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Original articles

The misplacement of external ventricular drain by freehand method in emergent neurosurgery

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Abstract

External ventricular drain (EVD) placement is one of the most basic and common neurosurgical procedure which most was performed by young neurosurgical trainees. This study is conducted to determinate the safe and accuracy of EVD placement by freehand method. About 129 EVD placements were evaluated in this study. Eighty-three catheters (64.3%) were located in the ipsilateral frontal horn or third ventricle. The functional accuracy was 86%. Of eighteen misplaced catheters, only 4 (3.1%) catheters were nonfunctional, requiring a replacement or reposition. The higher misplaced rate was significantly observed in patients whose head CT scans revealed the lower hydrocephalus ratio (28.85%) and the smaller ventricular size (5.6mm). Twenty-one (16.2%) new hemorrhages associated with EVD placements were observed. Using the freehand method, EVD placement is a safe and effective procedure in management of these emergent neurosurgical diseases.

Key words: Hydrocephalus; traumatic brain injury; ventriculostomy; subarachnoid hemorrhages; stroke.

Introduction

External ventricular drain (EVD) placement is one of the most important and common emergent procedures in neurosurgery. The goal of EVD is indicated in monitoring intracranial pressure and therapeutic drainage of cerebrospinal fluid which are secondary to multiple intracranial disorders including traumatic brain injury, intracranial hemorrhage, hydrocephalus, intracranial hypertension, ventriculitis, other intracranial neoplasms or vascular malformations.

EVD is a catheter inserted into the ventricular system and connected to an external tube and collection bag. Since Dandy introduced the ventriculostomy, the EVD placement by freehand method is a well-established basic procedure in neurosurgery and mostly performed by young neurosurgical trainees (Gardner *et al.* 2009). The incidence, prevention and management of infection and hemorrhage secondary to EVD placement have been well investigated (Anderson *et al.* 2004; Gardner *et al.* 2009). However, the accuracy of EVD placement by freehand method is rarely discussed especially when the frontal horn of lateral ventricle was dislocated or compressed.

In our hospital, the EVD placement is a basic neurosurgical technique and performed by neurosurgical trainees using the freehand method. We retrospectively reviewed 129 EVD insertions. The relevant risk factors and accuracy were also analyzed.

Patients and methods

Patients

Between January 2008 and August 2009, a total of 266 patients admitted to Tri-Service General Hospital after sustaining head trauma, intracerebral hemorrhage, subarachnoid hemorrhage or acute hydrocephalus were met criteria for emergent insertion of EVDs. Criteria for external ventricular drains were (1) Glasgow Coma Scale score of less than 9, (2) evidence of hydrocephalus, (3) monitoring intracranial pressure. All patients in whom no subsequent head computed tomographic (CT) scan was obtained after EVD placement were excluded.

Study methodology

We retrospectively reviewed patients' hospital charts, surgical indications, operative procedure, operator's experience and the pre-operative and post-operative head CT scans. The location of catheter tip of EVD shown on the postoperative head

CT scan was recorded. Midline shift was defined as the deviated distance from septum pellucidum to the midline. Hydrocephalus ratio was represented as the ratio of maximum width of the frontal horns to the maximum width of the inner table of the cranium. The ventricular size was defined as the width of ipsilateral frontal horn. Hemorrhage attributable to the insertion of the catheter was defined as a new area of hemorrhage along the device, which could be demonstrated on the postoperative head CT scan. The combined surgery was defined as if the EVD placement was the only one part of whole procedure such as clipping of aneurysms or removal of subdural hematomas, especially when the head was tilting.

Surgical procedure

The emergent EVD placement was all performed in operative room under general anesthesia. Neither image navigator nor a Ghaja guide device was used during the whole procedure. The frontal trephination performed with a 3 mm diameter twist drill was made 1 cm frontal to coronal suture and 2.5 cm lateral to midline, after making a 4 cm skin incision. The direction of ventriculostomy was aimed toward the ipsilateral inner canthus and external auditory meatus. The exact direction was modified based on the pre-operative head CT scan and the experience of operators. The ventricular metal needle was inserted with a depth of 5 cm below the brain surface. After cerebrospinal fluid (CSF) flew out through the ventricular needle, the catheter of EVD was inserted into the previous tract and attached to a trocar and was tunneled away about 5 cm from the skin incision. Then the catheter was connected to a sterile external drainage bag. The skin was closed as standard procedure.

Statistics

Results are given as mean ± standard error mean. The Student's *t*-test was used to compare continuous data in two categories. Qualitative variables were compared between groups using the Fischer's exact test or chi-square test. A p value less than 0.05 within a confidence interval of 95% was taken as statistically significant. The level of statistical significance was set at 0.05.

Results

125 patients including 84 men (67%) and 41 women (33%) were enrolled in our study. The mean age was 55.7 years, ranging from 16 to 93 years. A total of 129 EVDs were emergently placed. Four patients received bilateral EVD placements simultaneously due to the severe intraventricular hemorrhages resulting into the compartment-like ventricles. Forty-five patients (35%) presented with intracerebral hemorrhage, 41 (32%) with trauma, 37 (29%) with subarachnoid hemorrhage, and 6 (4%) with neoplasm.

Table 1

The summary of the tip locations of 129 EVD placements

Tip location	No (%)
Ipsilateral	
Frontal horn	70 (54.3)
Body of lateral ventricle	8 (6.2)
Basal ganglion	6 (4.7)
Thalamus	2 (1.6)
Cerebrum	1 (0.8)
Contralateral	
Frontal horn	17 (13.2)
Body of lateral ventricle	3 (2.3)
Basal ganglion	1 (0.8)
Thalamus	3 (2.3)
Cerebrum	2 (1.6)
Third ventricle	13 (10)
Corpus callosum	1 (0.8)
Suprasellar region	2 (1.6)

79 EVDs (61%) were inserted from the right trephination, where 50 EVDs (39%) were made from left approach. The final location of catheter tip was summarized as Table 1. The most common locations were ipsilateral frontal horn (54.3%), contralateral frontal horn (13.2%) and third ventricle (10%). 83 catheters (64.3%) were located in the ipsilateral frontal horn (Fig. 1) or third ventricle. There were 18 misplaced catheters in 14% of 129 EVD placements, including 7 basal ganglion, 5 thalamus, 3 cerebrum (Fig. 2), 2 suprasellar cistern and 1 corpus callosum. Only four (3.1%) catheters were nonfunctional, requiring a replacement or reposition. There were no known neurological complications from the misplaced catheters.

Because the 18 misplacements were all in eloquent area, we compared these cases (the misplaced group) with other 111 EVD insertions (the control group) for further analysis. As shown on Table 2, the difference of surgical indications including the trauma, intracerebral hemorrhage, subarachnoid hemorrhage or neoplasm between the misplaced group and control group did not reach the

FIG. 1. — The head computed tomographic scan revealed the catheter was located in the ipsilateral frontal horn above the Foramen of Monro, as known as the ideal target.

FIG. 2. — The head computed tomographic scan revealed the catheter was located in the contralateral cerebrum.

significance. Considering the radiological parameters in the head CT scan, the higher misplaced rate was significantly observed in patients whose head CT scans revealed the lower hydrocephalus ratio and the smaller ventricular size (P = 0.049 and 0.05, respectively). In the misplaced group, the mean hydrocephalus ratio was 28.85% (range, 20.8 ~ 38.2%) and the mean ventricular size was 5.6 mm (range, 0.6 ~ 15.5 mm). The midline shift and the site of ventriculostomy were not attributable to the misplacement of EVD (P = 0.54 and 0.441, respectively). Otherwise, the operator's experiences and combined surgery did not affect the accuracy of placement (P = 0.935 and 0.899, respectively).

Twenty-one (16.2%) new hemorrhages associated with EVD placements were observed on subsequent head CT scans (Fig. 3). No patients experienced this associated hemorrhages required a craniotomy. The occurrence of new hemorrhages between the misplaced group and control group didn't reach the significant differences.

Discussion

The EVD placement is one of the most effective and most frequently used therapeutic procedures in neurosurgery. EVD allows not only continuous drainage of CSF but also the measurement of intracranial pressure, acquisition of ventricular fluid and administration of antibiotics, chemotherapeutic agents and thrombrolytic medication. The frontal horn anterior to the foramen of Monro is ideal target for ventricular catheter placement because there is no choroid plexus anterior to the foramen of Monro (Lind *et al.*, 2008). The freehand method using surface landmark remains the most common and practical method for neurosurgeons. The frontal approach used the trajectory landmarks of the line of intersection of a coronal plane with the medial canthus of ipsilateral eye and a sagittal plane with ipsilateral external auditory meatus. The landmark of trephination is identified at the 2.5 cm lateral to the midline and 1cm anterior to the coronal suture. However, in case of brain shifting and ventricular compression, the exact direction of trajectory should be adapted according to the the pre-operative head CT scan and the operator's experience (Stangl *et al.*, 1998).

The complications of EVD placement are well-established, including dislocation, infection and hemorrhages (Khan *et al.*, 1998). Most studies emphasized the infection and hemorrhage, as known as the two most common complications of EVD placement (Gardner *et al.*, 2009). Only few studies discussed the accuracy of EVD placement (Bogdahn *et al.*, 1992; Khanna *et al.*, 1995; Stangl *et al.*, 1998; O'Leary *et al.*, 2000; Anderson *et al.*, 2004; Huyette *et al.*, 2008; Kakarla *et al.*, 2008; Lind *et al.*, 2008; Ngo *et al.*, 2009). Conventionally, the correct loca-

Table 2

The summary of clinical features in patients with misplacement of external ventricular drain placement and in controls

		Control group	Misplaced group	P
No of procedures		111	18	
Indications				
Trauma	Yes	35	6	0.904
	No	76	12	
ICH	Yes	39	6	0.906
		No	72	12
SAH	Yes	31	6	0.850
	No	80	12	
Tumor	Yes	6	0	
	No	105	0	
Midline shift (mm)*		3.69 ± 0.48	2.91 ± 1.05	0.54
Hydrocephalus ratio (%)*		32.44 ± 0.7	28.85 ± 1.2	0.049
Ventricle size (mm) *		7.7 ± 0.4	5.6 ± 0.9	0.05
Ventriculoostomy stie	Right	66	13	0.441
	Left	45	5	
Combined surgery	Yes	44	8	0.899
	No	67	10	
Operator experiences	3-4 years	23	3	0.935
	5-6 years	88	15	
New hemorrhage	Yes	17	4	0.695
	No	94	14	

*Value : mean ± standard error mean.

tion for the distal end of catheter is at or just above the foramen of Monro(Saladino *et al*., 2009). When the ipsilateral frontal horn or third ventricle is considered as the final location of the catheter, the inaccuracy ranged from 20% to 36% in the published literatures (Khanna *et al*., 1995; Kakarla *et al*., 2008). In this study, the inaccuracy was 35.7%, which was consistent with previous findings. However, compared to conventional definition, functional accuracy also has been described (Kakarla *et al*., 2008). The catheter was considered as misplacement when it was intraparenchymal or in extraventricular space. Based on different reference point of catheter tip, the overall inaccuracy of EVD placement varies, ranging from 6.3% to 36% (Table 3). Of these studies, most failed to describe the exact location of the misplaced catheters (Bogdahn *et al*., 1992; Stangl *et al*., 1998; O'Leary *et al*., 2000; Anderson *et al*., 2004). The relevant risk factors contributing to the final location of catheter placed by freehand method were also infrequently discussed (Khanna *et al*., 1995; Kakarla *et al*., 2008; Saladino *et al*., 2009).

In a retrospective review of 346 patients received freehand ventriculostomy placed by neurosurgical trainees over an 11-month period in a single institute, Kakarla *et al*. reported the overall functional accuracy was 87% (Kakarla *et al*., 2008). Depended on their new grading system, the misplacement in the eloquent parenchyma such as brainstem, cerebellum, internal capsule, basal ganglia, thalamus, occipital cortex and basal cisterns occurred in 46 occasions (13%). In the subgroup, the rate of misplaced EVDs was highest in patients with trauma, midline shift and absent subarachnoid hemorrhage. They concluded that the dislocated or compressed ventricles were the keystone resulting into these misplacements. According to the new grading system reported by Kakarla *et al*. (Kakarla *et al*., 2008), the functional accuracy in current study was 86%. In the subgroup, the misplaced EVDs didn't significantly occur in patients experienced trauma or absent subarachnoid hemorrhage. Neither midline shift nor combined surgery contributed the misplacement. Only the hydrocephalus ratio and the ventricular size

FIG. 3. — The head computed tomographic scan revealed the new hemorrhage around the catheter along the tract.

statistically and significantly affected the accuracy. In the misplaced group, the mean of hydrocephalus ratio and ventricular size were 28.8% and 5.6 mm, respectively. Except the brain shifting (midline shift), we concur with Kakarla *et al.* that the small ventricle was considered as the main reason contributing for the misplaced EVDs (Kakarla *et al.*, 2008).

Of the 212 catheters analyzed, Saladino *et al.* reported 12.3% was considered misplaced (Saladino *et al.*, 2009). The most misplaced catheter was intraparenchymal, where the contralateral or ipsilateral basal ganglia was the most common misplaced location. However, no detail description was mentioned. In current study, 7 (43.8%) of 16 intraparenchymal misplacement occurred in the ipsilataeral or contralateral basal ganglia. Otherwise, surprisingly, the previous studies also demonstrated the rare immediate neurological complications were associated with these misplaced catheters (Anderson *et al.*, 2004; Kakarla *et al.*, 2008). The overall replaced rate has been estimated approximately about 3% in the literature (Roitberg *et al.*, 2001; Kakarla *et al.*, 2008; Ngo *et al.*, 2009; Saladino *et al.*, 2009). In our study, although the 18 catheters were misplaced, no known neurological complications from the misplaced catheters were found. Otherwise, only four (3.1%) of them required a replacement or reposition. Our result was consisted with the previous findings.

Hemorrhage was another immediate complication associated with EVD placement. The rate of EVD-related hemorrhages ranges from 0 to 41% (Stangl *et al.*, 1998; Anderson *et al.*, 2004; Kakarla *et al.*, 2008; Gardner *et al.*, 2009). Some severe hemorrhages such as acute subdural hemorrhages, epidural hemorrhages or intracerebral hemorrhegas have been

Table 3

Summarized the accuracy of ventriculostomy by freehand method in the published literatures

Author	Year	Inaccuracy	Reference point
Bogdahn *et al.* (2)	1992	11%	Unknown
Khanna *et al.* (8)	1995	20%	Frontal horn
Stangl *et al.* (17)	1998	7%	Unknown
O'Leary *et al.* (13)	2000	8.3%	8 (33.3%) of 24 insertion crossed the midline but only two required replacement.
Anderson *et al.* (1)	2004	8.8%	Unknown
*Kakarla *et al.* (6)	2008	13%	Brainstem/cerebellum/internal capsule/basal ganglia/thalamus/ occipital cortex/ basal cisterns
Huyette *et al.* (5)	2008	22.4%	Nonventricular spaces.
Lind *et al.* (11)	2009	36%	Outside frontal horn and third ventricle
Ngo *et al.* (12)	2009	6.3%	Intraparenchyma and basal ganglia
Saladino *et al.* (16)	2009	12.3%	Intraparenchyma / extraventricular spaces
Current study		14%	Basal ganglia/thalamus/cerebrum/corpus Callosum/basal cistern

*The inaccuracy was 23.1% when the catheter was outside ipsilateral frontal horn or third ventricle.

described and some of them required a craniotomy (Huyette *et al*., 2008; Gardner *et al*., 2009; Lind *et al*., 2009; Ngo *et al*., 2009; Saladino *et al*., 2009). In this study, 21 (16.2%) new hemorrhages were observed on subsequent head CT scans. No patients experienced these EVD-related hemorrhages required a craniotomy. However, the difference of occurrence of new hemorrhages between the misplaced group and control group didn't reach the significances.

Despite the freehand method, several devices such as the Ghajar guide (Ghajar, 1985) have been developed to improve the accuracy of ventriculostomy (O'Leary *et al*., 2000). Except the surface landmarks, it provides to guide a catheter in a path perpendicular to the skull surface into the frontal horn of the lateral ventricle. However, in cases of compressed or dislocated ventricles, the ventriculostomy is difficult based on conventional surface landmarks or these assisted devices. The ideal direction should be still modified according to the pre-operative head CT scans and the operator's experience (Stangl *et al*., 1998; Anderson *et al*., 2004). With the development of equipments and techniques, the stereotactic system, frameless neuronavigation or CT-guidance offer the neurosurgeons in localizing the optimal site of catheter and in selecting the proper trajectory (Krotz *et al*., 2004; Prat *et al*., 2009). However, some disadvantages such the more expansive price, more required equipment, more technique requirement and the increase of the procedure time are not acceptable in an emergent situation.

There are some limitations in our study. First, it is a retrospective study and we only include the patients who have the subsequent head CT scans after EVD placements. The misplaced rate in current study can't reflect the overall situation. The further prospective study with regular subsequent head CT scans should be conducted to estimate the exact misplaced rate. Secondary, the majority of these misplaced EVDs didn't cause clinically immediate sequelaes. The long-term deficits also should be investigated. Third, we didn't record the number of "passes" required to achieve the successful ventricular puncture. Otherwise, the possibility of coagulopathy did not investigated in these emergent situations. These may be the main reason that we have the higher new hemorrhage rate after catheters insertion.

Conclusion

In this study, the functional accuracy of EVD placement was about 86%. Only 3.1% of misplaced EVDs required a replacement or reposition surgery. Although the new hemorrhage associated with EVD placement was higher about 16.2%, no patients required a craniotomy. Using the freehand method, EVD placement is a safe and effective procedure in management of these emergent neurosurgical diseases.

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