

Placement of External Ventricular Drains and Intracranial Pressure Monitors by Neurointensivists

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Abstract

Introduction External ventricular drains (EVDs) and intracranial pressure (ICP) monitors are widely used in the Neurological Critical Care Unit (NCCU) to measure ICP and divert cerebrospinal fluid (CSF). EVDs and ICP monitors have historically been placed by neurosurgeons; however, with recent staffing of NCCUs by neurointensivists, a growing number of EVDs and ICP monitors are being placed by these specialists.

Results Limited data are available concerning the safety or feasibility of such placements by neurointensivists. We present our experience with EVD and ICP monitor placement by a neurointensivist in the NCCU. A retrospective chart review of 29 patients with EVD placement and 7 patients with ICP monitors—all placed by a single neurointensivist—was conducted for patients admitted to the NCCU from August 2005 to January 2008.

Discussion These findings were compared to published outcomes from neurosurgeon placements. All 29 patients with EVDs remained infection-free, with CSF pleocytosis

occurring in one patient (3.4%). All 7 patients receiving ICP monitors remained free from infection. Complications after drain placement occurred in 20.7% ($n = 6$) of patients, with all six complications being EVD tract hematoma measuring less than 5 cm³.

Conclusion Patients receiving ICP monitors had no complications. These complication rates are comparable to published rates, which suggest that placement of EVDs and ICP monitors by neurointensivists may be safe and effective. However, small sample size ($n = 36$) prohibits definitive safety and efficacy conclusions. For this reason, further research analyzing a larger patient sample is warranted.

Keywords Intracerebral hemorrhage · Subarachnoid hemorrhage · External ventricular drain · Ventriculostomy · Intracranial pressure monitor · Neurological Critical Care Unit · Obstructive hydrocephalus · Neurointensivist · Safety

Introduction

External ventricular drainage (EVD) is an important diagnostic and therapeutic tool for the continuous management of intracranial pressure (ICP) and cerebrospinal fluid (CSF) analysis and drainage [1–12]. It can also function as a conduit for administration of various pharmacological agents into the intrathecal space. Alternatively, stand-alone intraparenchymal ICP monitors may be used when CSF analysis and access to intrathecal space are not required. These two types of ICP monitoring devices are available for patients with traumatic brain injury, malignant cerebral edema secondary to ischemia, hemorrhagic stroke, or subarachnoid hemorrhage. ICP measurements in the

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Neurological Critical Care Unit (NCCU) setting can help tailor management and improve patient outcomes [13–15].

Obstructive hydrocephalus is a common complication following intraventricular hemorrhage, traumatic brain injury, intracranial mass lesion, intracerebral hemorrhage, rupture of intracranial aneurysm, and arteriovenous malformation. Presence of obstructive hydrocephalus and high ICP can lead to significant morbidity and mortality. EVDs can reduce ICP by limiting obstructive hydrocephalus, thereby reducing morbidity and mortality [1–11].

Historically, EVDs and ICP monitors have been placed by neurosurgeons. With recent staffing of NCCUs by neurointensivists, a growing number of EVDs and ICP monitors are being placed by these specialists. This recent staffing change warrants careful evaluation of the safety and efficacy of EVD and ICP monitor placement by neurointensivists.

EVD placement is sometimes complicated by intraparenchymal, intraventricular, or subdural hemorrhage, as well as catheter-related infection. Recent studies have reported that catheter-related hemorrhages occur in 1–33% of patients [2, 7, 8, 16–18] and catheter infections occur in 1–12% of patients [12, 19–22]. If ventriculostomies performed by neurointensivists are as safe and effective as those performed by neurosurgeons, then complication rates should be comparable.

The current study includes a literature review and retrospective chart review in order to compare complication rates of EVD and ICP monitor placements by neurointensivist to the rate of other physicians in the literature.

Methods

Literature Review

The Medline, CINAHL Plus, PsycINFO, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Cochrane Central Register of Controlled Trials, Comprehensive Biomedical Reference Collection, Comprehensive Nursing & Allied Health Collection, Psychology and Behavioral Sciences Collection, Health Business Fulltext Elite, International Pharmaceutical Abstracts, and EJS E-Journals databases were searched for articles reporting EVD and ICP monitor complication rates. Patient data were extracted from 14 articles focusing on catheter-related hemorrhage, infections, and/or ICP monitor complications. All showed patient demographics and admitting diagnoses that matched those of the current neurointensivist's patients. None of the articles included EVD placements performed by neurointensivists. The neurointensivist data were compared with the data reported in these 14 published articles.

Training

All EVDs and ICP monitors were placed by a single fellowship-trained neurointensivist with hospital privileges to perform these procedures due to specialized training. This training included 50 successful EVD and ICP monitor placements under direct supervision of the neurosurgery faculty at the training medical institution. Privileges were approved by medical committee after training was successfully completed. Therefore, no IRB approval was necessary for these procedures.

Technique

An authorized agent representing each patient signed detailed informed consent indicating that the neurointensivist would perform these procedures. All EVDs and ICP monitors were placed at bedside in the Neurocritical Care Unit using VentriClear ventricular drainage catheter sets with Cook Spectrum antibiotic impregnation (Cook Surgical, Bloomington, Indiana), Camino ICP Monitoring Kits (Integra NeuroSciences, Plainsboro, New Jersey), and Licox Brain Tissue Oxygen Monitoring Systems (Integra NeuroSciences, Plainsboro, New Jersey). Antibiotics in the ventricular catheters included minocycline and rifampin, which have been demonstrated to reduce risk of catheter-related infection [12]. No prophylactic antibiotics were used.

After shaving the appropriate area of the head, patients were prepared and draped in the usual sterile fashion. A small incision was made in the frontal scalp, approximately 11–12 cm nasion and to the right or left of midline depending on ventricular or hemispheric pathology. A manual twist drill was used to penetrate both the outer and the inner tables of the skull. A probe was placed through the hole to ensure that the drill had completely penetrated through the bone. An 18-gauge needle was used to score and puncture the dural surface. At this point, either a ventricular catheter was inserted through the burr hole, to a depth of 55–60 mm and secured to external tubing, or an ICP monitoring device was screwed securely into place. ICP probe readings were adjusted to zero before insertion through the burr hole. After reaching appropriate insertion depth and visualizing appropriate waveform, probes were secured externally, and a sterile dressing was applied to the site.

For EVDs, catheter placement was initially verified by the presence of appropriate intracranial pressure modulation waveform observed via an ICP monitor. For both devices, confirmation of catheter placement was attained via computed tomography of the head, which was performed within 3–12 h of the procedure. Computed tomography was also inspected for hyperintensity along

the ventricular catheter and the corresponding subdural space, which would indicate catheter tract or subdural hemorrhage.

Data Collection

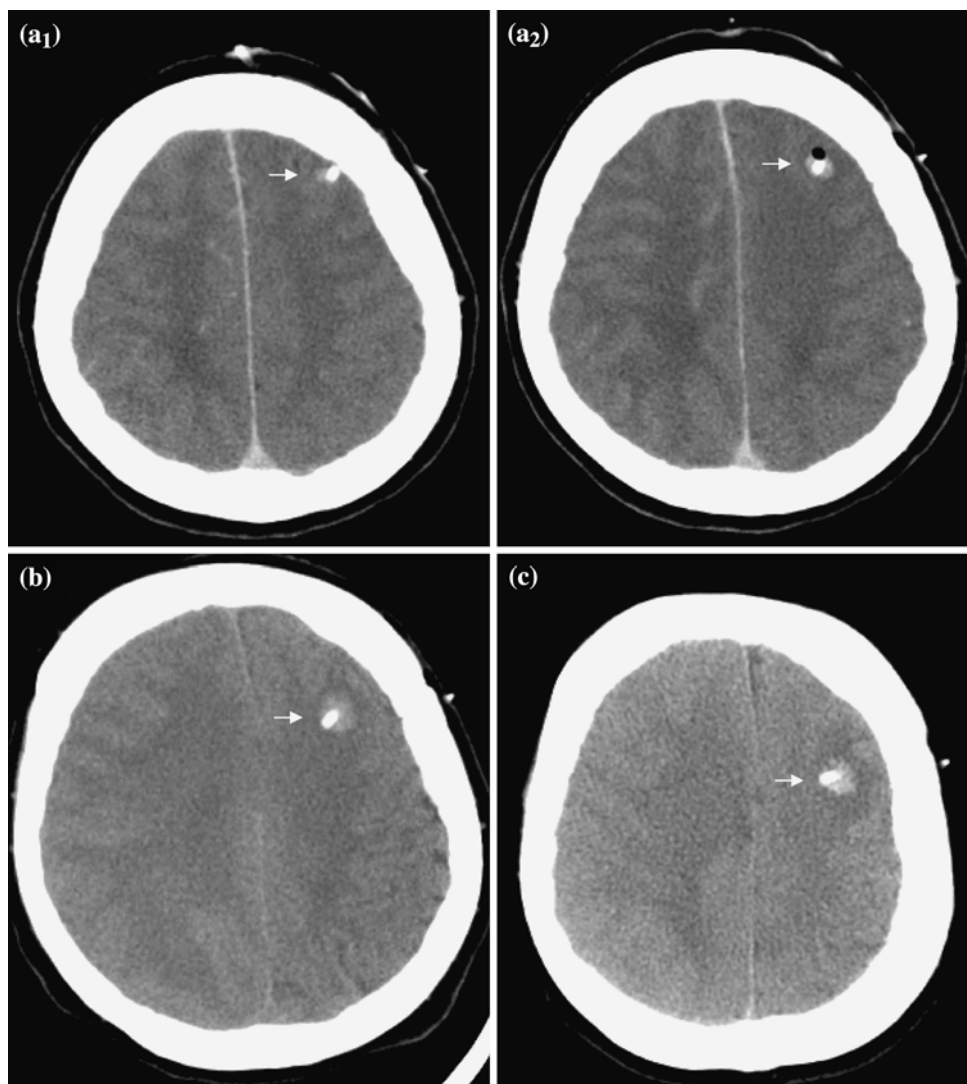
Data for all patients who underwent neurointensivist placement of an EVD or ICP monitoring device from August 2005 to January 2008 were retrospectively reviewed. For EVD patients, age, sex, presence of ventriculoperitoneal shunt, EVD distance, duration of placement, opening pressure, number of attempts for placement, indication for EVD, placement location, complications, and discharge destination were recorded. For ICP monitor patients, age, sex, indication for ICP monitor, type of monitor, placement location, ICP, duration of placement, and complications were recorded.

Results

Indications for EVD included obstructive hydrocephalus due to aneurysmal subarachnoid hemorrhage ($n = 14$), intraventricular hemorrhage ($n = 1$), intracerebral hemorrhage ($n = 10$), arteriovenous malformation ($n = 1$), ventriculitis ($n = 1$), left frontal mass ($n = 1$), and iatrogenic aneurysmal rupture ($n = 1$). Intraventricular extension of subarachnoid hemorrhage, intracerebral hemorrhage, or arteriovenous malformation was present in 11 patients. Patient age ranged from 22 to 55 years (mean, 51.6 years). Sixteen male (55.2%) and 13 female (44.8%) patients were included in our analysis.

Twenty-seven of the 29 EVDs (93.1%) were placed by the neurointensivist with one attempt. One required 2 attempts, and 1 required 3 attempts due to shifting of ventricular system caused by mass effect. Twenty-four of

Fig. 1 Non-contrasted CT scan images of 0.2 cm³ EVD tract hemorrhage showing no enlargement over a 48-h period. **a**₁ and **a**₂ are separate slices recorded immediately after EVD placement, **b** was recorded 24 h after EVD placement, and **c** was recorded 48 h after EVD placement. Arrows indicate catheter tract hematoma



the 29 (82.8%) were placed ipsilaterally in the anterior horn of the lateral ventricle, foramen of Monroe, or third ventricle. The other 5 were located in the contralateral frontal region. Six of the 29 EVDs (20.7%) resulted in drain tract hemorrhages. Of these, two measured less than 1 cm^3 , 2 measured 1 cm^3 , 1 measured 4 cm^3 , and 1 measured 5 cm^3 . Head CTs performed every 24 h failed to show enlargement (see Figs. 1 and 2), no surgical intervention was required, and patients remained neurologically stable without decline in level of mentation or Glasgow Coma Score. None of the hemorrhagic complications caused worsening of preexisting symptoms or decline in general patient condition. Three times per week, 1.5 ml of CSF was collected under sterile conditions and sent to the lab for routine analysis including glucose, protein, cell counts, and Gram staining. Cerebrospinal fluid pleocytosis was present in one patient. However, this cerebrospinal fluid did not yield any growth in bacterial culture.

Indications for ICP monitors included acute ischemic stroke with mass effect ($n = 2$), malignant cerebral edema ($n = 6$), intracerebral hemorrhage ($n = 4$), and intraventricular hemorrhage ($n = 1$). Patient age ranged from 20 to 74 years (mean, 49.4 years). There were 6 male (85.7%) and 1 female (14.3%) patients. No complications occurred.

Discussion

EVD procedure complications in the current study are compared with those of 11 published articles in Table 1. Complication rates for the neurointensivist were comparable to previous reports, though small sample size prohibited statistical hypothesis testing.

Hemorrhagic complication rate for the neurointensivist (20.7%) was comparable to previous reports, though there was wide variation among these reports (1–33%) [2, 7, 8, 12, 16–18]. Six out of 7 articles reported lower hemorrhagic complication rates than the neurointensivist; however, wide variation in results and lack of methodological detail in previous reports suggest that different authors may have defined complications differently.

Four out of 7 articles treated hemorrhagic complication as a dichotomous outcome; [2, 12, 17, 18] the other 3 reported the number of hemorrhagic complications requiring surgical evacuation [7, 8, 16]. Even among these 3 reports, proportions of hemorrhages requiring surgical evacuation varied substantially, from 0 to 33%. This raises questions about the sensitivity of different methods for detection of drain tract hemorrhage. Five out of the 7 articles did not report the method used to detect

Fig. 2 Non-contrasted CT scan images of 5.0 cm^3 EVD tract hemorrhage showing no enlargement over a 72-h period. **a₁** and **a₂** are separate slices recorded immediately after EVD placement, **b₁** and **b₂** are separate slices recorded 24 h after EVD placement, and **c₁** and **c₂** are separate slices recorded 72 h after EVD placement. Arrows indicate catheter tract hematoma

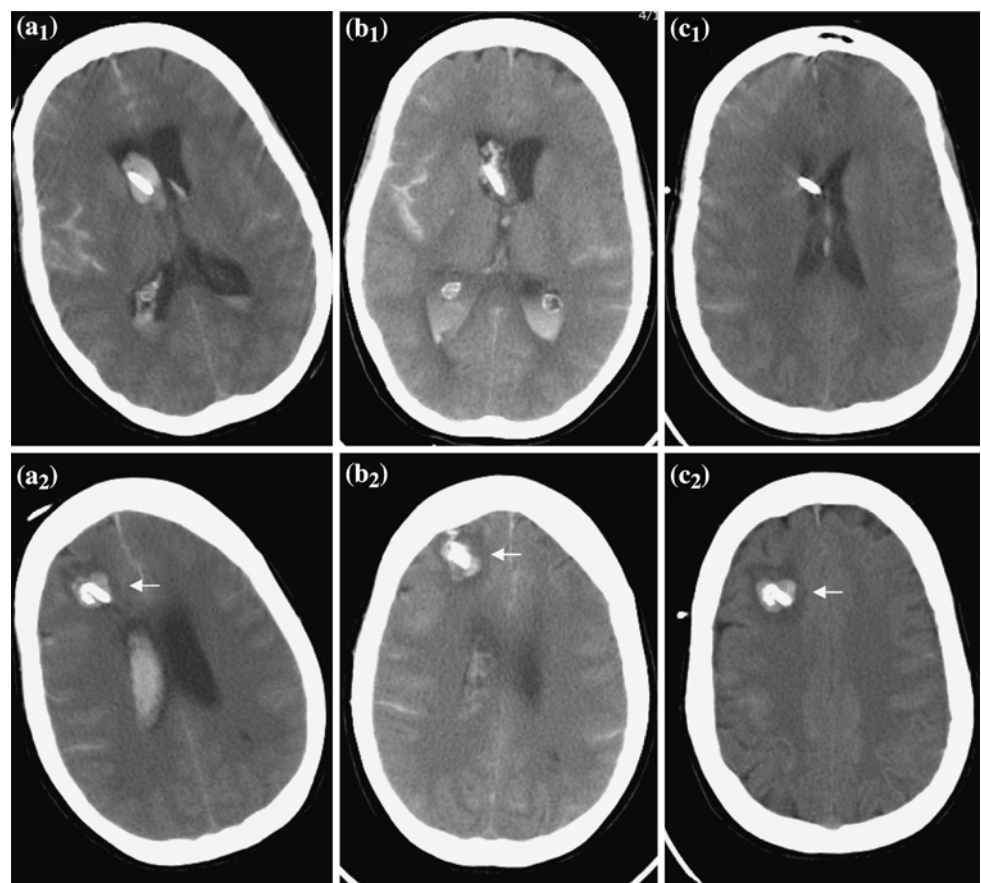


Table 1 Complications of published EVD placements and neurointensivist placements

	N	Infection rate (%)	Drain tract hemorrhage rate (%)	Drain tract hemorrhages requiring surgical evacuation	
				Proportion of total patients (%)	Proportion of drain tract hemorrhages (%)
Neurosurgeon placements					
Mack et al. [19]	220	12.0	–	–	–
Zabramski et al. [12]	149	1.3	–	–	–
Sloffer et al. [20]	100	1.0	–	–	–
Schade et al. [21]	220	9.6	–	–	–
Lo et al. [22]	199	10.6	–	–	–
Narayan et al. [7]	188	6.4	1.4 ^a	0.5	33.3
North et al. [17]	199	3.6	1.0 ^a	–	–
Guyot et al. [2]	274	7.3	3.3 ^a	–	–
Stangl et al. [18]	165	8.0	0.9 ^a	–	–
Roitberg et al. [8]	103	1.0	1.0 ^a	0.0	0.0
Maniker et al. [16]	160	–	32.5	1.3	3.8
Neurointensivist placements	29	0.0	20.7	0.0	0.0

^a Less sensitive technique may have been used for detection of asymptomatic drain tract hemorrhage in these studies

hemorrhagic complications, [7, 8, 12, 17, 18] so it remains unclear about method similarity. The authors believe that small tract hemorrhages are quite common and often excluded from published articles because they are clinically insignificant.

Maniker et al. [16] suggested that previous authors may have reported only major hemorrhagic complications such as those causing neurological deficit or requiring surgical intervention. Indeed, most articles report hemorrhagic complication rates comparable to major hemorrhage rates observed in the neurointensivist’s patients or the patient

sample collected by Maniker et al. Because minor hemorrhages may be detectable only on a CT or MRI scan, studies that did not perform postoperative CT scans may have failed to detect them. Until a standard definition of hemorrhagic complication is adopted, methodology should be elucidated in reports.

Only 1 comparison article reported placement attempt counts and precise catheter placement locations [18]. The neurointensivist experienced similar outcomes to the comparison article in this area, seldom requiring more than a single attempt and always placing the catheter in the

Table 2 Published ICP monitor placements and neurointensivist placements^a

	Age	Sex	Reason for monitor	Type of monitor	No. of days	Monitor-related complications (%)	SDH (%)
Neurosurgeons							
Eddy and Vitsky [13] (n = 100)	26.5 ± 15	>50% Male	48.0% SAH	100.0% Camino Bolt	4.0	0.0	–
Kaups et al. [23] (n = 105)	36 ± 2	–	–	100.0% Camino Bolt	3.6 ± 0.2	9.5 ^b	–
Guyot et al. [2] (n = 229)	–	–	–	100.0% Camino Bolt	–	1.3 ^c	–
General surgeons							
Harris et al. [24] (n = 130)	34.8 ± 19.8	78.8% Male	94.5% blunt trauma	100.0% Ventrix Bolt	6.8 ± 9.7	0.0	0.0
Neurointensivist (n = 7)	49.4 ± 18.4	85.7% Male	85.7% MCE	71% Camino Bolt, 29% Licox monitor	3.6 ± 1.5	0.0	0.0

^a ICP, intracranial pressure; MCE, malignant cerebral edema; SAH, subarachnoid hemorrhage; SDH, subdural hematoma

^b Complications noted in this study included dislodged devices, malfunctioning devices, and “spacer” retention below the scalp

^c Complications noted in this study included two intracranial hematomas and one scalp granuloma

ipsilateral (anterior horn of the lateral ventricle, foramen of Monroe, or third ventricle) region or the contralateral lateral ventricle.

Reported methodology was generally more detailed for detecting infection than hemorrhagic complications. Eight of the 10 explicitly defined infection, while two did not [2, 18]. Definitions included gram-staining observations [8] or growth in bacterial culture [7, 12, 17, 19–22]. Despite similar definitions, there was wide variation in rates of infection (1–12%) among studies (Table 1) [2, 7, 8, 12, 17–22]. No infections were found in the EVDs placed by the neurointensivist.

Patient demographics and outcomes of ICP monitor placements by the neurointensivist are compared with those of neurosurgeons and general surgeons, as reported in four previously published studies, [2, 13, 23, 24] in Table 2. Neurointensivist complication rates were comparable to surgeons.

Conclusions

The availability of neurointensivists to manage neurological emergencies in an ICU setting can decrease mortality and improve patient outcomes [25–27]. External ventricular drainage is a valuable tool to access, manage, and direct therapies for complex patients with hydrocephalus and intracranial hypertension.

The findings of this chart review suggest that EVDs and ICP monitors placed by a neurointensivist have outcomes similar to those placed by neurosurgeons. High incidence of ipsilateral placement, low infection rates, and low complication rates (including major catheter-related hemorrhage) indicate that EVD and ICP monitor placement by neurointensivists may be safe and effective. Prompt and careful placement of EVDs and ICP monitors by neurointensivists trained in this procedure appears to be a logical practice for management of neurological critical conditions. However, small sample size and limitations of single-site, retrospective chart review prohibit drawing safety and efficacy conclusions. Therefore, further research is warranted.

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