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Original Article

Determinants of Accuracy of Freehand, EVD Placement by Neurosurgical Trainees

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ABSTRACT

Background: The insertion of an external ventricular drain (EVD) is a fundamental neurosurgical procedure predominantly performed by junior neurosurgical trainees. It is vital for managing conditions like hydrocephalus, intracranial hypertension, traumatic brain injury, and others. The procedure's success heavily relies on the precise identification of anatomical landmarks and the trainee's experience.

Objective: This study aims to assess the precision and safety of EVD placement in patients treated by first-year (R1) and second-year (R2) neurosurgical residents, evaluating the impact of the residents' experience levels on the outcomes of the procedure.

Methods: Conducted at the Neurosurgery Department of Jinnah Post Graduate Medical Center, Karachi, from February to July 2022, this prospective cohort study involved individuals aged 18 years or older undergoing EVD placement for hydrocephalus. Exclusion criteria included patients with more than 5mm midline shift on initial scans or those without a post-EVD placement scan. Procedures were performed under senior resident supervision, with postoperative CT scans assessing catheter tip placement and potential complications. Statistical analyses utilized IBM SPSS Statistics for Windows, Version 25.0, with Student's t-test, Chi-square, and Fisher exact tests applied as appropriate.

Results: The study comprised 152 patients (mean age: 39.4 ± 10.7 years; 52.6% male). The initial GCS scores varied, with 44.7% scoring above 8. Most EVD placements (60.5%) were by residents in their fourth or fifth year. The average procedure duration was 43 ± 8.7 minutes, with an average of 1.44 ± 0.12 passes. Optimal placement (Kakarla Grade 1) was achieved in 59.2% of cases, with significant differences in placement accuracy between R1 and R2 residents ($p<0.05$).

Conclusion: The study highlights the significant role of experience and training in the successful placement of EVDs. The higher accuracy rates in more experienced residents underscore the need for enhanced training programs for junior neurosurgical trainees, focusing on anatomical landmark identification and procedural practice.

Keywords: External Ventricular Drain, Neurosurgery, Trainee Experience, EVD Placement Accuracy, Intracranial Pressure Management, Neurosurgical Education.

INTRODUCTION

The insertion of an external ventricular drain (EVD), a fundamental neurosurgical procedure, is predominantly performed by junior neurosurgical trainees using a freehand technique (1). Recognized as the initial procedure learned by these trainees, EVD plays a crucial role in monitoring intracranial pressure and facilitating therapeutic drainage of cerebral spinal fluid from the ventricles into an external system (2). Additionally, it assists in obtaining ventricular fluid and administering medications such as antibiotics, chemotherapeutics, and thrombolytics (2). EVD involves the insertion of a flexible plastic catheter into the ventricular system, connected externally to a tube and collection bag. This procedure is essential in managing elevated intracranial pressure resulting from various intracranial disorders, including hydrocephalus, intracranial hypertension, traumatic brain injury, ventriculitis, intracranial neoplasms, or malformations (2).

The significance of anatomical landmarks for determining Kocher's point and the use of image-guidance techniques for freehand EVD insertion are pivotal for optimal placement (3, 4). Factors like ventricular size and patient age significantly influence the success of EVD placement. The Evans index, which measures the ratio of the maximum width of the frontal horns of the lateral ventricles to

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the maximal internal diameter of the skull, serves as an indicator of ventriculomegaly (5). The accuracy of EVD placement is evaluated using the Kakarla grading system, based on postoperative computed tomographic (CT) imaging in patients who have undergone bedside freehand ventriculostomy (6). Studies have shown that the rate of suboptimal placement is highest in trauma patients, whereas optimal placement is more common in cases of subarachnoid hemorrhage (3).

Complications associated with EVD placement, such as bleeding, infection, obstruction, and misplacement, are well-documented (6). The likelihood of dislocation is influenced by factors including ventricular size and the presence of hydrocephalus. Therefore, the experience of neurosurgery residents is crucial for optimal burr hole placement and EVD positioning, underscoring the need for continual development and improvement in procedural accuracy to reduce complication rates (7, 8).

This research aims to assess the precision and safety of EVD placement by first-year residents (R1) compared to second-year residents (R2), examining how their differing levels of experience affect the outcomes of the procedure (6). This investigation is essential for enhancing training methods and improving patient care in neurosurgery, ensuring that junior trainees are well-equipped to perform this critical procedure with the highest degree of accuracy and safety.

MATERIAL AND METHODS

This prospective cohort study was conducted at the Neurosurgery Department of Jinnah Post Graduate Medical Center, Karachi, from February 2022 to July 2022, following approval from the Institutional Review Board of the medical institute (Ref: No.F.2-81/2022-GENL/148/JPMC). Consent was obtained from the patients' families for the inclusion of pertinent clinical data, which encompassed clinical examinations, necessary laboratory results, demographic details, and imaging studies.

The study involved individuals aged 18 years or older who underwent external ventricular drain (EVD) placement for hydrocephalus treatment. The inclusion criteria specified patients undergoing EVD for cerebrospinal fluid (CSF) diversion, excluding those with more than 5mm midline shift on initial scans and those who did not receive a scan post-EVD placement. Each EVD procedure was performed in the operating room by the on-call resident, under the supervision of a senior resident. Patients were prepared and draped following all aseptic measures, and a burr hole was made at Kocher’s point, preferably on the right side. After durotomy, the catheter, with a metal stylet, was inserted to a depth of 5cm from the dura, aiming for the frontal horn of the lateral ventricle. The placement was guided by the anatomic landmarks of the ipsilateral inner canthus and external auditory meatus. The catheter was advanced by 1-2cm into the ventricular space upon obtaining high flow CSF. Subsequently, an 8fr catheter was inserted, secured, and connected to the drain bag. A postoperative CT brain scan was planned for each patient.

Patient characteristics such as age, gender, and admission diagnosis were recorded. Mass lesions accompanied by hydrocephalus, subarachnoid hemorrhage, cerebral edema, or isolated intraventricular hemorrhage were characterized as intracerebral hematoma or tumor. The Evans ratio was calculated on preoperative CT scans, while postoperative scans assessed the catheter tip placement, burr hole location, and the distance from the catheter tip to the foramen of Monro. Potential complications associated with EVD placement were also evaluated.

The study examined the accuracy and safety of EVD placement among residents in their first and second years of training. Additionally, comparisons were made between residents with limited experience (fewer than 10 EVD placements) and those with more experience (more than 10 EVD placements). Data analysis involved categorizing continuous variables as means and standard deviations (SD) and categorical variables as numbers and percentages. The characteristics of patients and procedures, along with the accuracy of EVD placement, were analyzed in the ≤R3 versus >R3 cohort and the experienced versus inexperienced cohort. This analysis employed Student’s t-test for continuous variables and Chi-square and Fisher exact tests for categorical variables with fewer cases. The predicting factors for optimal EVD placement, as defined by the Kakarla grade 1, were evaluated using the Chi-square test. A p-value of less than 0.05 was considered statistically significant. Statistical analyses were conducted using SPSS, specifically IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp.).

RESULTS

In this study, a comprehensive analysis was conducted on the patient characteristics and procedural details associated with the placement of external ventricular drains (EVD) by neurosurgical residents. The results, as outlined in Table 1, indicate a mean age of 39.4 ± 10.7 years among the patients. Gender distribution was fairly balanced, with 52.6% (80 patients) being male and 47.4% (72 patients) female. The initial Glasgow Coma Scale (GCS) scores varied, with 9.2% (14 patients) scoring below 5, 46.1% (70 patients) between 5 and 8, and 44.7% (68 patients) scoring above 8. A notable 33.3% (46 patients) were transfers from other hospitals. The patient diagnosis at the time of admission varied, with 15.1% (23 patients) presenting with trauma, 12.5% (19 patients) with subarachnoid hemorrhage (SAH), 21.1% (32 patients) with intracerebral hemorrhage (ICH), 16.4% (25 patients) with intraventricular

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hemorrhage (IVH), 17.1% (26 patients) with hydrocephalus, 9.9% (15 patients) with brain mass, 4.6% (7 patients) with combined ICH and IVH, and 3.3% (5 patients) with infections.

Table 2 focuses on procedure-related characteristics. The distribution of residents by year showed that 39.5% (60 residents) were in their third year, while 60.5% (92 residents) were in their fourth or fifth year. Regarding experience, 40.8% (62 residents) had performed 10 or fewer EVD placements, while 59.2% (90 residents) had done more than 10. The average number of passes during the procedure was 1.44 ± 0.12, and the mean duration of the operation was 43 ± 8.7 minutes. In terms of midline shift, 57.9% (88 patients) exhibited this feature, while 42.1% (64 patients) did not. Catheter tip placement showed variability: 34.2% (52 patients) in the frontal horn, 19.1% (29 patients) in the body of the lateral ventricle, 10.5% (16 patients) in the basal ganglia, 13.8% (21 patients) in the thalamus, 7.2% (11 patients) in the 3rd ventricle, and 15.1% (23 patients) in the corpus callosum. Regarding the side of catheter tip placement, 61.8% (94 patients) were ipsilateral, 19.1% (29 patients) contralateral, and another 19.1% (29 patients) were midline.

Table 1 Patient Characteristics

Variables	Categories	Frequency
Mean Age		39.4 ± 10.7
Gender	Male	80 (52.6%)
	Female	72 (47.4%)
Initial GCS	<5	14 (9.2%)
	5-8	70 (46.1%)
	>8	68 (44.7%)
Transfer from other hospitals	Yes	46 (33.3%)
	No	106 (69.7%)
Patient diagnosis	Trauma	23 (15.1%)
	SAH (Subarachnoid Hemorrhage)	19 (12.5%)
	ICH (Intracerebral Hemorrhage)	32 (21.1%)
	IVH (Intraventricular Hemorrhage)	25 (16.4%)
	Hydrocephalus	26 (17.1%)
	Brain Mass	15 (9.9%)
	ICH + IVH	7 (4.6%)
	Infection	5 (3.3%)

Table 2 Procedure-Related Characteristics

Variables	Categories	Frequency
Residency Year	3rd Year	60 (39.5%)
	4-5 Year	92 (60.5%)
Experience	≤10	62 (40.8%)
	>10	90 (59.2%)
Number of Passes		1.44 ± 0.12
Duration of Operation (min)		43 ± 8.7
Midline Shift	Yes	88 (57.9%)
	No	64 (42.1%)
Catheter Tip Placement	Frontal Horn	52 (34.2%)
	Body of Lateral Ventricle	29 (19.1%)
	Basal Ganglia	16 (10.5%)
	Thalamus	21 (13.8%)
	3rd Ventricle	11 (7.2%)
	Corpus Callosum	23 (15.1%)
Catheter Tip Side	Ipsilateral	94 (61.8%)
	Contralateral	29 (19.1%)

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Variables	Categories	Frequency
	Midline	29 (19.1%)
Kakarla Grade	Grade 1	90 (59.2%)
	Grade 2	31 (20.4%)
	Grade 3	31 (20.4%)
Marshal Classification	Diffuse Injury 1	16 (10.5%)
	Diffuse Injury 2	84 (55.3%)
	Diffuse Injury 3	8 (5.3%)
	Diffuse Injury 4	15 (9.9%)
	Evacuated Lesion	16 (10.5%)
	Non-evacuated Lesion	13 (8.6%)

Table 3 Association of EVD Placement Between Resident Groups and Patient/Procedure Characteristics

Variables	Categories	R3	R4 and R5	Total	p-value
Age		43.2±10	39±10.4		0.453
Gender	Male	21 (35%)	59 (64.1%)	80 (52.6%)	<0.001
	Female	39 (65%)	33 (35.9%)	72 (47.4%)	
Initial GCS	<5	5 (8.3%)	9 (9.85%)	14 (9.2%)	<0.001
	5-8	36 (60%)	34 (37%)	70 (46.1%)	
	>8	19 (31.7%)	49 (53.3%)	68 (44.7%)	
Brain Edema	Yes	27 (45%)	57 (62%)	84 (55.3%)	<0.001
	No	33 (55%)	35 (38%)	68 (44.7%)	
Midline Shift on CT Scan	Yes	32 (53.3%)	56 (60.9%)	88 (57.9%)	0.358
HCP Ratio		0.24±0.04	0.24±0.03	0.24±0.04	0.897
Bifrontal Ventricular Width (mm)		35.20±1.25	35±1.19		0.085
Frontal Horn Size (mm)		6.5±5.4	7.2±5.7		<0.001
Catheter Tip to Bur Hole (mm)		49.4±7.8	50.2±7.4		0.802
Catheter Tip to Monro (mm)		9.1±5.7	10.2±6.8		0.457
Duration of Operation (min)		45±8.5	39±8.2		0.236
Inappropriately Located Bur Hole		30 (50%)	28 (30.4%)	58 (38.1%)	<0.001
Number of Passes		1.5±0.4	1.42±0.6		0.437
Kakarla Grade	Grade 1	18 (30%)	72 (78.2%)	90 (59.2%)	<0.001
	Grade 2	20 (33.3%)	11 (11.95%)	31 (20.4%)	
	Grade 3	22 (36.6%)	9 (9.8%)	31 (20.4%)	
Marshall's Classification	Diffuse Injury 1	10 (16.6%)	6 (6.5%)	16 (10.5%)	0.657
	Diffuse Injury 2	44 (73.3%)	40 (43.5%)	84 (55.3%)	
	Diffuse Injury 3	5 (8.3%)	3 (3.3%)	8 (5.3%)	
	Diffuse Injury 4	9 (15%)	6 (6.5%)	15 (9.9%)	
	Evacuated Lesion	7 (11.6%)	9 (9.7%)	16 (10.5%)	
	Non-evacuated Lesion	8 (13.3%)	5 (5.4%)	13 (8.6%)	
Bur Hole Side	Right	55 (91.6%)	88 (95.6%)	143 (94.1%)	<0.001
	Left	5 (8.3%)	4 (4.35%)	9 (5.9%)	

The association of EVD placement with resident groups and patient/procedure characteristics, as detailed in Table 3, revealed significant findings. There was no significant difference in age between residents in their third year (R3) and those in their fourth and fifth years (R4 and R5), with mean ages of 43.2±10 and 39±10.4, respectively (p=0.453). However, a significant difference was observed in gender distribution between the two groups (p<0.001). For initial GCS, there was a significant difference (p<0.001), with 8.3% of R3 and 9.85% of R4 and R5 patients having a GCS of less than 5. Brain edema was present in 45% of R3 and 62% of R4 and R5 patients, showing a significant association (p<0.001). Midline shift on CT scan was observed in 53.3% of R3 and 60.9% of R4 and R5 cases (p=0.358). Other parameters such as HCP ratio, bifrontal ventricular width, and catheter tip to bur hole distance showed

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no significant differences between the resident groups. However, the frontal horn size was significantly different (p<0.001). The duration of the operation, number of passes, and Marshall's classification did not show significant differences. Notably, the Kakarla Grade and bur hole side had significant differences between the groups, with Grade 1 being achieved in 30% of R3 and 78.2% of R4 and R5 cases (p<0.001), and the bur hole being appropriately located on the right side in 91.6% of R3 and 95.6% of R4 and R5 cases (p<0.001).

DISCUSSION

This study, the first of its kind in the region, aimed to assess the accuracy of external ventricular drain (EVD) placement across different residency years. The traditional freehand EVD insertion technique, leveraging superficial anatomical landmarks, is widely regarded as the gold standard due to its simplicity and efficiency. This method is prevalently employed by neurosurgeons as the standard care approach for accessing and evaluating the ventricular compartments. Despite the previous use of the ipsilateral medial canthus trajectory, our research found it less reliable compared to the contralateral medial canthus and perpendicularity to the skull trajectories, which demonstrated significant reliability for targeting the ipsilateral lateral ventricle's frontal horn (9).

To ascertain the success of EVD placement, we examined the unobstructed flow of cerebrospinal fluid (CSF) from the catheter's distal end and the equilibrated decompression of the ventricular system. However, it's important to note that such assessments may not always guarantee optimal EVD location. In our cohort, non-optimal placement (Kakarla 2 and 3) was observed in 40.8% of patients, aligning with other studies reporting a range of 2% to 60% (10-14). Fargen et al.'s study involving 98 patients also reported a 44% temporary and 19% permanent obstruction rate in EVDs (15). These findings underscore the higher risk of obstruction and subsequent need for revision when the EVD is improperly placed (16). Furthermore, an EVD's prolonged duration often necessitates replacement in about 19% of cases (15).

Our findings also highlighted a significant correlation between brain edema, frontal horn size, inappropriate bur hole location, and right-side bur hole placement. Patient-related factors, such as gender and initial Glasgow Coma Scale (GCS), were significantly associated with EVD placement. Contrastingly, prior research identified the Evans ratio, small ventricles, and midline shift as key predictors for EVD misplacement (11, 13).

The burr hole's location emerged as a critical anatomical landmark for EVD placement. An inappropriately placed burr hole can disrupt the optimal EVD trajectory, leading to the catheter tip's undesirable placement in the brain parenchyma. Conversely, a medially positioned tip could result in its placement in the contralateral lateral ventricle or parenchyma. Posteriorly drilled burr holes might lead to catheter placement within the lateral ventricle body, near the choroidal plexus or corpus callosum. This underscores the importance of residency training focusing on anatomical landmarks to enhance EVD placement accuracy and precision (17).

The primary limitation of our study was its unicentric nature. Conducting similar multicentric studies could yield more comprehensive results and provide a clearer understanding of EVD placement dynamics (18-20). Such expanded research could potentially lead to improved EVD placement techniques and outcomes (21, 22).

CONCLUSION

In conclusion, this study underscores the critical importance of precise anatomical knowledge and skillful technique in the placement of external ventricular drains (EVD), a common neurosurgical procedure. The findings reveal a substantial incidence of non-optimal EVD placement, which is associated with increased risk of complications like obstruction and the need for revision. These results emphasize the necessity for enhanced training and education, particularly in the use of anatomical landmarks for EVD placement. The study also highlights the need for multicentric research to validate and expand upon these findings, which could lead to significant improvements in patient outcomes. By addressing these educational and research gaps, the neurosurgical community can advance towards more consistent and safer EVD placements, ultimately benefiting patient care.

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