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SNI Open Access

Original Article

Freehand external ventricular drain insertion – is there a learning curve?

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Received : 12 February 2021
Accepted : 04 March 2021
Published : 26 April 2021

DOI
10.25259/SNI_151_2021

Quick Response Code:

ABSTRACT

Background: Accuracy of freehand insertion of external ventricular drains (EVDs) is influenced by many factors including etiology and presence of midline shift. We sought to assess if junior neurosurgical trainees' performance in accurately inserting EVDs improves with experience, using a radiological grading system.

Methods: EVD insertion procedures from the first 3 years of training were identified from the operative logbooks of three trainees. Postoperative CT head scans were graded for accuracy of placement and intraventricular catheter length.

Results: 40 frontal EVDs performed primarily by the trainees were identified, after 34 assists, revision surgeries, parietal, or occipital insertions were excluded from the study. The mean number (±1 SD) of procedures was 7.7 ± 4.5 at ST3, 4.7 ± 2.5 at ST2, and 1 ± 1 at ST1. About 80% of EVDs were optimally inserted. There was no statistically significant difference in placement accuracy between the three training grades ($P = 0.669$), nor any difference in intraventricular catheter length ($P = 0.697$). There were no statistically significant differences between surgeons' accuracy at each grade.

Conclusion: We report good accuracy of EVDs tip position inserted by junior neurosurgery trainees. Trainees perform more procedures independently as they progress in their career. Further studies including senior years of training performance, other procedure factors and outcome should be considered.

Keywords: Accuracy, Education, External ventricular drain, Learning curve, Training, Ventriculostomy

INTRODUCTION

External ventricular drain (EVD) insertion is a common neurosurgical procedure, often performed by junior neurosurgical trainees. EVDs measure intracranial pressure, divert cerebrospinal fluid in management of hydrocephalus and raised intracranial pressure, and allow for intrathecal administration of pharmacologic agents. Freehand insertion of EVDs using anatomical landmarks is considered the primary method for placement, although alternative techniques have shown improved accuracy in positioning.[15,18] The previous studies have reported on factors that influence ventricular catheter placement accuracy and length of catheter placed within the ventricular system, including etiology, presence of midline shift, approach for catheter placement, preoperative ventricular size, and burr hole location.[9,15,18-20]

Kakarla *et al*. examined postoperative computed tomographic (CT) head scans, in 346 patients who underwent freehand bedside ventriculostomy, using a radiological grading system to assess for accuracy of placement.[9] Overall, the majority of ventricular catheters (87%) were placed accurately, with hemorrhagic complications seen in 17 patients (5%), 4 (1.2%) of which were symptomatic, and 2 (0.6%) required surgery. This led Kakarla *et al*. to conclude that bedside freehand insertion of ventricular catheters is a safe and accurate procedure. They also reported that rates of suboptimal placement were highest for patients with trauma and optimal placement rates highest for patients with subarachnoid hemorrhage (SAH). There was a trend for less accurate placement with midline shift and for more accurate placement when the catheter was placed on the side of the midline shift, that is, a left frontal catheter with right to left shift.[9] Shtaya *et al.*[18] reported inaccuracy of EVD tip position in trauma patients with small ventricles, they also found that longer intracranial catheters are associated with EVD tip malposition even with the use of image guidance. Wan *et al*. examined factors that affected optimal placement of ventricular catheters, in the context of ventricular peritoneal shunt insertions.[20] Optimal placement was assessed with a radiological grading system that examined length of catheter within the ventricles. They reported that preoperative ventricular size and the age of the patient were the most important factors predicting successful placement, with larger ventricles and older age leading to better grades. Lind *et al*. examined success of placement of ventricular catheters in ventriculoperitoneal shunt insertions by approach, that is, frontal, parietal, and occipital.[12] Success in reaching the ventricular target zone, that is, tip beyond the foramen of Monroe with frontal and occipital approaches and in the atrium with the parietal approach, was assessed using postoperative CT head scans. Successful catheterization occurred in 85% of parietal and 64% of parietal shunts. In contrast only 42% of occipital shunts were successful. The authors postulated that this may reflect the limited range of trajectories with the occipital approach.

Simulated ventriculostomy procedures to circumvent the issues of patient safety, limited trainee working hours, and theater time have been developed.[1,11] Using the immersive touch virtual reality platform, Lemole *et al*. demonstrated that a simulation of ventricular catheter placement could be created, which was judged by neurosurgery faculty, residents, and medical students to be realistic in terms of visual, handling, and tactile characteristics.[11] Banerjee *et al*. reported that the accuracy of placement in terms of distance to the foramen of Monroe with this simulator was similar to that reported in a retrospective evaluation of free hand placement in patients, suggesting that the simulator faithfully reproduces the procedure.[2] While it is clear that simulators may accurately emulate surgical procedures such as placement of ventricular catheters, it remains unclear as to whether their use will lead to an improvement in performance for trainees. More fundamentally, does experience in general lead to an improvement in performance in placing ventricular catheters, that is, is there a learning curve, and if so what objective markers would best measure this improvement.

To assess whether there is a procedural learning curve in EVD placement, we sought to examine whether accuracy of placement of external ventricular catheters improves with experience in junior neurosurgical trainees from specialty training years one (ST1) to three (ST3), using a radiological grading system.

MATERIALS AND METHODS

Patient details for all EVDs inserted during the first 3 years (ST1-ST3) of each neurosurgical trainee's training were identified from the operative logbooks of three neurosurgical trainees. As the three trainees were at different grades, operations spanned 5 years from August 2006 to July 2011 inclusive. Cases where the surgeon was assisting or observing only and revision procedures were excluded from the analysis, as were occipital and parietal EVDs. Only first surgery frontal EVDs primarily performed by the trainees were included in the study. Details regarding etiology and presentation were collected from case notes.

Preoperative and postoperative CT head scans were obtained from the hospital Centricity Picture Archiving and Communications (PACS) and Clear Canvas Workstation systems. The most recent CT head scan before the date of EVD insertion was used as the preoperative scan for analysis. The first scan following the procedure was used as the postoperative scan for analysis. Hospital operating theater logbooks were checked to ensure that the EVD had not been revised in the interim.

Accuracy of ventricular catheter placement was assessed using the grading system described and validated by Kakarla *et al*. [Table 1].[9] Total length of catheter within the ventricular space was calculated trigonometrically, from the height of the catheter within the space (estimated from the number of slices the catheter was visible within the ventricular space) and the length from the tip to the site of ventricular puncture. We graded total intra-ventricular length of catheter based on the grading system of Wan *et al*. [Table 2].[20] Our modified grading system took into account the perforations present only in the most distal 25 mms of the Codman Bactiseal ventricular catheters solely used in our institution during this time period.

Table 1: Radiological grading system for accuracy of placement, after Kakarla *et al.*[9]

Grade	Accuracy of placement	Location of catheter tip
1	Optimal/adequate	Ipsilateral frontal horn including tip of third ventricle
2	Suboptimal (shallow in noneloquent tissue)	Contralateral frontal horn of lateral ventricle/ corpus callosum/ interhemispheric fissure
3	Suboptimal in eloquent tissue	Brainstem/cerebellum/ internal capsule/basal ganglia/thalamus/occipital cortex/basal cisterns

Table 2: Radiological grading system for intraventricular catheter length, after Wan *et al.*[20]

Grade	Length of catheter tip in cerebrospinal fluid (mm)
1	>24
2	20–24
3	15–19
4	10–14
5	<10

We compared accuracy and intra-ventricular length across the ST1, ST2, and ST3 grades by analysis of variance with PASW statistics 18.0.

RESULTS

40 frontal EVDs were performed primarily by the three trainees during the first 3 years of their training. 74 procedures were identified in total, but assistance, revision surgery, parietal, and occipital insertions were excluded from the study (n = 34). No procedures utilized image guidance or framed stereotaxy as all were performed freehand. The mean number (±1 SD) of procedures was 7.7± 4.5 at ST3, 4.7 ± 2.5 at ST2, and 1 ± 1 at ST1. The total number of procedures at each grade was 23 at ST3, 14 at ST2, and 3 at ST1. Etiology included SAH (n = 22), posterior fossa hemorrhage/infarct (n = 5), supratentorial intracerebral hemorrhage (n = 4), posterior fossa tumor/surgery (n = 5), intra-ventricular tumor (n = 2), meningitis (n = 1), and trauma (n = 1).

About 80% of EVDs were optimally inserted. 32 catheters were Grade 1 in placement, two Grade 2 and six Grade 3 [Table 1 for grading]. At ST3 level 18 catheters (78%) were Grade 1 in placement, two (9%) Grade 2, and three (13%) Grade 3. AT ST2 level 11 catheters (79%) were Grade 1 in placement and three (27%) Grade 3. At ST1 level all 3 catheters were Grade 1 in placement. There was no significant difference in placement accuracy between the three training grades [P = 0.669, Figure 1].

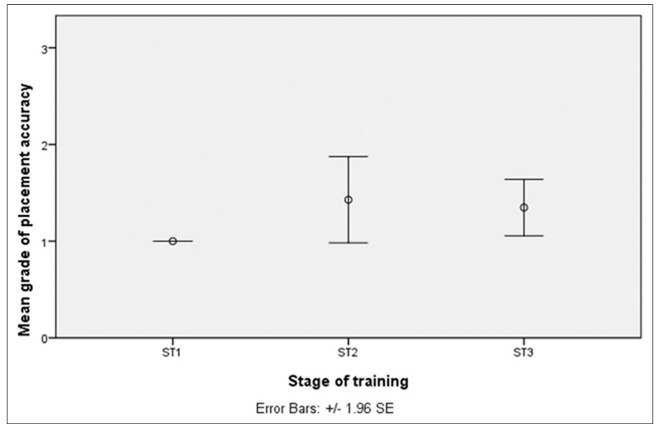

Figure 1: Mean grade of placement accuracy at ST1, ST2, and ST3 level. No statistically significant difference.

The mean (±1 SD) length of catheter within the ventricle was 23 mm ± 9.5. There was no significant difference in intra-ventricular catheter length between the three training grades [P = 0.697, Figure 2]. At ST3 level, grade of intra-ventricular length [Table 2] was one for eight procedures, two for five procedures, three for four procedures, and four for six procedures. At ST2 level, grade of intraventricular length was 1 for five procedures, two for five procedures, three for one procedure, four for one procedure, and five for two procedures. At ST1 level grade of intraventricular length was one for two procedures and three for one procedure. There was no statistically significant difference between individual surgeons' accuracy at each grade (P = 0.398). At ST3 level, there was a statistically significant difference in intraventricular catheter length between trainees (P = 0.026).

DISCUSSION

The freehand insertion of an EVD is often the remit of junior neurosurgical trainees. Indeed, in the authors' experience, alongside burr-hole drainage of chronic subdural hematomas, it is often one of the first neurosurgical operations performed by a trainee. Despite being a well-established treatment for hydrocephalus, published studies evaluating the success of placement by freehand insertion vary greatly in their estimates of surgical accuracy. For instance, Toma *et al*. reported accurate placement of EVD's in only 73 out of 183 procedures (39.9%).[19] Revision surgery for all causes such as blockage and infection was required for 18 of the optimally inserted catheters (25%). In contrast, 44 of the remaining 110 inaccurately placed EVDs (40%) required revision, a statistically significant difference. In contrast, Kakarla *et al*. reported misplacement rates of only 13%, and an overall revision rate of 3.8%.[9] No neurological deficits were noted with misplacement of ventricular catheters, an observation reiterated by Hsieh *et al*., who reported a similar accuracy of 86%, and low

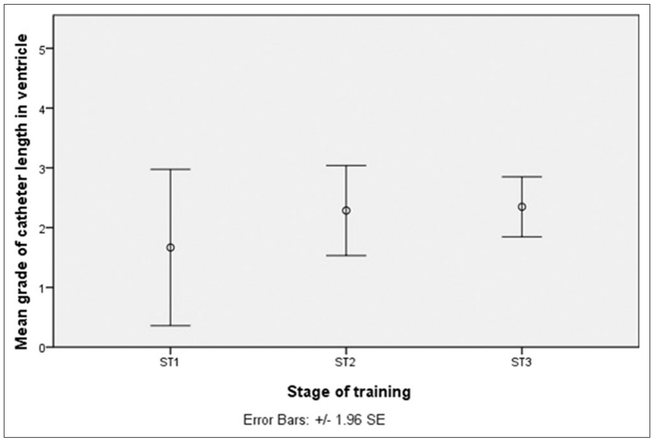

Figure 2: Mean grade of catheter length in ventricle at ST1, ST2, and ST3 level. No statistically significant difference.

revision rate amongst misplaced catheters with only four out of 18 misplaced catheters revised.[8]

Recently, three-dimensional volumetric reconstruction of CT scans has also been used with mapping of virtual EVD trajectories to suggest that trajectories perpendicular to the skull or using the surface landmark of contralateral medial canthus are superior to ipsilateral medial canthus for determining the optimal freehand approach for cannulating the ventricles in a small study of ten patients, although a learning curve was not able to be assessed.[14] Others have used virtual cannulation and simulation to train neurosurgeons. Krombach *et al*. using a frameless neuronavigation system exposed neurosurgeon to normal and abnormal ventricular anatomy using magnetic resonance imaging scans, using the pointer to simulate catheter placement.[10] Yudkowsky using the Immersive Touch system and a library of 15 brains generated from CT head scans to simulate placement of ventricular catheters for neurosurgical trainees.[21] Trainee's performance with respect to cannulation rates improved during the simulated exercises. First-pass cannulation rates improved during operations on real patients following exposure to the simulated exercises. However, deeper and contralateral hemisphere cannulation increased in the simulated exercises, and third ventricular cannulation rates increased during live operations. Cenydd *et al*. recently developed VCath, a tablet based frontal EVD insertion training tool.[4] However, to the best of our knowledge, there have been no published studies examining how same operator experience over time affects placement accuracy. Kakarla *et al*. visited the issue briefly by comparing placement accuracy between the first 3 months of the academic year and the past 3 months.[9] They found no statistically significant differences and hence no learning curve ($p = 0.384$). Shtaya *et al*. described the level of surgeon placing an EVD, although they did not compare the experience of the same trainees overtime, they reported approximately 40% of freehand EVDs placed by ST1-3 or equivalent trainees.[18]

Here, we utilized the previously described grading systems of Kakarla *et al*.[9] and Wan *et al*.,[20] to examine placement accuracy and total length of catheter within the cerebral ventricular space as a function of experience of three neurosurgical trainees, progressing from their first (ST1) to third (ST3) years of training. The majority of EVDs were placed accurately (80%). This is in agreement with the findings of Kakarla *et al*.,[9] Hsieh *et al*.,[8] and Shtaya *et al*.[18] that accuracy of freehand placement of ventricular drains is good and acceptable in most of the cases. Our study showed that the number of EVDs inserted by junior trainees increases as the trainee progresses in their training (3 at ST1, 14 at ST2, and 23 at ST3). This is expected and reflects the natural progression in the training process in a well-controlled and supervised environment. Trainees will assist more in the 1st year and start inserting EVDs toward the end of the year and during their following years. As the number of EVDs inserted was small in the 1st year, there were no significant differences in EVDs placement accuracy when comparing ST1 to ST2 and ST3 for the same trainees. Someone can argue that bigger numbers are required to accurately study whether there is a learning curve or not.

With the learning of any new procedure, performance is anticipated to improve with experience. Plotting such improvements with experience produces a so-called "learning curve." In the context of surgery, performance can be measured through quantitative measures of surgical processes such as time taken to perform a procedure, extent of resection, or blood loss, or clinical outcomes such as length of stay, morbidity, and mortality.[7] Within surgical specialties, neurosurgical ventricular catheter placement provides a rare opportunity to measure a surgeons' performance objectively given the opportunity to perform neuroimaging after surgery and the advent of tentatively ratified grading systems to assess accuracy. In this study, we examined the accuracy of placement of ventricular catheters, and length placed within the ventricles, and although our results suggest that neither improved with surgeon experience, it is actually a learning experience as the trainee progressed from 1 ± 1 operation in the 1st year to 7.7 ± 4.5. Further studies with large numbers may help clarify the learning curve theory in EVDs placements. Other factors in the surgical processes of EVD placement may exhibit a learning curve. For example, the operative time, number of EVD catheter passes or need for supervision. However, in our series, there was no significant difference in all the previous potential factors. Similarly, patients' outcome such as need for revision and infection rates, might be influenced by learning curves and all such factors are worthy of further investigation.

CONCLUSION

We report good accuracy of EVDs inserted by junior neurosurgery trainees in the early years of their training in a busy neurosurgery unit. Trainees perform more procedures independently as they progress in their career. Although there was no significant improvement in placement accuracy and intra-ventricular length of EVDs with experience, the number of EVDs inserted in the 1st year of training was small to perform meaningful statistical analysis. To attain a certificate of completion of training within the United Kingdom for neurosurgery, minimum quotas of index cases at varying supervision levels have been suggested. The majority are cranial micro neurosurgical operations such as clipping a cerebral aneurysm which clearly exhibits a learning curve.[13] EVD insertion is not included, but objective assessment of surgical performance is desirable,[5] and if such a quota was to be introduced although for training progression if not completion or when reviewing junior neurosurgeons performance during formal and informal appraisal and assessment, we would recommend consideration of grading accuracy of ventricular catheter placement and reflection on it by the trainee as there is evidence that surgical skill is enhanced by improving one's ability to detect errors[3] and that error detection should be quantified.[6] However, we also suggest increasing number of cases studied by including EVDs at more senior years of training, in addition to considering other surgical processes and patient outcomes in the analysis which may reflect on learning curve.

British neurosurgical trainees' complete workplace-based assessments (WBAs) both in the domains of procedure-based assessments and direct observations of procedural skill (DOPS) within their intercollegiate surgical curriculum program. These WBAs remain of questionable validity a decade since their introduction and objective quantitative measures of procedural success and error detection may prove more valid.[16,17] Nevertheless, further studies are desirable to characterize which factors are valid and accurate reflections of a neurosurgical trainee's improvement in performance with experience in the insertion of EVDs.

Acknowledgments

The authors acknowledge sharing of data from surgical logbooks of Mr Martin Gillies and Mr Tim Lawrence.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Jayasekera BA, Al-Mousa A, Shtaya A, Pereira E. Freehand external ventricular drain insertion – is there a learning curve? Surg Neurol Int 2021;12:193.