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Original Article

Endovascular management of external ventricular drain-associated cerebrovascular injuries

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Abstract

Background: Placement of external ventricular drains (EVDs) is a common, life-saving neurosurgical procedure indicated across a variety of settings. While advances have made the procedure quite safe, the potential for iatrogenic morbidity and mortality continues. We document our experience with the endovascular management of three pseudoaneurysms associated with EVD placement and discuss the endovascular treatment options for EVD-associated cerebrovascular injury.

Methods: We performed a retrospective analysis to identify all EVDs placed from 2008 through 2013 at our institution. In instances of EVD-associated cerebrovascular injury, all admission and subsequent radiographic studies were reviewed, including cerebral angiograms and computed tomography (CT) scans where available. Angiograms were reviewed to record the extent of vascular injury and outcomes after treatment.

Results: One female and two male patients (age range, 40-75 years) were found to have developed vascular injuries associated with EVD placement. Three pseudoaneurysms, of the posterior communicating artery (PCOM), pericallosal artery branch, and the middle meningeal artery, respectively, were treated by coil and/or glue embolization.

Conclusions: Although EVD-associated cerebrovascular injury remains a rare phenomenon, such procedures are not entirely benign. Endovascular repair for such lesions proves a viable, effective option.

Key Words: Cerebrovascular injury, endovascular repair, external ventricular drain, pseudoaneurysm

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INTRODUCTION

Placement of an external ventricular drain (EVD) is a common neurosurgical procedure, first described in the mid-18th century.[34] Subsequent efforts greatly advanced placement technique,[16] catheter material, and technology.[12] Indications for EVD placement include treatment or monitoring of increased intracranial pressure, including acute hydrocephalus, ventriculoperitoneal shunt (VPS) failure, traumatic brain injury, intraventricular hemorrhage, and subarachnoid hemorrhage (SAH)-associated hydrocephalus.[2,5,7,10,20]

Common complications of EVD placement include infection and shunt malfunction. Recent reports have also described subdural hematoma, seizures, and intracerebral or intraventricular hemorrhage.[11,17,24,27] EVD placement may predispose to rebleeding in patients with unprotected aneurysms,[26] and up to 41% of EVD insertions may produce detectable intracerebral hemorrhage.[8,35] However, very few reports of EVD-associated cerebrovascular injury exist. Documented lesions include arteriovenous fistulae (AVFs), consisting of six of dural[6,18] and one of pial[32] origin. Traumatic catheter-associated pseudoaneurysms have also been described in the literature in adult[1,18] and pediatric populations.[3,4,14,15] Herein, we share our experience with endovascular management of three pseudoaneurysms associated with EVD placement in adult patients.

MATERIALS AND METHODS

All patients in this study were treated in the neurosurgical and neurocritical care departments of a university level I trauma center. Patients had an EVD placed at the bedside at the outside transferring hospital or at the university hospital. Cerebral angiographic studies obtained after EVD placement were evaluated to identify EVD-associated vascular lesions. Angiograms were reviewed by OC, JJH, and HMD to record the extent of vascular injury and angiographic outcomes after treatment. This study was performed in accordance with institution-specific Internal Review Board policies.

Information presented in this study was extracted from clinical history, physical examination, operative reports, and follow-up records documented in patient electronic medical records. We performed retrospective data collection on three patients in whom EVD-associated vascular injury was suspected. All admission and subsequent radiographic studies were reviewed, including cerebral angiograms and computed tomography (CT) scans.

EVD placement

EVD placement was performed using standard techniques. Briefly, Kocher's point (11 cm from the nasion along the mid-pupillary line) was identified. The appropriate scalp area was shaved, prepped, and draped in a sterile fashion. The skin was then infiltrated with 1% lidocaine in 1:100,000 epinephrine solution. A 5-mm longitudinal incision was made down to the skull surface, and a burr hole was made using a hand drill. A spinal needle was then used to pierce the dura mater. The ventricular catheter was then passed perpendicular to the skull surface with a stylet in place. At a depth of 5.5 cm, the inner stylet was removed to check for cerebrospinal fluid. After clear cerebrospinal fluid was visualized, the drain was tunneled through the scalp and secured and the incision closed with nylon suture. A sterile dressing was then applied to the area and the ventricular catheter connected to the drainage outlet in a sterile fashion. Catheter position was confirmed by head CT after the procedure.

In two instances (cases 2 and 3 discussed below), the EVD associated with the vascular lesion was placed at an outside hospital prior to arrival at our institution. In both of these cases, outside imaging studies were obtained for comparison prior to intervention and reviewed in preparation of this report.

RESULTS

Patient population

Three patients were found to have EVD-associated vascular lesions as confirmed by intraoperative angiography and correlation with EVD placement. EVD placement was indicated as a therapeutic tool for treatment of hydrocephalus from SAH and as a monitoring tool for intracranial pressures. One female and two male patients (age range, 40-75 years) developed vascular injuries associated with EVD placement. EVDs were placed for the treatment of hydrocephalus following SAH or intracranial hemorrhage after tumor resection. All EVDs were placed via a right frontal burr hole. Clinical presentations are described in Table 1.

Case illustrations

Case 1

This patient experienced a sudden severe headache and syncope following rupture of a 5.5-mm bilobed anterior communicating artery aneurysm [Figure 1]. A right-sided EVD was placed prior to aneurysm repair given the presence of hydrocephalus on the presenting head CT. The aneurysm was subsequently treated by endovascular coil embolization. Intraoperative angiographic studies demonstrated active extravasation from the middle inferior frontal branch of the pericallosal artery with pseudoaneurysm formation, directly adjacent to the

Table 1: Clinical characteristics of patients presenting with external ventricular drain-associated vascular lesions

Case	Admission diagnosis	Vascular injury associated with EVD	Injured vessel	Management
1	Subarachnoid hemorrhage	Pseudoaneurysm	Pericallosal artery branch	Coil and glue embolization
2	Resection cavity hemorrhage and diffuse vasospasm	Pseudoaneurysm	PCOM	Coil embolization
3	Subarachnoid hemorrhage	Pseudoaneurysm and extravasation	MMA	Glue embolization

MMA: Middle meningeal artery; PCOM: Posterior communicating artery, EVD: External ventricular drain

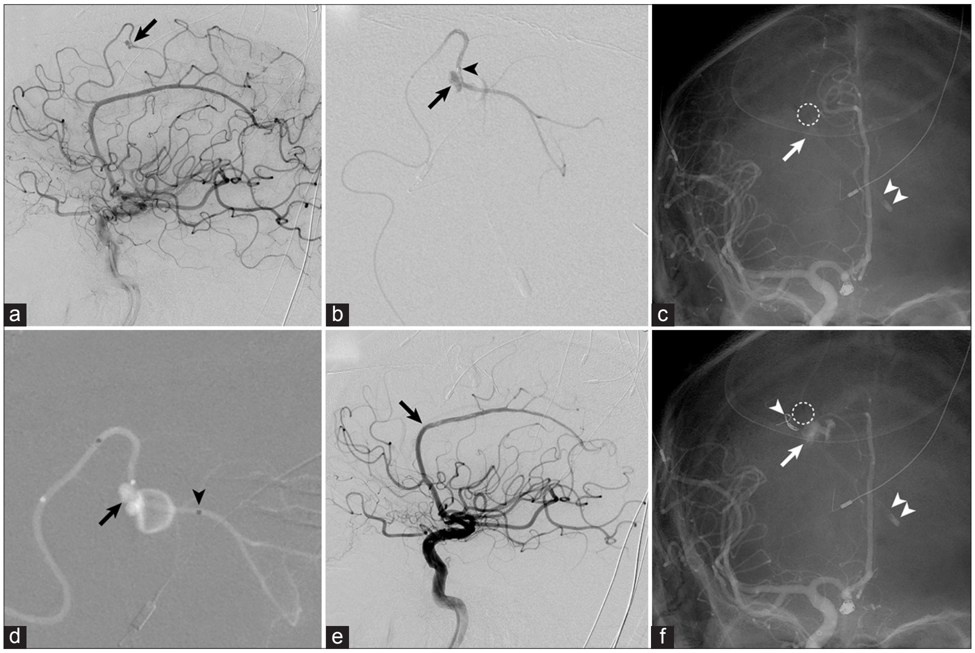

Figure 1: Angiographic findings with EVD-associated pericallosal artery branch injury. (a) Lateral projection angiographic image showing pseudoaneurysm formation (arrow) involving middle inferior frontal branch of pericallosal artery. (b) Microcatheter injection with microcatheter tip (arrowhead) just proximal to the pseudoaneurysm (arrow) in the pericallosal artery branch. (c) Unsubtracted anteroposterior (AP) view demonstrating the ventricular catheter trajectory and burr hole (dashed circle) in proximity to the site of pseudoaneurysm (arrow). The medial course of ventricular catheter is also illustrated with catheter tip (arrowheads) across the midline. (d) Roadmap view with microcatheter tip (arrowhead) past the pseudoaneurysmal segment (arrow). We coiled backward from this position across the aneurysmal segment. (e) Lateral projection angiographic image demonstrating successful embolization of the pseudoaneurysm and sacrifice of the pericallosal artery branch (arrow showing its prior expected origin). (f) Post-embolization unsubtracted AP angiographic image identifying the coil (arrowhead) across the pseudoaneurysmal segment having the glue embolic material (arrow)

ventricular catheter trajectory. A decision was made to treat the pseudoaneurysm via an endovascular approach. A microcatheter was passed into the inferior frontal branch of the pericallosal artery, and two Target 360 coils (Stryker, Kalamazoo, MI, USA) were used to occlude the vessel distally. Subsequently, 0.5 cc of 1:1 *n*-butyl cyanoacrylate (NBCA): Ethiodized oil mixture (Codman and Shurtleff, Raynham, MA, USA) was injected to completely occlude the middle inferior frontal branch. At the end of the procedure, no active contrast extravasation or pseudoaneurysm was visualized. The EVD was eventually converted to a VPS. Follow-up CT at 1 month confirmed integrity of the embolization. The patient suffered no adverse consequences as a result of embolization.

Case 2

The patient underwent endoscopic transsphenoidal resection of a pituitary adenoma at an outside hospital and postoperatively developed a resection cavity hemorrhage that required two operations for hematoma evacuation, with placement of a right frontal EVD to treat symptomatic hydrocephalus [Figure 2]. Of note, the EVD required multiple replacements due to repeated involuntary removal. Subsequent development of seizures and somnolence prompted follow-up CT scan, which revealed SAH and a large 1.1 cm × 8 mm pseudoaneurysm at the interface between the left posterior communicating artery (PCOM) and posterior cerebral artery (PCA), corresponding to the site of a previously placed EVD. Severe vasospasm of several major vessels was noted bilaterally. The patient was then transferred to our institution, where endovascular coil embolization of the pseudoaneurysm and PCOM sacrifice was performed using three Target 360 coils (Stryker). The coil embolization was stable upon follow-up imaging 1 day postoperatively. Endovascular vasospasm treatment was also performed, which markedly improved cerebral perfusion. The patient subsequently developed reperfusion injury in the right cerebral hemisphere with intracranial hemorrhage, requiring right hemicraniectomy. The patient did poorly, was placed on comfort care, and expired.

Case 3

This patient presented with a severe headache after rupture of a right PCOM aneurysm [Figure 3]. A right frontal EVD was placed at an outside hospital prior to transfer to our institution. Primary coil embolization of the PCOM aneurysm was carried out, and intraoperative angiography demonstrated laceration of the right middle meningeal artery (MMA) with an associated pseudoaneurysm in the path of the EVD. CT imaging demonstrated an associated small epidural hematoma without significant mass effect. The affected MMA was treated by endovascular embolization using a 1:3 mixture

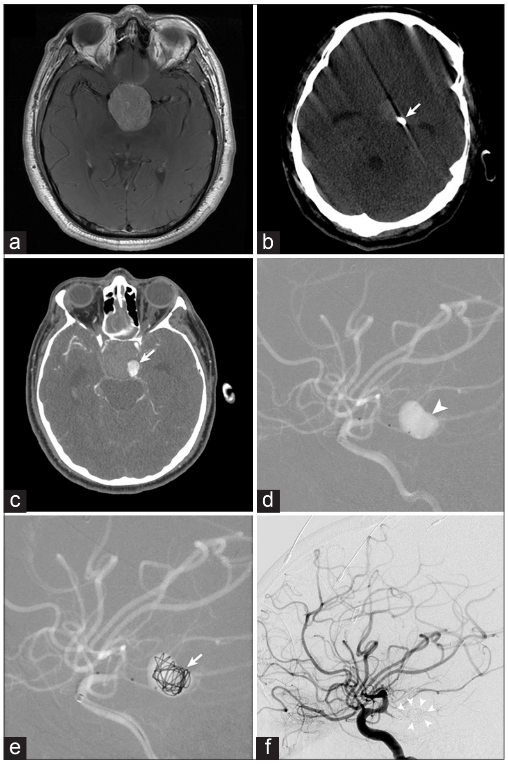

Figure 2: Imaging findings with EVD-associated PCOM pseudoaneurysm formation. (a) Axial post-contrast MR image showing suprasellar extension of an enhancing large pituitary adenoma. (b) Non-contrast head CT showing tip of microcatheter in the interpeduncular cistern. (c) CT angiogram axial image showing pseudoaneurysm formation at the junction of left PCOM and left PCA, corresponding with the site of anomalous EVD placement. (d) Roadmap lateral projection angiographic image identifying the large pseudoaneurysm (arrowhead) with Scepter balloon tip inside the pseudoaneurysm across the PCOM. (e) Roadmap lateral projection angiographic image with primary coil mass inside the pseudoaneurysm (arrow). (f) Post-embolization lateral projection angiographic image showing complete obliteration of pseudoaneurysm (arrowheads) and the parent PCOM has been coil-sacrificed

of NBCA: Ethiodized oil (Codman and Shurtleff), which terminated contrast extravasation from the lesion. Non-contrast head CTs at 9 and 13 days postoperatively verified coiling and hematoma stability. The EVD was subsequently converted to a VPS. The patient experienced no adverse consequences from embolization.

DISCUSSION

EVD placement is an essential, life-saving technique in the management of a number of neurosurgical emergencies. Although rare, vascular complications related to EVD placement do occur. Kosty *et al*. identified iatrogenic vascular injuries in 2.8% of patients in their institutional review of 299 ventriculostomies.[18] We describe three patients who developed pseudoaneurysms associated with EVD placement, and demonstrate that these lesions can be successfully treated with endovascular techniques [Table 1].

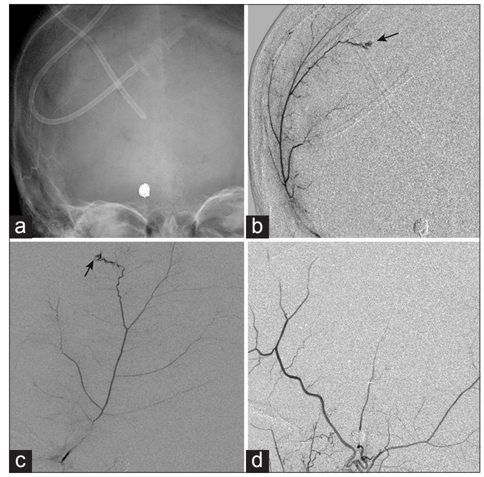

Figure 3: Angiographic findings of EVD-associated MMA injury. (a) Unsubtracted AP image showing the course of external ventricular drain traversing the MMA branch. (b) AP angiographic image with microcatheter injection showing pseudoaneurysm (arrow) at the site of MMA injury. (c) Lateral angiographic image with microcatheter injection showing contrast extravasation with associated pseudoaneurysm (arrow) at the site of MMA injury. (d) Post-embolization lateral angiographic image showing obliteration of MMA frontal and squamosal branch post-NBCA glue embolization

Identifying EVD-associated vascular injuries by cerebral angiogram is critical. Excessive bleeding during placement or evidence of hemorrhage on CT should raise suspicion for these lesions. Appropriate training and reinforcement of proper technique, in conjunction with technological aids, where available, can possibly reduce many of these complications. Stereotactic navigation and the Ghajar device are two tools that have been used to allow accurate placements of the EVD where appropriate.[9,21]

Ghajar pioneered an EVD placement technique with the catheter trajectory perpendicular to the skull surface.[25] Skin incision and burr hole placement is ideally 3 cm from the midline in the mid-pupillary line and 1 cm anterior to the coronal suture.[28] Following these landmarks minimizes the risk of vascular injury to the MMA, superficial temporal artery, and eloquent cortex;[6] however, poor burr hole localization or introduction at a variant angle risks vascular injury in the scalp, dural interface, pia, and large cortical vessels [Table 2].

The ideal course of an EVD is through the middle frontal gyrus, usually in the non-dominant hemisphere. The EVD should traverse the white matter tracts of the anterior cerebral artery (ACA)–middle cerebral artery (MCA) watershed area prior to entering the frontal horn of the ipsilateral lateral ventricle. Case 1 in our series illustrates that medial deviation of burr hole and catheter trajectory may cause injury to ACA branches, while posterior deviation risks injury to the supplementary motor area. Pseudoaneurysms arising from MCA branches after ventriculostomy catheter placement via a parietal

Table 2: Vascular injury associated with ventricular catheters: Reported cases

Vessels injured	Procedure	Pathology	Treatment	Author, year
Superficial temporal artery	EVD	Pseudoaneurysm	Surgical excision Conservative	Angevine and Connolly, 2002[1] Kosty *et al.*, 2013[18]
MMA	EVD	Dural AVF	Embolization	Kosty *et al.*, 2013[18]
Pial vessels	Ventriculostomy placement	Pial AVF	Surgical obliteration Spontaneous resolution	Field *et al.*, 2002[6] Schuette *et al.*, 2012[32] Kosty *et al.*, 2013[18]
ACA and branches	EVD placement	Pseudoaneurysm	Surgical trapping Embolization	Tubbs *et al.*, 2006[37] Horowitz *et al.*, 2005[14] Kosty *et al.*, 2013[18] Choudhri *et al.*, 2014
PCOM	EVD placement	Pseudoaneurysm	Coil sacrifice of parent vessel	Choudhri *et al.*, 2014
ICA/anterior choroidal artery	Removal of old ventricular catheter	Pseudoaneurysm	Surgical clipping	Shirane *et al.*, 1999[33]
MCA branches	VPS insertion	Pseudoaneurysm	Surgical trapping	Jenkinson *et al.*, 2006[15]

AVF: Arteriovenous fistula, ACA: Anterior cerebral artery, EVD: External ventricular drain, ICA: Internal carotid artery, MCA: Middle cerebral artery, VPS: Ventriculoperitoneal shunt

approach have been previously described.[15]

Monitoring ventricular catheter depth is important to limit the risk of injury to the vascular structures within the circle of Willis, and catheter placement with a depth greater than 6.5 cm should be avoided.[28] Case 2 illustrates how overly deep and posterior placement may result in PCOM pseudoaneurysm. Similar iatrogenic injury to the circle of Willis has been described after endoscopic third ventriculostomy.[13,23,29]

EVD placement may also cause dural or pial AV fistula formation.[6,18,32] Use of electrocautery in the achievement of hemostasis is well-established to minimize the risk of subsequent dural AVF iatrogenesis. However, EVD placement is often performed at the bedside where electrocautery may not be available for hemostasis, and injury of the pial veins may predispose to the formation of an AVF. These iatrogenic AVFs may initially be clinically silent, but can subsequently cause intraparenchymal hemorrhage or SAH.

Repair of EVD-induced cerebrovascular injury has been described in several prior studies;[3,4,6,14,15,19,22,30-33,36] however, management has primarily consisted of open surgical repair with very few documented cases of endovascular treatment [Table 1]. Even in the limited reports of endovascular treatment, the choice of embolization technique has varied widely. Kosty *et al*. described four patients who developed dural AVFs after EVD placement and were successfully treated with endovascular embolization using polyvinyl alcohol particles.[18] Field *et al*. employed microfibrillar collagen and endovascular coils to embolize a dural AVF in the middle meningeal vasculature.[6]

Only two cases of endovascular treatment for pseudoaneurysm secondary to EVD placement have been described. Horowitz *et al*. undertook vessel sacrifice with detachable platinum coils to treat an ACA pseudoaneurysm in an infant, with full recovery at 1-year follow up.[14] Kosty *et al*. successfully treated an ACA pseudoaneurysm using Onyx liquid embolic agent.[18] To our knowledge, we have presented the first report of a single institution undertaking independent successful use of both coil and glue embolization for any EVD-associated vascular injury, as well as the first report of combined coil and glue embolization of a pseudoaneurysm in this setting.

In conclusion, placement of EVDs and related devices may rarely be complicated by cerebrovascular injury. Endovascular repair of these iatrogenic lesions by coil and/or glue embolization proves to be a viable modality of treatment, without evidence of recurrence or long-term neurological insult. The wide variety of embolization modalities that have been successful suggests that endovascular treatment may play a critical role in averting high-risk open surgical intervention in this setting.

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