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ORIGINAL ARTICLE

Malplacement of Ventricular Catheters by Neurosurgeons: A Single Institution Experience

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Abstract
Introduction The placement of cerebrospinal fluid (CSF) diversion devices requires an appropriate technical expertise associated with proper surgical training in order to minimize undue complications. This study sought to review a single institution's experience with placement of external ventricular drains (EVD) and ventriculoperitoneal (VP) shunts as performed by neurosurgeons with procedure-specific training.
Methods A retrospective database review was conducted for all patients who underwent intraventricular CSF diversion over a 5-year period from March 2003 to February 2008. Included in the analysis were ventriculostomy procedures that included EVDs, VP shunts, and ventriculoatrial shunts.
Results A total of 138 patients underwent 212 ventriculostomy procedures. Seventy-one (51%) patients were male and sixty-seven (49%) were female. The median age was 50.1 years. A ventriculostomy-related hemorrhage was identified in 15 (7.1%) patients—4 of whom developed new symptoms. Twenty-six (12.3%) ventriculostomy catheters were malplaced as determined from post-procedural imaging. Ventriculostomy-related infections were identified in 7 (3.3%) patients, 4 of whom had EVDs and 3 of whom had VP shunts.
Conclusion The placement of intraventricular catheters by neurosurgeons remains a relatively safe and effective procedure that is associated with infrequent rates of symptomatic hemorrhage and infection.

Keywords Ventriculostomy · Hemorrhage · Infection

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Introduction

The placement of cerebrospinal fluid (CSF) diversion devices such as external ventricular drains (EVDs) and ventriculoperitoneal (VP) shunts is an integral component of neurosurgical care. Passage of EVDs or VP shunts into the intraventricular space is typically performed without image-guidance using well-defined anatomical landmarks. Despite the relative technical simplicity of their placement, a malpositioned ventricular catheter can lead to devastating outcomes for patients.

An appropriate technical expertise and proper surgical training serve to minimize peri-procedural related complications and ensure correct anatomic placement and therefore intended functionality of CSF diversion devices. As the demands upon intensive patient care increase, so do the number of specialists that have expressed interest in the placement of ventricular catheters. The purpose of this study was to review a single institution's experience with placement of EVDs and VP shunts as performed by neurosurgeons and fairly evaluate their procedural outcomes.

Methods

Patient Population

A retrospective database review was conducted for all patients who underwent intraventricular CSF diversion over a 5-year period from March 2003 to February 2008. Included in the present analysis were all ventriculostomy procedures performed which included those for EVD as well as VP and ventriculoatrial (VA) shunts.

Ventriculostomy Catheter Placement

The preferred side for intraventricular catheter placement is the presumed non-dominant (right) side unless the patient's anatomy or underlying pathology is otherwise prohibitive. Kocher's point [1] is first identified and the area is then prepped and draped in a sterile fashion. Following the infiltration of a local anesthetic, a skin incision is created through which a bur hole is placed with either a perforating or twist drill. For larger bur holes, the underlying dura is coagulated and opened in a cruciate manner. For smaller twist-drill holes, the dura is penetrated without coagulation using a sharp trocar. The ventricular catheter is advanced to an initial depth of 5 cm with an angle of insertion that is perpendicular to the skull surface. If CSF is noted to egress from the catheter, it is advanced slightly farther without the aid of the stylet. The intended end-point is an intraventricular location at or just above the foramen of Monroe [2].

The classical external landmarks to direct the catheter insertion are the ipsilateral medial canthus on the coronal plane and the external acoustic meatus on the sagittal plane [1]. Alternatively, an occipital bone entry site located 6 cm above the inion and 3 cm lateral to the midline can be used. The external landmark toward which the drain is to be directed is the ipsilateral medial canthus in both sagittal and axial planes. The target depth of insertion is approximately 10–12 cm, depending on the age of the patient.

The catheter is then subcutaneously tunneled as far as possible from the incision. For EVDs, it is externalized by connection to a gravity-dependent drainage system. In the case of VP shunts, the distal portion of the catheter is attached to a pressure valve which is subsequently connected to a distal catheter. All patients with EVDs are started on an antibiotic regimen using Ancef or Vancomycin until the catheter is removed. All shunt patients are placed on antibiotics for 24 h following their surgery. It is worth noting that since our institution emphasizes education, a substantial majority of all ventricular catheters are placed by neurosurgery residents with varying degrees of supervision.

Imaging Studies and Imaging Analysis

Pre- and post-procedural head imaging stored in an electronic format was available for every patient included in this study. CT scans were the most common available modality and is the preferred method for analysis. In a few cases, a pre- and post-operative T1-weighted MRI scan was used for evaluation. In one case of intraventricular hemorrhage at birth, the only exam performed was ultrasonography.

In order to measure the ventricular size in preoperative images, we focused on the third ventricle transverse diameter as an indicator of ventricular enlargement. In cases of selective enlargement of one or both lateral ventricles due to obstruction at the level of the foramen of Monroe, the maximum transverse diameter of the anterior horns of the lateral ventricles was determined.

Ventricular size was arbitrarily binned based upon the following criteria: small when the third ventricle transverse diameter was less than 5 mm; normal when it was between 5 and 9 mm; large when it was between 10 and 14 mm; and giant when it exceeded 15 mm. For isolated enlargement of the lateral ventricles, the ventricles were classified as small, normal, large, and giant for measures below 5 mm, between 5 and 14 mm, between 15 and 24 mm, and greater than 25 mm, respectively.

Post-procedural scans were evaluated for the presence of new findings which included intraparenchymal, intraventricular, subdural, or epidural hemorrhage. Hematoma volume was calculated using the simplified ellipsoid equation ($a \times b \times c/2$) as described by Kothari et al. [3]. Malplacement was defined as any catheter that was extraventricular in location or intraventricular with a tip that inadvertently penetrated surrounding parenchyma (i.e. thalamus).

Results

A total of 139 patients in whom 226 CSF diversion procedures had been performed were identified from a database search. One patient with 14 assisted-procedures (8 placements under CT guidance, 4 endoscope-assisted placement, and 2 catheters placed during open surgery) was excluded from analysis. The study population consisted of 138 patients who underwent 212 ventriculostomies (Table 1). Seventy-one (51%) patients were male and sixty-seven (49%) were female. The median age was 50.1 years (range, 1 day to 87 years).

The diagnosis at admission included post-aneurysmal subarachnoid hemorrhage (SAH) ($n = 49$–35.5%), hypertensive intracerebral hemorrhage (ICH) ($n = 25$–18.1%), tumor ($n = 25$–18.1%), malfunction or infection of a

Table 1 Summary of 138 patients

	n (%)
Gender	
Male	71 (51)
Female	67 (49)
Admitting diagnosis	
Subarachnoid hemorrhage	49 (35.5)
Intracranial hemorrhage	25 (18.1)
Tumor	25 (18.1)
Traumatic head injury	7 (5.1)
Intraventricular hemorrhage	7 (5.1)
Shunt malfunction	6 (4.3)
Inflammatory process	5 (3.6)
Shunt infection	3 (2.2)
Aqueductal stenosis	3 (2.2)
Others	8 (5.8)
Procedure	
EVD	169 (79.7)
Shunt	43 (20.3)
Complications	
Malplacement	26 (12.3)
(Required adjustment)	5 (2.4)
Hemorrhage	15 (7.1)
(Symptomatic)	4 (1.9)
Infection	7 (3.3)
EVD	4 (2.4)[a]
Shunt	3 (7.0)[a]

[a] Calculated as a percentage of each procedure

preexisting ventriculo-peritoneal shunt (*n* = 6 and *n* = 3, respectively—6.5%), traumatic head injury (THI) (*n* = 7–5.1%), spontaneous isolated intraventricular hemorrhage (IVH) (*n* = 7–5.1%), intracranial infective/inflammatory processes (*n* = 5–3.6%), and congenital aqueductal stenosis (*n* = 3–2.2%). Other less frequent causes (*n* = 8–5.8%) were dural artero-venous fistula (AVF), Chiari type I malformation, IVH from a deep-seated artero-venous malformation (AVM), IPH after AVM surgery, hydrocephalus of prematurity and "idiopathic" hydrocephalus.

One-hundred and seventy (80.2%) ventriculostomy catheters were inserted through a frontal bur-hole, of which 136 (64.2%) were placed on the right side and 34 (16%) on the left side. Forty-one (19.3%) catheters were inserted through an occipital bur hole—35 (16.5%) on the right side and 6 (2.8%) on the left side. One (0.5%) catheter was placed in the fourth ventricle through a suboccipital bur hole on the right. One-hundred and sixty-nine (79.7%) were connected to an external drain, whereas 43 (20.3%) were connected to either a VA or VP shunt system.

Hemorrhage

A ventriculostomy-related hemorrhage was identified in 15 (7.1%) post-operative scans (Table 1). Of those, four (1.9%) were symptomatic with hemorrhage volumes of 3.3, 6.3, 13.5, and 18 cm^3. One patient required operative evacuation and one was associated with a large IVH hemorrhage leading to clinical demise and withdrawal of care (mortality = 0.05%). Small punctate hemorrhages occurred in five cases, one of which was associated with a small epidural hematoma with no clinical sequelae. The remaining hemorrhages consisted of thin clot layering along the drain (*n* = 3), isolated IVH (*n* = 2), and an isolated epidural hematoma (*n* = 1).

Malplacement

Twenty-six (12.3%) ventriculostomy catheters were malplaced because the distal catheter tip was intraparenchymal (*n* = 21) or in other extraventricular spaces (*n* = 5, Table 1). In the former cases, most catheters were in the contralateral or ipsilateral basal ganglia. Extraventricular locations were primarily in the basal cisterns (carotid-ophthalmic, chiasmatic, prepontine). A replacement procedure was required in five of these cases. There were no known neurologic complications from malplaced catheters.

Based upon our measurement criteria, ventricular size was deemed small in 10 patients, normal in 49 patients, large in 136 patients, and giant in 17 patients. The frequency of malplacement in these patients was 10, 18, 10, and 12% respectively.

Infections

Post-procedural infections were identified in 7 (3.3%) patients, 4 of whom had EVDs and 3 who had VP shunts (Table 1). In the EVD group, the most common agents were coagulase-negative *Staphylococci* (*n* = 3, in association with *Klebsiella oxytoca* in one case) followed by *Propionibacterium acnes* (*n* = 1), with subsequent superinfection by *Enterococcus faecalis* and coagulase-negative *Staphylococcus*. For the VP shunt infections, the only agent involved was *Staphylococcus aureus*. One patient, who had undergone multiple previous shunt revisions, experienced a superficial skin infection along the subcutaneous track of his catheter two years after placement. No patient experienced a clinical deterioration from ventriculitis or meningitis.

Discussion

This study of ventricular malplacement rates and their subsequent complications represents the largest single institution study to date. Our results reaffirm the relatively safe complication profile that is associated with these procedures when performed by adequately trained physicians. Not only were misplaced catheters not associated with neurologic sequelae, but the rate of symptomatic hemorrhage in our patient cohort was exceptionally low with one unfortunate mortality.

Hemorrhage

To be as inclusive as possible, we reported hemorrhage as any new hyper-dense/-intense finding on post-procedural CT/MRI scans which included blood along the catheter tract, blood within the ventricle, and hemorrhage within the epidural, subdural, and intraparenchymal compartments. Our reported hemorrhage rate of 7.1% following ventricular catheter insertion is markedly lower than contemporary reports [4–7]. Most of the hemorrhages identified in our analysis were small and produced little mass effect. Only 1.9% of our patients were noted to experience a neurologic change as a consequence of their hemorrhage—a frequency along the lower spectrum of other reports within the literature [5, 6, 8]. The one mortality and one operative intervention in our series were both from large mass producing hemorrhages.

Malplacement

Of the 212 catheter passes analyzed, we report that 12.3% were considered misplaced upon subsequent imaging. Our threshold for defining misplacement was low and therefore even sub-millimeter encroachments upon the surrounding brain were flagged as incorrect. The majority of misplaced catheters traversed the ventricle but landed within adjacent parenchymal structures such as the basal ganglia, thalamus, caudate, or corpus collosum. Fortunately, not a single misplaced catheter was believed to have impacted our patients neurologically.

The rate of misplacement in this study is substantially lower than that reported in other recent "freehand pass" reports [9]. Somewhat surprisingly, and yet consistent with other studies, patients rarely develop neurologic symptoms from misplaced catheters in the absence of associated hemorrhage [4, 9]. The potential however for subtle or long-term cognitive manifestations has been reported [9].

Infection

Many groups have reported their incidence of infection from intraventricular catheters, particularly EVDs with rates of CSF colonization as high as 27% [10–14]. Standard protocol for EVD monitoring includes the use of IV antibiotics in an attempt to keep infection rates low. Antibiotic-impregnated catheters have also been touted as an important technologic advance as they have been shown in one study to reduce infections by seven-fold to 1.3% [15].

We report an infection rate of 3.3% in our series, the majority of which were EVDs. As a percentage of all EVDs placed, the infection rate was only 2.4%. Not one EVD placed in this study was antibiotic-impregnated, the utility of which is called into question with our rates of EVD infection as compared to historical controls [15, 16]. We routinely (every 48 h) monitor CSF in patients with EVDs and those with positive cultures are treated with IV antibiotics based upon susceptibilities and undergo replacement of their EVD. For infected shunts, the shunt hardware is removed and an EVD is placed until the infection clears as determined from serial CSF cultures. All of the infected catheters in this study were successfully treated without an adverse outcome to the patients.

Limitations

Convention has taught that the correct location for the distal end of intraventricular catheters is at or just above the foramen of Monroe [2]. For this study, our placement criteria were not as stringent as we felt that an isolated intraventricular catheter was a functional and sufficiently placed one. Others have measured the distance from the foramen of Monroe to catheter tips to quantify degrees of malplacement and doing so in this study may have led to higher rates of malplacement [9].

Our technique for measuring ventricle size is established but differs from other known methods for assessing hydrocephalus [17]. We recognize that utilizing other forms of measurement may have altered the association between malplacement and ventricle size.

Finally, we did not record the number of "passes" required to achieve "success" because that data in our records were scarce, which underscores another limitation of this study—the retrospective manner in which the data were collected.

Conclusions

The placement of intraventricular catheters by neurosurgeons is a relatively low-risk procedure with infrequent rates of associated symptomatic hemorrhage and infection. Practitioners should be cognizant of the potential dangers of catheter placement and be prepared to intervene when necessary. As with most procedures, appropriate training and adequate experience are key to maintaining low complication rates and should therefore be requisite for those intending to incorporate catheter placement as part of their practice.

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