External Ventricular Drain Insertion Accuracy: Is There a Need for Change in Practice?

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OBJECTIVE: Free-hand insertion of an external ventricular drain (EVD) is a common emergency neurosurgical procedure, mostly performed for critically ill patients. Although EVD complications have been studied thoroughly, the accuracy of EVD positioning has been audited only occasionally.

METHODS: Post-EVD insertion computed tomographic scans performed in our unit over a 2-year period were analyzed for EVD tip location and intracranial catheter length.

RESULTS: A total of 183 post-EVD insertion scans were reviewed. Of those, 73 EVD tips (39.9%) were in the ipsilateral frontal horn of the lateral ventricle (the desired target); of those, 18 (25%) required EVD revision/reinsertion. Of the others, 35 (19.1%) were in the third ventricle, 33 (18%) in the body of the lateral ventricle, 19 (10.4%) in the subarachnoid space, 5 (2.7%) in the contralateral frontal horn, and 18 (9.8%) within the brain parenchyma. When the EVD tip was outside the desired target, 44 of the patients (40%) required EVD revision/reinsertion procedure ($P = 0.0383$).

CONCLUSION: Free-hand insertion of an EVD is an inaccurate procedure, and further studies are required to assess the accuracy and feasibility of the routine use of neuronavigation, ultrasonography, or other guidance techniques and the possible implication of the decreasing revision rate, complications, and length of hospital stay.

KEY WORDS: Acute hydrocephalus, External ventricular drain, Ventriculostomy

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Insertion of an external ventricular drain (EVD) is one of the most common lifesaving emergency neurosurgical procedures performed to measure and relieve increased intracranial pressure. Patients requiring EVD insertion are usually in critical condition and are managed in the intensive care setting (14).

The standard technique of EVD insertion is by free-hand insertion, using surface landmarks to direct the ventricular catheter from a frontal burr hole toward the desired target in the ipsilateral frontal horn of the lateral ventricle close to the foramen of Monro (4, 5, 10).

Most published studies deal with EVD complications, particularly infection (1, 3, 9). In this study, we audited our unit practice of EVD insertion in terms of accurate localization of the tip.

ABBREVIATIONS: CSF, cerebrospinal fluid; **CT**, computed tomographic; **EVD**, external ventricular drain

MATERIALS AND METHODS

Approval for this study was granted by the Joint Research Ethics Committee of the National Hospital for Neurology and Neurosurgery. All the EVD insertion procedures performed in our unit during the period from April 2006 to April 2008 were analyzed for patient age, diagnosis, surgeon seniority (consultant versus trainee), number of EVDs, and final outcome (mortality).

Computed tomographic (CT) scans of the brain were reviewed by the first author (AKT) using the Hospital PACS system. The preoperative Evan's index (the maximal frontal horn ventricular width divided by the transverse inner diameter of the cranium at the same brain scan section) was measured using the software's (mark-up caliper) function; EVD tip location was categorized into 1 of the following groups: ipsilateral anterior horn of the lateral ventricle, other cerebrospinal fluid (CSF) spaces (third ventricle, body or contralateral frontal horn of the lateral ventricle, and subarachnoid cisterns), and intraparenchymal (Fig. 1).

Estimated intracranial EVD length was measured on the scout images of the CT scan, measuring from the tip of the EVD to the inner table of the cranium at

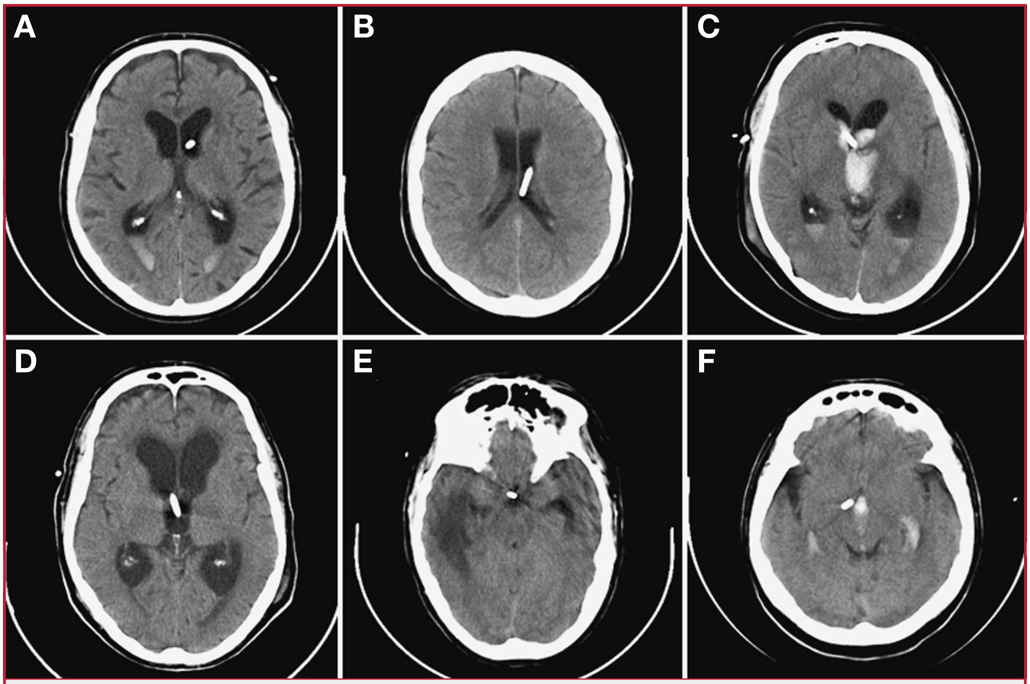

FIGURE 1. *Axial computed tomographic scans showing an external ventricular drain's tip location accuracy: ipsilateral frontal horn (**A**), body (**B**), contralateral frontal horn of the lateral ventricle (**C**), third ventricle (**D**), basal cisterns (**E**), and parenchyma (**F**).*

the burr hole. The standard practice in our unit is to perform all EVD insertion procedures in the operating theater with the patient under general anesthesia after routine skin preparation and draping, with the head in a neutral position. A 3-cm skin incision is made over the Kocher point (2.5 cm from midline and 1 cm anterior to the coronal suture). A burr hole is made using a CODMAN disposable perforator (14 mm) (Codman, Raynham, MA), and then a dural opening is created after diathermy coagulation and the stylet-loaded ventricular catheter is introduced, aimed at the medial epicanthus in the coronal plane and just anterior to the external auditory meatus in the sagittal plane. The desired target is the ipsilateral anterior horn of the lateral ventricle close to the foramen of Monro. The catheter should not be advanced beyond 6 cm from brain surface. Free flow of CSF is considered an indication of successful placement, which is usually followed by subcutaneous tunneling of the distal end of the ventricular catheter before closing the skin and fixing the catheter to avoid postoperative inadvertent pullout. The distal end of the catheter is then attached to a Medtronic Becker Closed External Drainage and Monitoring System (Goleta, CA).

During the first year of the audit period, the EVD catheter used was the Medtronic External Drainage and Monitoring System ventricular catheter (barium impregnated), which is 35 cm in length and 2.8 mm in outer diameter; it has 3 markings at 5-cm intervals with 4 proximal rows each of 4 fenestrations that extend over 2.4 cm. In the second year, the Codman Bactiseal EVD catheter (Codman) was used; it measures 35 cm in length and 3 mm in outer diameter with numeric depth markings measured in centimeters from the proximal tip, beginning at 3 cm and ending at 15 cm and has 4 rows each of 5 holes extending over approximately 2.5 cm. Postoperatively, the need for a CT scan was based on clinical need. Management of an EVD is based on clinical grounds; patients with functioning EVDs with the tip in an undesirable position were followed as long as the EVD was functioning.

RESULTS

A total of 161 patients underwent 234 EVD insertion procedures during the 2-year period. The mean age of the patients was 52.9 ± 16 years (age range, 18–89 years). The most common indication for EVD insertion was intraventricular or subarachnoid hemorrhage (44.9%) (Fig. 2). Only 1 procedure was performed in112 patients (69.5%), and 49 (30.5%) had 1 or more revision/reinsertion procedures. The EVD was inserted on the right side in 143 procedures (61%), on the left in 51 (21.8%), and bilaterally in 14 (6%). The mean preoperative Evan's index was 0.32 ± 0.059.

Twenty-five procedures were performed by 10 consultant neurosurgeons, and 209 procedures were inserted by 30 neurosurgical trainees. A postoperative CT scan before EVD removal was performed in 183 procedures (76%). Of those, 73 EVD tips (39.9%) were in the ipsilateral frontal horn, 35 (19.1%) in the third ventricle, 33 (18%) the body of the lateral ventricle, 19 (10.4%) in the subarachnoid space, and 5 (2.7%) in the contralateral frontal horn of the lateral ventricle. Eighteen (9.8%) were within the parenchyma.

The mean estimated EVD length was 66 ± 11.8 mm. The mean length of the EVDs ending in the frontal horn was 59.2 ±

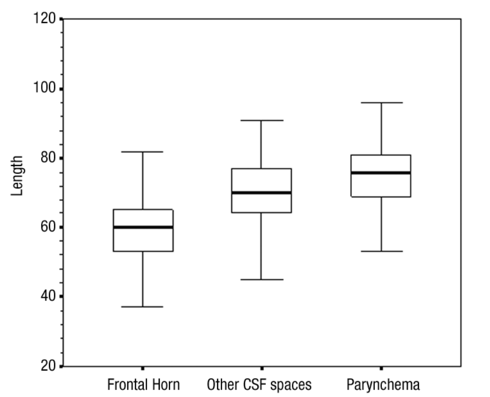

FIGURE 2. *Relationship between estimated intracranial external ventricular drain length and tip location. CSF, cerebrospinal fluid.*

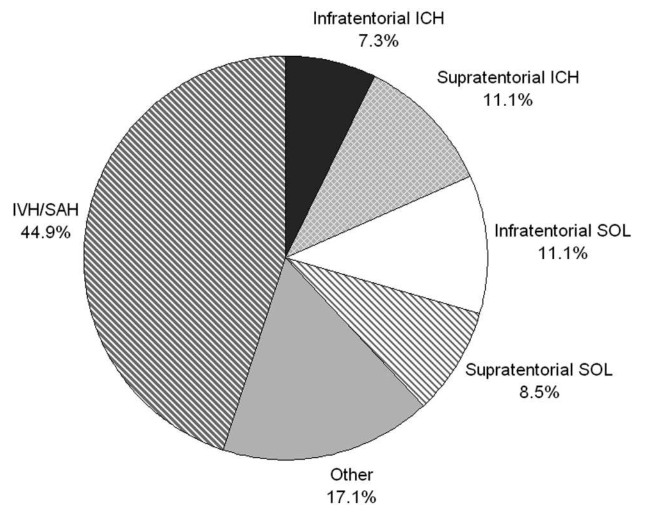

FIGURE 3. *A pie chart showing the pre-external ventricular drain insertion diagnosis expressed as a percentage of the total. SOL, space-occupying lesion; ICH, intracranial hemorrhage; IVH, intraventricular hemorrhage; SAH, subarachnoid hemorrhage.*

8.7 mm, whereas the mean length of the EVDs ending in other CSF spaces and cerebral parenchyma were 70.2 ± 10 mm and 75.4 ± 13.1 mm, respectively (Fig. 3).

When Evan's index of preoperative CT scans was less than 0.3, 34.1% of the EVD tips were in the frontal horn compared with 66.7% with an Evan's index of more than 0.4 (P <0.05) (Table 1).

There was no statistically significant relationship between age, diagnosis, surgeon seniority, whether the procedure was a revision, on the one hand, and the tip location and EVD length, on the other.

Eighteen of the patients (25%) with the EVD tip in the desired target required EVD revision/reinsertion compared with 44 (40%) who required revision when the EVD tip was outside the desired target (P = 0.0383).

DISCUSSION

Intraoperatively, neurosurgeons typically measure the success of free-hand EVD placement by the free flow of CSF from the distal end of the EVD. Most ventricular catheters have multiple holes along the distal 2.5 cm. Successful placement of a few of these holes within any CSF space (even the subarachnoid cistern) would produce at least brief CSF flow intraoperatively, even though the tip might be within the parenchyma. This explains our observation that approximately 50% of EVD tips were in CSF spaces other than the desired frontal horn of the lateral ventricle and that approximately 10% of the tips were within the parenchyma. As expected, small ventricles and long intracranial segment of EVDs were associated with less accurate placement.

TABLE 1. Evan's index versus extraventricular drain tip location cross-tabulation[a]

Evan's index	Tip location: Frontal horn	Tip location: Other CSF spaces	Tip location: Parenchyma	Total
<0.3	15 (34.1)	27 (61.4)	2 (4.5)	44
0.3–0.4	26 (43.3)	28 (46.7)	6 (10.0)	60
>0.4	10 (66.7)	4 (26.7)	1 (6.7)	15
Total	51 (42.9)	59 (49.6)	9 (7.6)	119

[a] CSF, cerebrospinal fluid. Figures in parentheses are percentages and those in bold are the actual numbers of patients.

Twenty-four percent of the procedures were not followed by CT scan prior to EVD removal, which can underestimate the actual accuracy of EVD tip location. Patients who improve and have successful removal of their EVD are often managed without CT monitoring. Conversely, patients might have their EVD pulled out inadvertently before undergoing a CT scan, and their need to have an EVD reinsertion surgery is based on their clinical need. Our findings were similar to those of Huyette et al. (6) who studied postoperative CT scans of ventriculostomy patients. Of the 98 catheter tips, 55 (56.1%) were located in the ipsilateral lateral ventricle compared with 106 (58%) in the current study and 22 (22.4%) were in extraventricular spaces compared with 37 (20.2%) in the current study. The mean distance from the catheter tip to the foramen of Monro was 16.1 ± 9.6 mm. The mean distance of the catheter tip to the center of the burr hole was 87.4 ± 14.0 mm.

In a surgical competition of EVD placement using a virtual reality simulator, the mean distance from the catheter tip to the Monro foramen in 78 trials was 16.09 ± 7.85 mm. The mean distance from the catheter tip to the center of the burr hole was 63.63 ± 13.45 mm. Of the 78 catheter tips, 57 (73%) successfully reached the ventricle, and 21 of 78 attempts (27%) were unsuccessful. Of the successful attempts, 22 (38.5%) reached the anterior horn of the right lateral ventricle compared with 73 (39.9%) in the current study (2). There was no significant correlation between the number of training years and the performance, which was also found in the current study.

Incorrect placement of the EVD results in a considerable increase in the complication rate and revision surgeries in an already compromised patient (13). Neurosurgeons tend to overestimate the accuracy of their EVD insertion procedures. In 1 survey, the estimated rate of successful cannulation of the ipsilateral ventricle ranged from 72% to 84% among trainees and consultant neurosurgeons. Both groups admit to frequently using multiple passes and frequent catheter placement outside the ipsilateral frontal horn. Still, respondents were reluctant to embrace technology that could improve placement accuracy if it increased procedure time (12).

Many techniques have been used in the past to improve the success rate and accuracy of ventricular catheter placement. Percutaneous CT controlled ventriculostomy (as opposed to guided because the catheter placement itself is not CT-guided during the procedure) improved operating time and reduced number of passes required as well as allowed the use of a twist drill hole as opposed to burr hole (7, 15).

The Ghajar Guide (Neurodynamics, Inc., New York, NY) is a device that sits on the calvarial surface and guides the ventriculostomy perpendicular to the plane tangent to the calvarium at the burr hole. It is useful only when the patient's brain anatomy has not been distorted by a mass lesion. In a prospective trial assessing EVD placement accuracy using the Ghajar Guide, the average distance from the ventriculostomy catheter tip to the foramen of Monro was 3.7 ± 5.7 mm using the guide and 9.7 ± 6.3 mm without the guide (11). Comparing the results of the free-hand group in this prospective trial with those in the retrospective study of Huyette et al. (6) in terms of distance from foramen of Monro (9.7 ± 6.3 mm versus 16.1 ± 9.6 mm) raises the question of whether placement accuracy is related to training, the competitive nature of a prospective study, or the emphasis on using a 5.5-cm EVD length.

In a study of image-guided robotic placement of 16 ventricular catheters, successful placement with a single pass was reported with no intraparenchymal catheter tip placement. The mean distance of the catheter tip from the target was 1.5 ± 2.8 mm. Furthermore, 9 of 16 patients (56%) had a ventricular diameter of 5 mm or less (8). Image-guided EVD insertion is already in use in our unit for patients with distorted anatomy or slit ventricles. In many neurosurgical units, there is no added cost because image guidance systems are already in use; the only difference in management is the type of brain scan (volumetric study) and the setting time of the image guidance system. The time used for setting might be compensated by the time gained by reducing the number of passes, which might also reduce brain injury. In neurosurgical units with no image guidance facility, improving the outcome or reducing the length of hospital stay or revision rates might not only improve patient outcome but also save costs. A prospective study is needed to prove or dismiss these assumptions.

This study has the inherent limitations of a retrospective studies. We did not investigate the reason for revision or the outcome and relation to the malposition of the EVD tips. We also did not look into the number of passes needed for successful CSF drainage, which can be related to a poor outcome.

Many neurosurgeons may resist a change in practice because they see it as complicating a relatively simple, time-proven practice. However, our observations and other published studies suggest a substantial rate of inaccurate placement and multiple passes. Further prospective studies would be useful to define to what extent the revision rate, complications, length of hospital stay, and possible mortality are related to inaccurate EVD placement and whether these factors can be altered by introducing an image-guided technique for this procedure.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

The authors have examined the accuracy of external ventricular drain (EVD) insertion by examining post-insertion computed tomographic (CT) scans. They calculated the length of the catheter as well as the tip location in relation to the target (frontal horn of ipsilateral ventricle). They demonstrate the inaccuracy associated with free-hand insertion in that only 40% of catheters were located within the target location. Furthermore, when the EVD tip was located outside the target, 44 (40%) of patients required EVD revision/reinsertion compared to 18 patients (25%) who required revision when the catheter was in the desired position ($P = 0.0383$).

These data are complementary to prior work demonstrating the relatively frequent placement of EVD catheters outside the target area.

Certainly, this work demonstrates that there is clear room for improvement in accuracy of catheter tip placement.

This study is subject to the usual limitations associated with retrospective chart reviews but does provide basis for future prospective study and the investigation of techniques to improve accuracy of EVD insertion.

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This is a timely analysis of the precision of EVD placement in consecutive cases using conventional free-hand technique at a single busy clinical service. Results are similar to those in other recently reported studies, where the EVD tip is in the desired ipsilateral frontal horn in about 2/5th of the cases, in the third ventricle in 1/5th of the cases, and in other less desirable locations in up to 2/5th of cases. Of those EVDs outside the ipsilateral frontal horn location, there was more significant likelihood of requiring revision or reinsertion. Regardless of EVD placement target, there were frequent instances where replacement or revision were needed. While the authors recommend consideration of image-guidance techniques up front, this proposition is not tested, and we note that the availability of image-guidance in emergency situations remains highly variable.

The authors do not analyze precision of EVD insertion with regard to the experience of the practitioner performing the procedure. Other studies had revealed more of a bell shaped relationship, whereby undesirable performance was more likely with most junior (inexperienced) or most senior (unpracticed) practitioners. The goal of EVD insertion, as close to the ipsilateral foramen of Monro as possible, may not represent the desirable gold standard in every case. In cases with "trapped" ventricle, skewed placement of the EVD to drain the trapped ventricle is needed. In instances where there is blood casting one ventricle more than another, it is not clear if the EVD should drain the less or more casted ventricle. These targets may be different if the treatment objective is intracranial pressure control, decompression of casted ventricle, or both. And these might be different in the setting of emerging intraventricular thrombolysis. Perhaps we need a more comprehensive analysis of the most desirable EVD target placement. Various target locations would need to be correlated not only with need of EVD replacement, but also with effectiveness of intracranial pressure (ICP) control, frequency of requiring a second catheter, etc., and clinical outcome. In emerging indication of EVD placement for intraventricular thrombolysis for obstructive intraventricular hemorrhage, objectives will best be gauged against blood clearance rates from the ventricles.

As the gold standard EVD placement objectives are better defined, we will need prospective studies to assess our ability to meet those objectives using free-hand technique, Ghajar guide-assisted procedure, and image-guided techniques. In recently launched phase III trial of intraventricular thrombolysis (CLEAR IVH), the trial's Surgical Committee has sought to balance the desire for emergent ventricular decompression (more likely with free-hand technique), versus placement precision (more likely with image guidance). A compromise emerged, recommending image-guidance for catheter re-placements, or second catheter placements aimed at trapped ventricles or obstructive clots with mass effect. This study supports consideration of a similar policy for all placements of EVDs in clinical practice.

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