Phototgraph showing a 3½ years boy with normally functioning VP shunt following accurate placement of ventricular catheter tip

Figure 2b: Phototgraph showing nonfunctioning VP shunt due to inaccurate placement of ventricular catheter tip

Table 9: Different Complications of VP shunts surgery

Complication	Number of patients	Percentage
Walking difficulty	10	7.14%
Seizure	5	3.57%
Developmental delay	3	2.14%
Shunt malfunction	2	1.43%
Shunt Infection	2	1.43%
Chronic subdual effusion	1	0.71%
Trans migration of VP shunt	1	0.71%

Discussion

Cerebrospinal fluid diversion using V shunt placement is one of the most commonly performed neurological procedures and one that carries a significant risk of failure requiring revision. Only 34.28% of catheters placed using the freehand technique were accurately paced on our study. The relationship of the location of the ventricular catheter tip and function of the ventriculoperitoneal shunt was analyzed in 63 patients. VP Shunt function was well maintained in 43 patients (68.25%) of whom 19 were in accurate group 7 was in suboptimal group and 17 were in incurrence group. Surprisingly VP shunt function was maintained well in 17 patients of inaccurate location; most of the Ventricular catheter tips crossed midline and resided in contralateral frontal horn and lateral ventricle. In these cases, VP shunts were functioned well because of ventricular catheter tip was surrounded by cerebrospinal fluid (CSF). Many studies including Tuli *et al.*, have shown that a ventricular tip surrounded by cerebrospinal fluid (CSF) could decrease the risk of shunt failure [11]. In this study, two patients developed shunt malfunction, one was in suboptimal group and I were in inaccurate group, underwent revision later. 19 patients died during follow up period, among them 8 patients were brain tumours (Craniopharyngioma-5, post fossa tumour-3). In rest II patients 5 were in suboptimal group and 6 were in inaccurate group. No patient without brain tumor died in accurate group. Death rate was more in inaccurate and suboptimal group of patients without brain tumours. In this study, death rate was very high and rate of revision surgery was low. All death occurred during postoperative period outside our hospital, they did not come in appropriate time to correct shunt malfunction. 8 patients (12.70%) died due to brain tumour (Craniopharyngioma-5, post, fossa tumour-3) related complication, one patient died from pneumonia and another one patient died from Diarrhoea. The incidence of shunt malformation in patient with hydrocephalus (without brain tumour) was nil, when tip was placed in accurate location and statistically significant difference was identified. The prevalence of shunt malformation was also low when the tip was located in contralateral frontal horn and body of lateral ventricle of both side and surrounded by CSF. 26 patients (41.27%) had good outcome with normal development and normal IQ. Yamada *et al.*, reported that the incidence of shunt malfunction was very low when the ventricular catheter tip was placed in ipsilateral frontal horn [1]. Previous data suggest that the almost one third of adult patients undergoing CSF shunting will require revision [12]. Optimal catheter placement may help reduce the risk of shunt failure. Ultrasonic and stereotactic guidance significantly improve the accuracy of ventricular catheter placement in comparison with freehand placement using surface anatomical landmarks. The only factor identified in this study to be a risk factor for inaccurate placement was use of the freehand technique using standard anatomical landmarks. Among the freehand catheter placements, none of the factors identified in this study increased the risk of inaccurate placement. It is not surprising that the side of placement. It is not surprising that the side of placement was not significant, but notably neither the location nr the ventricle size. While a 38.57% rate of inaccurate placement with the freehand technique appears to be exceptionally high, it is consistent with other published data [15]. Wilson T J *et al.*, reported that 55% of catheters were placed accurately in their study [13]. T Yamada SM *et al.*, found that 42.9% of catheters were placed accurately in their study [1]. Jason CG *et al.*, published that 43.9% of catheter were placed accurately in their study [14]. Whitehead WE *et al.*, found that 49% of catheters were placed accurately in their study [4]. Theoposopoulos *et al.*, found that only 38% of catheters were optimally placed. Similarly, Lind *et al.*, found that 56% of catheter was placed accurately in their study. Out data, together with theirs suggest that we likely underestimate the rate of catheter misplacement using the freehand technique, ultimately more accurate placement of only matters if leads to reduced failure rates. Previous data from the pediatric literature suggest that utilizing an endoscope to ensure accurate placement of ventricular catheter leads to reduced proximal failure bur dose not decrease the overall rate of shunt failure. Based on that data, we hypothesized that increased utilization of stereotactic neuronavigation and ultrasonic guidance with resultant increases in accuracy of placement would head to reduce proximal catheter failure. Although image guidance offers a promising solution to lower the risk of inaccurate catheter placement, our review demonstrated that there is not yet a clear benefit of these technologies. Furthermore, there is some data to softest that the use of programmable valves reduces shunt failure revision [13]. Findings from this study illustrate the importance of optimal placement of a VP shunt. The ventricular catheter tip must be inside the ventricle and surrounded by CSF.

Limitations of the Study

Every hospital-based study has some limitations and the present study undertaken is no exception to this fact. The limitations of the present study are mentioned. Therefore, the results of the present study may not be representative of the whole of the country or the world at large. The number of patients included in the present study was less in comparison to other studies. Because the trial was short, it was difficult to remark on complications and mortality.

Conclusion and Recommendations

Mechanical malfunction and infection are the most significant problems associated with VP shunt surgery in children. A significant proportion of shunt failure is due to obstruction of the ventricular catheter correlated with accurate placement of shunt catheter tip. Through ipsilateral frontal horn is the ideal location for VP shunt catheter tip placement, tip in contralateral frontal horn, body of the ipsilateral and contralateral lateral ventricle are also acceptable locations where tip is surrounded by CSF.

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