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Original Article

Freehand Insertion of External Ventricular Drainage Catheter: Evaluation of Accuracy in a Single Center

Abstract

Introduction: External ventricular drain (EVD) placement is the gold standard for managing acute hydrocephalus. Freehand EVD, using surface anatomical landmarks, is performed for ventricular cannulation due to its simplicity and efficiency. This study evaluates accuracy and reason(s) for misplacements as few studies have analyzed the accuracy of freehand EVD insertion. **Patients and Methods:** Preoperative and postoperative computed tomography scans of patients who underwent EVD insertion in 2014 were retrospectively reviewed. Diagnosis, Evans ratio, midline shift, position of burr hole, length of the catheter, and procedural complications were tabulated. The procedures were classified as satisfactory (catheter tip in the frontal horn ipsilateral lateral ventricle) and unsatisfactory. Unsatisfactory cases were further analyzed in relation to position of burr hole from midline and length of the catheter. **Results:** Seventy-seven EVD placements in seventy patients were evaluated. The mean age of the patients was 57.5 years. About 83.1% were satisfactory placements and 11.7% were unsatisfactory in the contralateral ventricle, corpus callosum, and interhemispheric fissure. Nearly 5.2% were in extraventricular locations. Almost 2.6% EVD placements were complicated by hemorrhage and 1 catheter was reinserted. Suboptimal placements were significantly associated with longer intracranial catheter length. The mean length was 66.54 ± 10.1 mm in unsatisfactory placements compared to 58.32 ± 4.85 mm in satisfactory placements. Between the two groups, no significant difference was observed in Evans ratio, midline shift, surgeon's experience, distance of burr hole from midline, and coronal suture. **Conclusion:** Freehand EVD insertion is safe and accurate. In small number of cases, unsatisfactory placement is related to longer catheter length.

Keywords: *Accuracy, acute hydrocephalus, external ventricular drain, ipsilateral ventricle, ventriculostomy*

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Introduction

External ventricular drain (EVD) placement, also known as ventriculostomy, is the gold standard for managing acute hydrocephalus and for intracranial pressure (ICP) monitoring. Common indications of EVD are hydrocephalus due to subarachnoid hemorrhage (SAH), intracerebral hemorrhage (ICH), or intraventricular hemorrhage (IVH) and traumatic brain injury (TBI). EVD was described as early as the 1950s.[1] It is a common procedure routinely performed by neurosurgical residents. At our institution, EVDs are performed freehand using surface anatomical landmarks. Freehand EVD is currently the standard of care for ventricular cannulation due to its simplicity and efficiency in time-sensitive emergency situations. Despite it being an everyday procedure, few studies have evaluated the accuracy of freehand EVD tip placement in the literature. This generated our interest in evaluating its accuracy and reasons for unsatisfactory placements.

Patients and Methods

Data collection

Following approval from the Institutional Review Board, hospital record databases were searched for patients who had undergone freehand EVD insertion at National University Hospital (NUH), Singapore, in 2014. Records showed that there were 77 EVD cases in 70 patients. We retrospectively reviewed the pre- and postoperative computed tomography (CT) scans of these 77 EVD cases. Diagnosis, Evans ratio, midline shift, position of the burr hole, length of the catheter, and procedural complications were tabulated.

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At our institution, EVDs are primarily placed by Y1-6 residents. Comparing the results during the first 3 years of the academic year (resident) with the past 3 years (senior resident) gives a crude estimate of operator experience. In total, we had four residents and four senior residents.

The procedures were classified as either satisfactory or unsatisfactory based only on accuracy [Figure 1 and Table 1]. A satisfactory procedure would be defined as having the catheter tip in the frontal horn of the ipsilateral lateral ventricle, toward the foramen of Monro. Unsatisfactory procedures include the tip placement in the contralateral ventricle, third ventricle, and other eloquent locations such as the brainstem, internal capsule, basal ganglia, thalamus, and basal cisterns.

Statistical analysis

Univariate analysis was performed to identify predictors of unsatisfactory EVD placement. Categorical variables were compared using Pearson's Chi-squared test and numerical variables were compared using Student's *t*-test. All analysis was performed with R software version 3.4.3 (R Foundation for Statistical Computing, Vienna, Austria; 2016). $P < 0.05$ was considered statistically significant.

Method of external ventricular drain insertion

At NUH, almost all EVD placements are performed by the residents at the operating theater (OT). All placements are performed freehand without imaging guidance.

To prevent contamination problems, our residents use the ventriculostomy technique described by Friedman and Vries that involves tunneling the ventricular catheter through the scalp, between the dermis and the galea.[2] The patient is placed under general anesthesia, supine with the neck slightly flexed with 0-degree rotation. The right nondominant entry side is preferred as it is not involved in language in 90% of right-handed patients.[3] The Kocher's point is the surface entry point on the cranium (in the mid-pupillary line, avoiding the superior sagittal sinus and 1–2 cm anterior to the coronal suture to avoid the motor strip). The incision area is shaved, draped, and prepared. A 3–4 cm scalp incision is made, exposing the bone. A high-speed drill or a perforator is then used to make the burr hole. After adequate hemostasis, a duratomy is performed and a small cortisectomy is made. The ventriculostomy catheter, together with the stylet, is directed perpendicularly to the cortical surface, toward the foramen of Monro in the plane of the ipsilateral medial canthus. A postoperative CT scan of the brain is then routinely obtained to immediately verify catheter placement and to identify any procedure-related hemorrhagic complications.

Results

Seventy-seven EVD placements in seventy patients were evaluated in this study. Seven patients had bilateral EVD placement. The mean age of the patients was 57.5 years. Among the patients who underwent ventriculostomy, the most common indication was SAH (29.8%), followed by ICH/IVH (24.7%) and TBI (19.5%) [Figure 2].

There were 64 (83.1%) satisfactory placements in the ipsilateral frontal horn and 9 (11.7%) unsatisfactory placements in the contralateral ventricle, corpus callosum, and interhemispheric fissure. Four placements (5.2%) were in extraventricular locations. One (1.3%) misplaced catheter was nonfunctional and required reinsertion. Two (2.6%) EVD placements were complicated by hemorrhage and one catheter was reinserted [Table 2].

Suboptimal placements were significantly associated with longer intracranial catheter length. The mean length was 66.54 ± 10.1 mm in unsatisfactory placements compared to 58.32 ± 4.85 mm in satisfactory placements ($P < 0.001$).

Table 1: Criteria for accurate external ventricular drain catheter tip placement

	Catheter tip location
Satisfactory placement	Frontal horn of the ipsilateral lateral ventricle
Unsatisfactory placement	Anywhere beyond the frontal horn of the ipsilateral lateral ventricle, including Contralateral ventricle Third ventricle Other eloquent locations – brainstem, internal capsule, basal ganglia, thalamus, basal cisterns

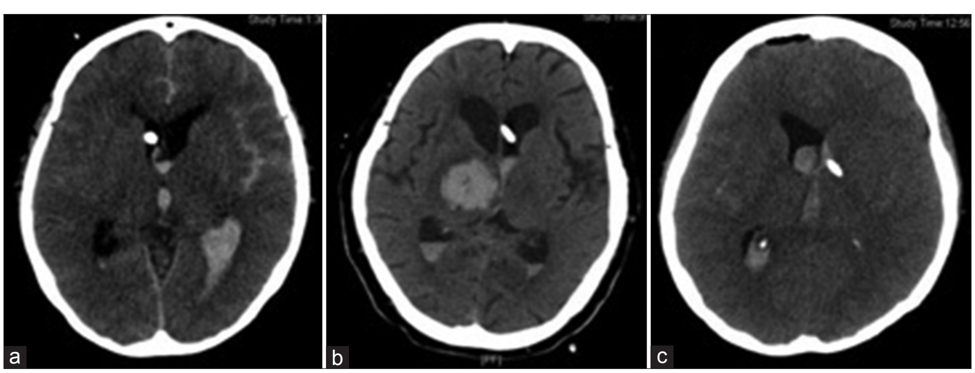

Figure 1: (a) Satisfactory placement in the ipsilateral frontal horn of lateral ventricle. (b) Unsatisfactory placement in the contralateral frontal horn of lateral ventricle. (c) Unsatisfactory placement in caudate nucleus

No significant difference was observed in Evans ratio (P = 0.456), midline shift (P = 0.613), distance of burr hole from midline (P = 0.077) and coronal suture (P = 0.503), and surgeon's experience (P = 0.823) between satisfactory and unsatisfactory placements of EVD catheter tips.

Discussion

EVD placement accuracy is very important as ventricular catheter misplacement in eloquent brain tissue can result in serious morbidities such as coma, pial arteriovenous fistula, upgaze palsy, and iatrogenic pseudoaneurysm.[4-7] Paramore and Turner have noted that two-thirds of noninfectious complications have been associated with misplacement of catheters.[8]

Misplaced catheters may require revision and further interventions, and these involve additional costs and time of repeat CT scan and procedures. Placement is ideally completed in a single pass as each additional pass potentially results in more injuries including hemorrhage, neurological injury, and infection to the already traumatized brain, thereby losing the benefit of therapeutic drainage.

Accuracy

It should be noted that neurosurgeons typically measure the success of freehand EVD placements by the free flow of cerebrospinal fluid (CSF) from the distal end of the EVD.[8] However, this in itself is falsely reassuring, as a large percentage of EVD tips have been observed in CSF spaces other than the frontal horn of the lateral ventricle (e.g. subarachnoid space) even though there was CSF drainage at the start.[9]

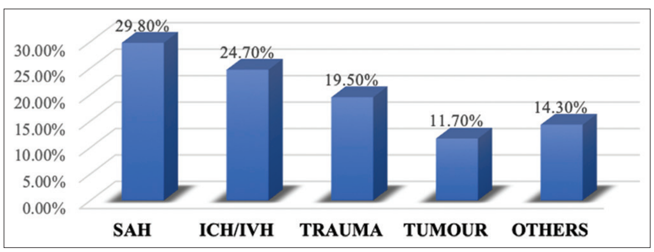

Figure 2: Indications for external ventricular drain placement

It is mostly agreed that accurate catheter placement is defined as the catheter tip being located within the frontal horn of the ipsilateral lateral ventricle or tip of the third ventricle. In the literature, institutions that abide this definition noted accurate freehand placement occurring in between 39.9% and 97.8% of procedures.[1,3,10-14] This lower limit is significantly higher when we include the ipsilateral body of the lateral ventricle.

Ji-Hoon Lee *et al*.[15] reported 48 (42.5%) of freehand placements in the ipsilateral frontal horn of the lateral ventricle. Hsieh *et al*.[16] reported 83 (64.3%) accurate placements. Ellens *et al*.[17] reported that accurate EVD placement was near 90% for both mid-level practitioners (nurses) and neurosurgeons. Our institution fairs very well at 83.1% which indicates that freehand EVD placement is associated with a high rate of accuracy. In small number of cases, the unsatisfactory position is associated with longer catheter length.

Surgical site

The right frontal lobe is the preferred point of insertion due to its nondominance in 90% of right-handed patients. This is true even for 50% of left-handed patients.[18,19]

In a retrospective study by Park *et al*.[20] comparing the accuracy of EVD placement using the Kocher's point and forehead (burr hole made approximately 4 cm superior to the nasion and 3 cm lateral to the midline), they found that Kakarla Grade 1 placement was 82 (81.1%) in the Kocher's point EVD placement group and 139 (93.3%) in the forehead placement group. The mean number of single successful passes was also higher in the forehead group.

Table 2: Summary of results

	Satisfactory placements	Unsatisfactory placements	Total	*P*
Overall	64	13	77	
Location				
Right frontal	46	10	56	0.710
Left frontal	18	3	21	
Midline shift				
Present	20	5	25	0.613
Absent	44	8	52	
Evans ratio	0.32±0.04	0.31±0.06		0.456
Distance from midline (mm)	34.69±3.61	32.23±7.66		0.077
Distance from coronal suture (mm)	14.66±6.22	16.15±11.31		0.503
Intracranial catheter length (mm)	58.32±4.85	66.54±10.1		<0.001
Operators' experience				
Resident	51	10	61	0.823
Senior residents/consultants	13	3	16	

Trauma

EVD is frequently used for patients with TBI to monitor and or reduce ICP. In the setting of trauma, several challenges exist which increase the risk of EVD misplacement.[21] Patients with severe TBI tend to have collapsed or smaller ventricles, or a midline shift causing ventricular displacement, both of which have been shown to decrease the accuracy of freehand EVD insertion.[10,16,22]

Evans ratio is defined as the maximal frontal horn ventricular width divided by the transverse inner diameter of the skull. Smaller ventricular sizes have been associated with poorer rates of accuracy. Patil *et al*.[23] noted that patients who presented with trauma tend to have a higher statistic for misplacement.

In general, trauma patients tend to be younger and have small ventricles because of their age or the presence of cerebral edema. These factors might have contributed to a higher rate of inaccuracy in this subgroup.[9,11] At our institution, however, Evans ratio makes an insignificant difference to placement accuracy. Catheter tip misplacement also appeared significantly more often in patients with a preoperative midline shift >5 mm.[24]

Image guidance

Accuracy of freehand EVD placements may be limited due to anatomical variations, distorted ventricular anatomy due from trauma, or small ventricles.[25] There have been a number of studies evaluating the efficacy of intraoperative image guidance for EVD placement. Image guidance may improve the accuracy of catheter placements, but in many, if not most, neurosurgical centers, freehand placement is still regular practice; this may be due to cumbersome and time-consuming setups, the lack of real-time imaging, or expenses.

A 2004 prospective study, Krötz *et al*.[26] compared a prospective group of cranial CT-guided EVD placement to a control group of conventional freehand placement. There were no misplaced catheters in the CT-guided placement (0/52) and only one misplacement in the control group (1/13). Thus, there was no significant difference in placement accuracy.

Ultrasound imaging may be another option as it is relatively inexpensive and provides real-time feedback.[27] Jakola *et al*.[28] studied the effectiveness of three-dimensional ultrasound placement of ventricular catheters in four patients. Single-pass satisfactory placement of the catheter was achieved in all the patients.

AlAzri *et al*.[29] prospectively applied navigation for new severe TBI patients who required ventricular catheter placement and compared with a retrospective cohort of severe TBI patients who had EVD inserted freehand in the preceding year. The placement accuracy was evaluated using the Kakarla grading system.[11] Results showed that misplacement rates were only 5.3% in the navigation cohort, whereas rates were as high as 42.9% in the freehand cohort.

Shtaya *et al*.[9] compared the accuracy of electromagnetic navigation-guided and freehand EVD placements. Results showed that in the freehand group, 60.6% of catheter tips were in the ipsilateral frontal horn, whereas in the image guidance group, this statistic improved to 75% with an insignificant difference in mean operating room time.

The practice of image-guided EVD insertion could be adopted in select cases of severe TBI with split ventricles, patients with distorted anatomy due to multiple surgeries, or in pediatric patients. EVD insertion under ultrasound guidance seems to be the most optimal when considering multiple factors such as cost, operative setup time, ease of use, and efficacy. However, for the large portion of EVD insertions, it is reasonable to continue with the widely accepted freehand insertion technique.

Comparison with accuracy of shunt placement

Similar to EVD insertion, most ventricular catheters are placed in a freehand fashion using anatomical landmarks. However, almost a third of adult patients undergoing CSF shunting would require revision.[30] Misplacement rates for freehand insertion of ventricular catheter have been reported to be about 44%–47%.[31-33] This is higher than the general misplacement rates reported across the literature for freehand EVD placement [Table 3].

At times, adjuncts such as stereotactic neuronavigation and intraoperative ultrasonography may be used to improve the accuracy of shunt placement. Wilson *et al*. showed that freehand placement of CSF shunts is six times as likely to result in misplacement compared to placement using neuronavigation or ultrasonography.[31] Azeem and Origitano also demonstrated the effectiveness of a frameless neuronavigation system in improving accuracy of shunt placement, with a 100% accuracy rate in their study sample of 34 patients.[37]

Several factors have been described in previous literature to contribute to the difference in accuracy of freehand placement of shunts compared to EVDs. Increased misplacement rates in shunt placement could be attributed to a greater difficulty in identifying anatomical landmarks. The standard head position for placement of a ventriculoperitoneal shunt is turned to the side, making assessment of the midline and confirming a trajectory orthogonal to the skull more challenging than in the face-up position during EVD insertion. It has also been postulated that the presence of a drape during insertion of shunts in the OT makes identification of surface landmarks more challenging compared to in bedside EVD procedures where no drape is used, but this was not the case at our institution, where all EVD placement procedures were performed in the operating room with a drape present.[31]

Table 3: Summary of freehand external ventricular drain placement accuracy in the published literature

Authors	Publishing year	Misplacement rates (%)	Reference point used for misplacement	Misplacement rates using our criteria (%)
Ghajar[34]	1985	35.3	Beyond the ipsilateral frontal horn of the lateral ventricle	35.3
Krötz *et al*.[26]	2004	7.7	Beyond the ipsilateral lateral ventricle	
Kakarla *et al*.[11]	2008	13	Brainstem, cerebellum, internal capsule, basal ganglia, thalamus, occipital cortex, basal cisterns	23
Huyette *et al*.[3]	2008	43.9	Beyond the ipsilateral lateral ventricle	
Toma *et al*.[10]	2009	60.1	Beyond the ipsilateral frontal horn of the lateral ventricle	60.1
Saladino *et al*.[12]	2009	12.3	Intraparenchymal/extraventricular spaces	
Ji-Hoon Lee *et al*.[15]	2010	57.5	Beyond the ipsilateral frontal horn of the lateral ventricle	57.5
Hsieh *et al*.[16]	2011	14	Basal ganglia/thalamus/cerebrum corpus callosum/basal cistern	35.7
Park *et al*.[20]	2011	17.9	Beyond the ipsilateral frontal horn of the lateral ventricle	17.9
Abdoh *et al*.[35]	2012	4.0	Extraventricular spaces	
Patil *et al*.[23]	2013	21.0	Ipsilateral frontal horn including the anterior portion of the third ventricle	21
AlAzri *et al*.[29]	2017	42.9	Beyond the ipsilateral frontal horn of the lateral ventricle	42.9
Yoon *et al*.[36]	2017	31.7	Beyond the ipsilateral frontal horn of the lateral ventricle	31.7
Ellens *et al*.[17]	2018	10.0	Intraparenchymal/extraventricular spaces	
Shtaya[9]	2018	39.4	Beyond the ipsilateral frontal horn of the lateral ventricle	16.9
Schuss *et al*.[24]	2018	3.0	Extraventricular spaces	
Our study		16.9	Beyond the ipsilateral frontal horn of the lateral ventricle	16.9

Conclusion

In this study, we can conclude that freehand frontal EVD insertion is a safe procedure in terms of accuracy of position. The placement accuracy is at 83.1% with marginal complications. Unsatisfactory placement is related to longer intracranial catheter length. In the future, further trials on image guidance could improve the accuracy rates of catheter placement.

Limitation

We are limited by the retrospective nature of the data collection for this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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