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The Effect of External Ventricular Drain Use in Intracerebral Hemorrhage

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■ BACKGROUND: **Spontaneous intracerebral hemorrhage (ICH) commonly presents with intraventricular hemorrhage (IVH) and remains a highly disabling form of stroke. External ventricular drains (EVDs) are associated with decreased short-term mortality, but indications for use and outcomes benefit are controversial.**

■ METHODS: **A multi-institutional, retrospective analysis of 563 patients with spontaneous ICH from 2010 to 2014 was performed with multivariate regression modeling. Primary outcomes were patient mortality and functional status with modified Rankin Scale score. To control for differences in patient and clinical characteristics influencing EVD utilization, a propensity score analysis was performed with patient-specific predicted probability of EVD use.**

■ RESULTS: **The multivariable logistic regression model showed odds of EVD use increased with younger age, lower ICH volume, ICH located outside the brainstem, increasing IVH volume, and concurrent IVH; the model showed high discriminability for EVD use (area under the receiver operating curve 0.84, $R^2_{McFadden} = 0.27$). The use of EVD was associated with lower 30-day mortality in patients with ICH score of 4 (odds ratio = 0.09, $P = 0.002$), greater ICH volume (>11 cc, odds ratio = 0.47, $P = 0.019$), and lower initial GCS (<13, 0.38, $P = 0.003$) in propensity score-adjusted analyses, as well as a trend toward lower mortality in patients with IVH and greater modified Graeb score. There was no benefit to morbidity in patients receiving an EVD.**

■ CONCLUSIONS: **Among a large, multi-institutional cohort, this statistical propensity analysis model accurately predicted EVD use in ICH. EVD use was associated with a trend towards decreased mortality but greater modified Rankin Scale score for functional outcomes.**

INTRODUCTION

Intracerebral hemorrhage (ICH) accounts for 10%–15% of all strokes and is associated with significant morbidity and mortality.[1-4] Patients with ICH are affected by concomitant tissue infarction and increased intracranial pressure (ICP) from hemorrhagic mass effect, which negatively impacts neurologic outcomes.[5] In addition, intraventricular hemorrhage (IVH) is present in approximately 40% of patients with ICH and is associated with worse short- and long-term outcomes.[1-4,6,7]

The use of an external ventricular drain (EVD) provides simultaneous benefits of ICP monitoring, diversion of cerebrospinal fluid (CSF), and evacuation of intraventricular blood, when present.[8] Previous studies have demonstrated the positive impact of ICP monitoring and aggressive control of ICP in traumatic brain injuries.[9] In patients with primary IVH or intraventricular extension of an intraparenchymal hemorrhage, EVDs are associated with increased patient survival.[10,11] Although the placement of an EVD is considered a safe and life-saving procedure, reported rates of infection range from 0% to 22%,[12-17] and EVD-related hemorrhages range from 0% to 32.5%[18-23] Evidence-based criteria for the use of EVDs in ICH patients

Key words
- External ventricular drain
- Hemorrhagic stroke
- Intracerebral hemorrhage
- Stroke

Abbreviations and Acronyms
AUROC: Area under receiver operating curve
CI: Confidence interval
CSF: Cerebrospinal fluid
CT: Computed tomography
EVD: External ventricular drain
GCS: Glasgow coma scale
ICH: Intracerebral hemorrhage
ICP: Intracranial pressure
IVH: Intraventricular hemorrhage
mGraeb: Modified Graeb Score
mRS: Modified Rankin Scale
OR: odds ratio
VPS: Ventriculoperitoneal shunt

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with and without intraventricular extension have not reached consensus, and assessment of the impact of EVD use in the neurologic outcomes of these patients has been limited to small series reports. Although the role of ICP monitoring in acute cerebrovascular injury has been reported extensively, most published studies are limited by nonstandardized indications for EVD placement and lack of control for confounding factors in patient selection.

Considering the vastly heterogeneous patient population affected by ICH, we hypothesized that EVD placement achieves variable therapeutic success resulting in mixed neurologic outcomes and that adequate patient selection can maximize its success while minimizing its potential complications. The present study retrospectively evaluated a large multi-institutional cohort of patients with primary ICH with and without IVH to determine the impact of EVD placement on patient morbidity and mortality and evaluates the ability of the propensity score analysis to identify subgroups attaining the greatest benefit.

METHODS

Study Population and Data Sources

All adult patients (N = 563) presenting with spontaneous ICH to a public safety net tertiary care academic hospital (Grady Memorial Hospital) and to a private tertiary care academic hospital (Emory University Hospital) from January 2010 to December 2014 were included in the present study. An emergent neurosurgery consult and evaluation was performed in all cases. Medical records, including clinical evaluations, imaging, procedure/operative notes, and follow-up data were reviewed retrospectively. All patient data used in the development of the model were gathered from patient charts in the medical record at initial presentation and evaluation. Cases were identified with a retrospective diagnosis-coded search, the *International Classification of Diseases*, Ninth Revision—coded search, for the diagnosis of "intracerebral hemorrhage," Diagnosis Code 431, which was audited and verified case-by-case for specificity by the authors. Patients with spontaneous ICH caused by hypertension, amyloid angiopathy, or idiopathic causes were included in the cohort. Patients with traumatic, neoplastic, venous sinus thrombosis, or vascular malformation—induced ICH were excluded based on results of computed tomography (CT) angiography and magnetic resonance imaging with or without angiography. The Emory University Institutional Review Board approved the study protocol, and compliance with the Health Insurance Portability and Accountability Act of 1996 was maintained at all times.

EVD Insertion and Management

Indication for the insertion of an EVD was determined by a constellation of 1 or more of the following signs or symptoms: occlusive hydrocephalus, presence of IVH, severe mass effect, Glasgow coma scale (GCS) ≤8, need for continuous ICP monitoring for an unreliable neurologic exam, or the administration of intraventricular thrombolytics. The decision to place an EVD was based on the presumed benefit to the patient if survival was likely (typically in patients with ICH scores of 0—3). Placement of an EVD in patients with "poor prognosis" ICH scores (4 or 5) was up to the discretion of the treating neurosurgeon after discussion of risks, benefits, and possible complications of the procedure with the family.

All EVDs were inserted at the Kocher point into the frontal horn of the right lateral ventricle, unless it was obliterated by the hematoma, in which case a left frontal EVD was placed. In only 5 cases was it necessary to insert bilateral EVDs when severe "casting" of both lateral ventricles was present to insure CSF drainage. CSF was monitored every other day for infection by removing 2—3 mL of fluid from the patient and sending for culture. Intraventricular thrombolytics in the form of sterile tissue plasminogen activator were administered when significant obstruction of the third or fourth ventricle by IVH and treated according to the guidelines of the Clot Lysis Evaluation of Accelerated Resolution of Intraventricular Hemorrhage III (CLEAR III) Trial.[24]

Weaning of the EVD took place after the following patient conditions were met: improved neurologic exam without the need for ICP monitoring or normal ICP after at least 48 hours of monitoring without concomitant IVH, serial noncontrasted CT scans showing clearance of intraventricular blood, or resolution of ICH with relief of mass effect on the obstruction of CSF at the level of the foramen of Monro, cerebral aqueduct, or fourth ventricle. EVD height was raised progressively to a maximum height of 20 cm above the external acoustic meatus and then clamped for 24 hours. If patients tolerated the clamping without progressive headache, decline in neurologic exam, and sustained ICPs ≤20 for 24 hours, a confirmatory CT scan was obtained to prove ventricular stability and then removed. For patients in whom EVD weaning and removal was not possible, a ventriculoperitoneal shunt (VPS) was placed.

Study Variables and Outcomes

Presence of ICH and IVH were established with CT scan on presentation. ICH volume was calculated in cubic centimeters (cc) via the Cartesian ABC/2 method, where A is the greatest diameter on the largest hematoma slice, B is the hematoma diameter perpendicular to A, and C is the number of axial slices multiplied by slice thickness as validated in the literature.[25] The ICH Score and Modified Graeb Score (mGraeb) were calculated with the use of their respective algorithms as published in the literature.[3,6]

The primary outcomes were 30-day mortality and functional status on discharge via use of the modified Rankin Scale (mRS). mRS at discharge was chosen as a marker of short-term functional outcomes to best approximate the 30-day interval for mortality comparison and was extracted from neurologic exam, physical/occupational therapy, and rehabilitation documentation in the patient medical record. An mRS of 0—2 was considered a favorable functional outcome (functional independence) as described previously in the literature,[26-28] whereas a score of 3—5 was defined as functional dependence. Secondary outcomes of interest were complications of EVD use, including duration of EVD use, CSF infection and ventriculitis, and failure to wean the EVD requiring a definitive CSF-shunting procedure. Ventriculitis was defined as any positive CSF culture during the index hospital course.

Statistical Methods

Statistical analyses were conducted with SAS 9.3 (Cary, North Carolina, USA). Statistical significance was assessed at the 0.05