Safety and Accuracy of Bedside External Ventricular Drain Placement

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Received, May 7, 2007.
Accepted, February 8, 2008.

OBJECTIVE: To study the safety and accuracy of ventriculostomy by neurosurgical trainees.

METHODS: Initial computed tomographic studies of 346 consecutive patients who underwent bedside ventriculostomy were reviewed retrospectively. Diagnosis, catheter tip location, midline shift, and procedural complications were tabulated. To analyze catheter placement, we used a new grading system: Grade 1, optimal placement in the ipsilateral frontal horn or third ventricle; Grade 2, functional placement in the contralateral lateral ventricle or noneloquent cortex; and Grade 3, suboptimal placement in the eloquent cortex or nontarget cerebrospinal fluid space, with or without functional drainage. Statistical analysis was performed using Fisher's exact test and a weighted κ coefficient.

RESULTS: Diagnoses included the following: subarachnoid hemorrhage, n = 153 (44%); trauma, n = 64 (18%); intracerebral hemorrhage/intraventricular hemorrhage, n = 63 (18%); and other, n = 66 (20%). There were 266 (77%) Grade 1, 34 (10%) Grade 2, and 46 (13%) Grade 3 catheter placements. Hemorrhagic complications occurred in 17 (5%). Four patients (1.2%) were symptomatic, with two (0.6%) requiring surgery. Inter- and intraobserver agreement was almost perfect ($\kappa = 0.846$ and 0.922, respectively) as applied to our grading system. Rates of suboptimal placement were highest in patients with midline shift ($P = 0.059$) and trauma ($P = 0.0001$). Rates of optimal placement were highest in patients with subarachnoid hemorrhage ($P = 0.003$) and when the catheter was placed ipsilateral to the side of midline shift ($P = 0.063$). Neither the resident's training experience nor the side of placement seemed to affect accuracy.

CONCLUSION: Bedside ventriculostomy is a safe and accurate procedure for intracranial pressure monitoring and cerebrospinal fluid drainage.

KEY WORDS: Accuracy, Grading, Neurosurgical trainees, Safety, Subarachnoid hemorrhage, Trauma, Ventriculostomy

Neurosurgery 63[ONS Suppl 1]:ONS164–ONS169, 2008 DOI: 10.1227/01.NEU.0000312390.83127.7F

Bedside ventriculostomy, or external ventricular drain (EVD), placement is the most common neurosurgical procedure and is often performed at our institution by a junior neurosurgical resident. The most common indications are primary or secondary hydrocephalus associated with subarachnoid hemorrhage (SAH) and traumatic brain injury with a Glasgow Coma Scale score of 8 or less. Many studies have addressed the infectious and hemorrhagic complications associated with EVDs. However, few studies have evaluated the accuracy of bedside EVD placement. Therefore, we investigated the safety and accuracy of bedside EVD placement by neurosurgical trainees.

PATIENTS AND METHODS

Over an 11-month period (February 1–December 31, 2003), hospital record databases were searched for patients who had undergone ventriculostomy at St. Joseph's Hospital and Medical Center, a designated Level I trauma center and a tertiary referral center for neurosurgical patients in Phoenix, AZ. Records showed that 521 patients had undergone ventriculostomy. Of these, 175 patients who had a previous EVD or shunt at the same surgical site, had undergone EVD placement in the operating room (including trauma patients), or had tumor bed drains or ventricular access devices were excluded from the study. Thus, the remaining 346 consecutive patients had undergone bedside EVD placement at a virgin surgical site.

TABLE 1. Grading system for catheter tip location

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 or lateral ventricle/ corpus callosum/ interhemispheric fissure
3	Suboptimal in eloquent tissue	Brainstem/ cerebellum/ internal capsule/ basal ganglia/ thalamus/ occipital cortex/ basal cisterns

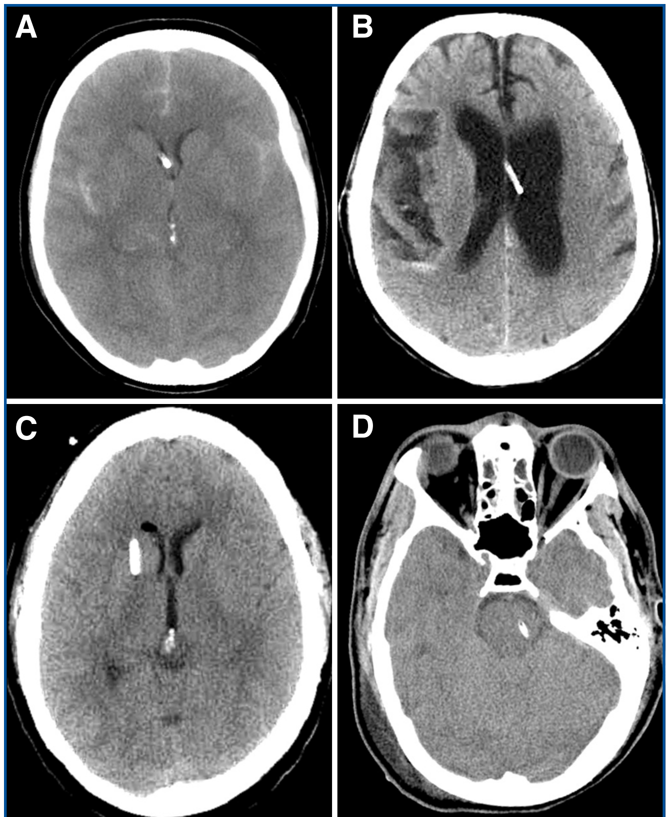

FIGURE 1. **A**, *Grade 1 placement at the foramen of Monro.* **B**, *Grade 2 placement in the contralateral body of the ventricle. Grade 3 placement in the ipsilateral internal capsule (***C***) or in the brainstem (***D***).*

We retrospectively reviewed the initial computed tomographic (CT) scans and all available neuroradiological studies obtained after placement of an EVD in the 346 patients. Diagnosis, surgical site, catheter-tip location, midline shift, and procedural complications as noted on CT scans were tabulated. Hospital charts were reviewed to study the neurological consequences only for patients with misplaced catheters and procedural complications.

We used a new grading system to evaluate catheter tip location (*Table 1*). Grade 1 represented optimal placement with the tip in the ipsilateral frontal horn or third ventricle through the foramen of Monro (*Fig. 1A*). Grade 2 represented functional placement into the contralateral lateral ventricle or noneloquent cortex (*Fig. 1B*). Grade 3 represented suboptimal placement into eloquent cortex or nontarget cerebrospinal fluid space, with or without functional drainage (*Fig. 1C*). Subgroups were analyzed using contingency tables for Grade 1 versus Grade 3 (optimal versus suboptimal) using Fisher's exact test (*Table 2*). The proposed grading system was applied by two observers (a resident and an attending neurosurgeon) on a subgroup of 28 patients selected randomly from the cohort. Inter- and intraobserver variability was quantified using κ analysis. Statistical analysis was performed using free software (GraphPad, La Jolla, CA) available through www.graphpad.com. κ can be thought of as the chance-corrected proportional agreement, and its possible values range from +1 (perfect agreement) via 0 (no agreement above that expected by chance) to -1 (complete disagreement). Using κ, strength of agreement is considered substantial for values between 0.61 and 0.80 and almost perfect for values between 0.81 and 1.00.

At our institution, ventriculostomies are almost always placed by junior neurosurgical residents. When an intern starts on the neurosurgical service, he or she performs at least three to five ventriculostomies under direct supervision until approved by a senior resident or until the intern feels comfortable with the procedure. When an intern or junior resident is unsuccessful in placing an EVD, the senior resident helps with the procedure. If both fail, a CT scan is usually obtained to rule out an increasing mass lesion. In our experience, patients are rarely transported to the operating room for EVD placement unless a temporal or occipital EVD is desired by the attending physician and image guidance is planned. Such patients were excluded from this study.

All residents use the following technique as described by Friedman and Vries (4). Neither image guidance nor a Ghajar guide was used for bedside EVD placement. The right or left frontal ventriculostomy site was usually 10 cm posterior to the nasion and 3 cm lateral to the mid-pupillary line. This site was shaved, prepared, and draped in sterile surgical fashion. The surgical site was infiltrated widely with local anesthetic, and a 1-cm incision was made. A twist-drill craniotomy was performed, and the dura was lacerated with the sharp end of a needle trocar. A ventriculostomy catheter was then passed in freehand manner at a trajectory directed at the foramen of Monro, using an imaginary point of intersection of the ipsilateral medial canthus of the orbit and tragus of the ear as the target. The catheter was passed 6 cm from the outer table of the cranium to cannulate the frontal horn and then tunneled beneath the scalp. It exited approximately 5 cm from the surgical incision. The same surgical technique was used for parietooccipital and temporal EVD placement. At our institution, a CT scan of the brain is routinely obtained immediately to verify catheter placement and to identify any hemorrhagic complications.

At our institution, EVDs are primarily placed by postgraduate year (PGY)-1 and -2 residents. By the end of PGY 2, a resident would have placed approximately 150 bedside EVDs. Comparing the results during the first 3 months of the academic year (July–September) with the last 3 months (April–June) gives a crude estimate of operator experience. This rationale was the basis of our analysis.

TABLE 2. Summary of results[a]

	Grade 1	Grade 2	Grade 3	Total	*P* value
Overall	266	34	46	346	0.3511[b]
Location					
RF	225	24	37	286	
LF	33	5	8	46	
RPO	7	3	0	10	
LPO	1	2	1	4	
Midline shift					0.0591
Present	57	6	16	79	
Absent	209	28	30	267	
Trauma					0.0001
Present	36	9	19	64	
Absent	230	25	27	282	
SAH					0.0038
Present	131	10	12	153	
Absent	135	23	34	193	
Relation to shift					0.0633
Ipsilateral	42	2	7	51	
Contralateral	15	2	8	25	
Operator experience					0.3836
April–June	76	9	15	100	
July–September	70	11	9	96	

[a] RF, right frontal; LF, left frontal; RPO, right parietooccipital; LPO, left parietooccipital; SAH, subarachnoid hemorrhage.
[b] RF versus LF.

TABLE 3. Intraobserver variability of grading system[a]

		Observer 1 (second time)			
	Grade	1	2	3	Total
Observer 1 (first time)	1	12	0	1	13
	2	0	7	0	7
	3	0	0	8	8
	Total	12	7	9	28

[a] Weighted κ = 0.922 (95% confidence interval, 0.838–1.051). The strength of agreement is considered to be very good.

TABLE 4. Interobserver variability of grading system[a]

		Observer 2			
	Grade	1	2	3	Total
Observer 1	1	11	0	1	12
	2	0	7	0	7
	3	1	0	8	9
	Total	12	7	9	28

[a] Weighted κ = 0.846 (95% confidence interval, 0.744–1.037). The strength of agreement is considered to be very good.

RESULTS

Among the 346 patients who underwent ventriculostomy, the diagnosis was SAH in 153 (44%), trauma in 64 (18%), intracerebral/intraventricular hemorrhage (IVH) in 63 (18%), tumor in 51 (15%), hydrocephalus in nine (3%), and other diagnoses in six (2%) patients. The surgical site was right frontal in 286 (83%), left frontal in 46 (13%), right parietooccipital in 10 (3%), and left parietooccipital in four (1%) patients.

The proposed grading system was applied to 28 randomly selected patients from the study by a neurosurgery resident and an attending neurosurgeon. Both intra- and interobserver agreement were considered almost perfect (weighted κ of 0.922 and 0.846, respectively) (*Tables 3* and *4*). The most common disagreement was whether the catheter tip was in the head of the caudate or in the frontal horn, Grade 3 or Grade 1 situations, respectively. However, the strength of agreement was almost perfect for the grading system as applied in this study.

Overall, placement of the catheter tip was Grade 1 in 266 (77%) patients, Grade 2 in 34 (10%) patients, and Grade 3 in 46 (13%) patients. The highest rate of suboptimal placement was observed in the trauma subgroup ($P = 0.0001$). The highest rate of optimal placement (Grade 1) was observed in the SAH subgroup ($P = 0.0038$). There was a strong trend toward Grade 3 placement in the presence of midline shift ($P = 0.0591$) and if the surgical site was contralateral to the midline shift ($P = 0.0633$). Operator experience (first 3 mo of the academic year versus last 3 mo) and side of ventriculostomy did not affect the accuracy of placement ($P = 0.384$ and 0.351, respectively).

Noninfectious EVD-related complications occurred in 17 (4.9%) patients; track hemorrhages occurred in 13 (3.8%); epidural hematomas (EDH) occurred in two (0.6%); subdural hematoma (SDH) occurred in two (0.6%); and IVH occurred in one (0.3%). The neurological condition of two patients with track hemorrhages deteriorated, and both were managed nonsurgically (*Fig. 2*). Two patients with extraaxial complications were

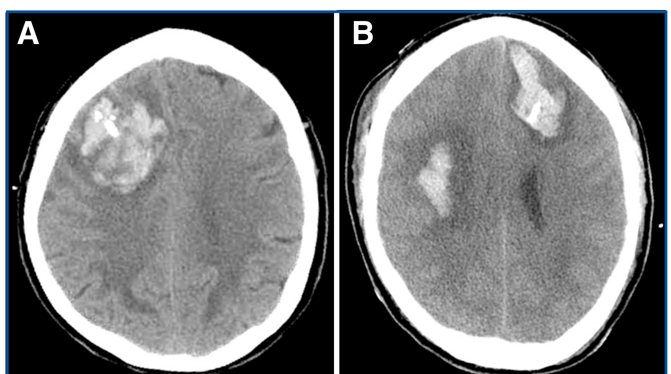

FIGURE 2. *Computed tomographic (CT) scans showing 66-year-old woman (**A**) and a 54-year-old man (**B**) with track hemorrhages from external ventricular drain (EVD) catheters managed nonsurgically.*

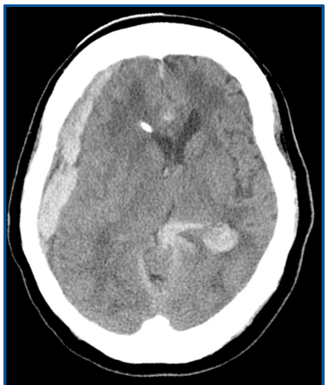

FIGURE 3. *CT scan showing a 78-year-old woman with intraventricular hemorrhage who developed a large right acute subdural hematoma and required a craniotomy after EVD placement.*

symptomatic and required a craniotomy. One had an SDH (*Fig. 3*) and one had an EDH (*Fig. 4*); both patients subsequently died. Overall, the mortality rate associated with EVD placement was 0.6%. The remaining patients experienced no clinical neurological sequelae as a result of suboptimal EVD placement (Grade 3). In only 13 (28% of Grade 3 patients, 3.7% overall) of these patients was the catheter nonfunctional, requiring repositioning or replacement.

DISCUSSION

EVD is a widely used neurosurgical technique in the management of hydrocephalus and intracranial pressure (ICP) monitoring. It was described as early as the 1950s (3). Most reports have been on EVD-related infections. A few have concerned hemorrhagic complications. However, very few studies have addressed the accuracy of this important neurosurgical procedure in a meaningful way.

To date, only one study has quantitatively addressed the accuracy of EVD placement. O'Leary et al. (9) prospectively compared EVD placement via freehand placement with use of a Ghajar guide and found that the latter significantly improved the accuracy of placement. This analysis was based strictly on the distance of the catheter tip from the foramen of Monro. A third of the freehand EVD placements (8 of 24) crossed the midline, two (8.3%) of which required replacement with no reasons given.

Accuracy

Khanna et al. (6) retrospectively compared EVDs with parenchymal ICP monitors. The rate of misplaced EVDs was 20% (21 of 104) and included the catheter tip in the third ventricle, thalamus, brainstem, and other eloquent areas. Bogdahn et al. (3) reported an 11% rate of misplaced EVDs that had to be replaced but offered no further analysis. In their pediatric series, Anderson et al. (1) reported an 8.8% rate of misplacement. In their series of needle trephinations, Stangl et al. (11) reported a 7% rate of misplacement. Except for Khan et al. (5), the above studies failed to describe the location of the misplaced catheters. In our study, the rate of misplacement was 13%. Only 13 of these patients (3.8% overall) required repositioning of a nonfunctioning catheter. None of the patients showed new neurological deficits as a result of misplacement. This finding indicates that bedside EVD placement is associated with a high rate of functional accuracy and that the rare misplaced EVD is well tolerated by patients.

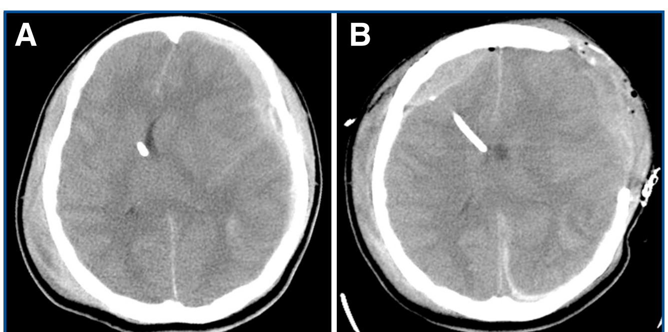

FIGURE 4. *CT scan showing a 14-year-old girl with a left subdural hematoma (**A**) who developed a delayed right epidural hematoma at the EVD site after a left craniotomy (**B**) and required surgical evacuation.*

Surgical Site

In selecting the surgical site for EVD placement, the right frontal site is often preferred, given the relative noneloquence of the right frontal lobe. Even in patients with left-sided hemorrhages, the right side is often preferred for EVD placement. In a subgroup analysis of patients with midline shift, we found that overall accuracy was not affected by the side of the shift. However, EVD placement tended to be more accurate if the surgical side was ipsilateral toward the midline shift ($P = 0.0633$) (e.g., a left frontal site in a patient with a right-to-left midline shift). This finding may reflect the relatively shorter distance between the frontal horn and surgical site if it is ipsilateral to the midline shift.

Trauma

As noted, Anderson et al. (1) reported an 8.8% rate of misplaced EVDs that required revision in a pediatric population with traumatic brain injury. The total number of misplaced EVDs in this series was unavailable because only those that required revision were reported. We calculated the rate of misplaced EVDs in our trauma subgroup to be 30%. Although this rate is statistically significantly higher than that of the overall group, these misplaced EVDs were clinically silent. In general, trauma patients tend to be younger and to have small ventricles because of their age or the presence of cerebral edema. These factors might have contributed to a higher rate of inaccuracy in this subgroup. Given the relatively high rate of misplacement in our trauma subgroup, it may be reasonable to consider using an ICP monitor instead of an EVD in selected cases. Furthermore, bedside image guidance, the subject of current studies at our institution, may be useful in this population.

Subarachnoid Hemorrhage

Most patients in our series experienced SAH (44%). In this subset, the overall rate of misplacement was only 7.8% ($P = 0.0038$) compared with 17.6% in patients without SAH. This difference most likely reflects the presence of hydrocephalus, which would provide a larger target for EVD placement.

Hemorrhagic Complications

The rate of hemorrhages associated with EVD placement ranged from 0 to 15% (1, 2, 6, 8, 10). However, none of these studies reported EVD-related mortality rates. The hemorrhage rate of 5% in our series is within the range reported in the literature. Two of our patients required surgical intervention, and two deaths (0.6%) were associated with EVDs. One of these patients developed an EDH at the surgical site only after a large contralateral SDH was evacuated (*Fig. 3*). She was taken for surgical evacuation but developed malignant intracranial hypertension and suffered brain death. After EVD placement, the second patient developed a large SDH that was evacuated emergently (*Fig. 4*). Her neurological status returned to baseline after evacuation, but care was withdrawn because of her primary IVH.

Operator Experience

In large academic centers, EVDs are often placed by neurosurgical trainees. In our institution, bedside EVDs are placed by the rotating intern on service (PGY-1) or by the junior neurosurgical resident (PGY-2). As the residents gain experience, the accuracy of their EVD placement would be expected to improve. We compared EVDs placed in the months of July through September (first 3 mo of the academic year) with those placed from April through June (last 3 mo of the academic year) and found no statistical difference based on operator experience ($P = 0.384$).

Image Guidance

The role of image guidance in the placement of a ventriculostomy is unclear. Krötz et al. (7) prospectively evaluated computed tomography-guided EVD placement compared with a control group of freehand placement and reported no misplaced catheters. However, there was no statistically significant difference in the rate of overall misplacement, infection, or risk of hemorrhage compared with the control group. However, the availability of a bedside image-guidance system for EVD placement may help improve the accuracy of EVD placement. Given the added time and cost, however, it is important to recognize situations in which use of these systems is most useful.

Our grading system provides a rapid way of communicating the accuracy of EVD placement. This system may help improve discussions across institutions about the accuracy of image-guided systems compared with freehand passage for EVD placement. Given the relatively large number of patients in this study, our data suggest that freehand EVD placement can be performed with safety and functional accuracy. It also serves as a benchmark for future EVD placement studies that evaluate the efficacy of bedside or intraoperative image-guidance systems for EVD placement.

CONCLUSION

EVD is one of the most important neurosurgical procedures performed by a neurosurgeon. On the basis of our new grading system to describe the accuracy of this common neurosurgical procedure, we find it to be a safe and effective procedure, with an overall rate of functional accuracy of 87% and low rates of mortality and morbidity. Future studies on bedside image-guidance systems may help optimize accuracy of placement.

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COMMENTS

This retrospective analysis of a large series of patients with varying diseases showed an overall functional accuracy rate of 87% for bedside placement of ventriculostomy catheters. Among the different patient populations, the highest rate of misplaced external ventricular drains (EVDs) was 30%; this occurred in trauma patients. Despite this result, it is still worthwhile to consider an EVD as the initial intracranial pressure (ICP) monitoring device of choice in trauma patients because an EVD permits drainage of cerebrospinal fluid (CSF) as a therapeutic measure. A parenchymal monitor can be inserted if the ventricles cannot be cannulated. In trauma patients, the relatively high rate of failed EVD placement even among neurosurgeons should give pause to physicians of other specialties who are eager to take over the performance of these procedures.

Alex B. Valadka
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In this article, Kakarla et al. report on the accuracy of freehand ventriculostomy placement by neurosurgical trainees in 346 patients over an 11-month period in a single institution by retrospective review. They introduced a new grading system, and by that system reported that there were 266 (77%) Grade 1, 34 (10%) Grade 2, and 46 (13%) Grade 3 catheter placements. Ventriculostomy-related hemorrhagic complications occurred in 17 (5%) patients. Four patients (1.2%) were symptomatic with two (0.6%) requiring surgery.

This is an interesting topic and probably reflects the results of this procedure in a busy general neurosurgery unit. The grading system had high intraobserver and interobserver agreement when tested on a small subset of the patients. A comparison of the first academic quarter with the last three, as a measure of experience, showed no difference. One could argue with the conclusion that the results in the trauma patients were "safe and effective" with a misplacement rate of 30% and one catheter that seeming to have ended up in the midbrain. For this group, in particular, the use of image guidance or ultrasound might be a benefit, which Kakarla et al. have suggested as a next step.

James M. Drake
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In this study, Kakarla et al. examine the results of a group of free-hand bedside placements of ventriculostomies in 346 patients. In 77% of patients the tip of the catheter was in the ipsilateral frontal horn or third ventricle (Grade 1), in 10% it was in the contralateral lateral ventricle or noneloquent parenchyma but functional, i.e., measuring ICP and draining CSF (Grade 2), and in 13% it was in eloquent parenchyma and may or may not have been functional (Grade 3).

Hemorrhagic complications occurred in 5% (17 of 346) of the patients, with 4 becoming symptomatic, 2 requiring operative intervention, and 2 dying. No catheter placement grade was assigned to the patients with hemorrhagic complications.

The purpose of placing a ventriculostomy is to measure ICP and/or to drain CSF. The distinction between Grade 1 and Grade 2 locations does not seem to be helpful as it makes little difference when the ventriculostomy is measuring ICP accurately and/or draining CSF well. Kakarla et al. did not make a distinction between Grade 3 locations that were or were not functional. Once the pass for catheter placement has been made, the damage is done, excluding the development of a subsequent bleeding episode. Of the 46 Grade 3 catheter locations, only 13 (28%) were replaced, presumably because they were not functioning, whereas 33 (72%) were not. Would it not have been better to subdivide those Grade 3 locations that were functional from those that were not?

Kakarla et al. indicate that even though the tip of the catheter was placed in eloquent parenchyma on 46 occasions, there were no neurological deficits that resulted. This seems somewhat surprising. The charts for the 300 patients with Grade 1 and 2 locations were not reviewed to see whether a deficit had occurred. The number of ventricular catheter placement passes was not recorded. Even though the location was judged to be Grade 1 or 2, it might have taken more than one pass to achieve and could have resulted in a deficit.

If the catheter is functioning well why obtain a routine postplacement computed tomographic scan for all patients? Kakarla et al. only replaced 13 of the Grade 3 location catheters presumably because they were not functioning well. Of the 17 patients with hemorrhagic complications, only 4 became symptomatic and would have received scans. Computed tomographic scans are not without cost, and there is the factor of radiation exposure, which is more significant if the patient is an infant or child.

It was gratifying to see that the learning curve was flat with no differences being seen in the placement location and complication rate between the beginning and end of the academic year. It will be interesting to learn the outcome of the next study that is in planning or even already under way.

J. Gordon McComb
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Kakarla et al. at the Barrow Neurological Institute retrospectively reviewed their accuracy in placing intraventricular catheters in 346 patients. These were selected patients, all of whom had their catheters placed at a virgin site. We are not told how often the junior and senior resident aborted the procedure because they were unable to cannulate CSF space at the bedside. The series is unique in that all the patients were evaluated by a head computed tomographic scan immediately after the catheters were placed. The authors developed a rating scale to evaluate the catheter placement, which they validated as part of this study. The scale is based on the anatomic location of the catheter tip and not whether or not the catheter is draining CSF. The statistics generated by this study are useful when one is talking to patients and their families about the risks of performing a ventriculostomy. For instance, hemorrhages occurred in 17 patients resulting in neurological deterioration in four. In 46 patients, ventriculostomies were suboptimally placed, although only 13 of these "ugly" catheters required replacement. These numbers put the risks of catheter placement at the bedside in perspective and can be compared with those of any other techniques for catheter placement.

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Kakarla et al. provide us with a review of 346 patients treated with bedside ventriculostomy. The goal of the study was to determine the overall risks of ventriculostomy placement in the setting of patients with neurological disease. As one might expect, the placement of a catheter in a suboptimal position was identified in patients with midline shift and trauma. Patients with subarachnoid hemorrhage had a high chance of having adequate ventricular placement. Although these statements may seem intuitive, this is one of the first studies to actually document them statistically.

It is well known that even the simplest procedures have certain risks. As Kakarla et al. note, bedside ventriculostomies are often performed by the resident staff, and this is often a procedure that is taught to junior residents by senior residents. The authors find no relationship between operator experience and accuracy of the ventriculostomy. This study highlights the fact that this procedure should not be taken lightly and that complications can indeed occur.

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