Original Article

Endovascular management of external ventricular drain-associated cerebrovascular injuries

Omar Choudhri, Mihir Gupta, Abdullah H. Feroze, Jeremy J. Heit, Huy M. Do

Departments of Neurosurgery and Radiology, Stanford University School of Medicine, Stanford, California 94305, USA

E-mail: *Omar Choudhri - ochoudhri@stanford.edu; Mihir Gupta - nose.mihir@gmail.com; Abdullah Feroze - aferoze@stanford.edu; Jeremy Heit - jheit@stanford.edu; Huy Do - huymdo@stanford.edu

*Corresponding Author

Received: 11 July 14   Accepted: 22 September 14  Published: 29 November 14

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

INTRODUCTION

Placement of an external ventricular drain (EVD) is a common neurosurgical procedure, first described in the mid-18th century. Subsequent efforts greatly advanced placement technique, catheter material, and technology. 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.
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.\[^{8,15}\] 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\[^{12}\] origin. Traumatic catheter-associated pseudoaneurysms have also been described in the literature in adult\[^{11,18}\] 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...
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 transphenoidal 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
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].

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; 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
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. 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.

EVD placement may also cause dural or pial AV fistula formation. 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; 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. Field et al. employed microfibrillar collagen and endovascular coils to embolize a dural AVF in the middle meningeal vasculature.

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. Kosty et al. successfully treated an ACA pseudoaneurysm using Onyx liquid embolic agent. 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.

ACKNOWLEDGMENT

The authors wish to thank Cindy H. Samos for assistance with preparation of the manuscript.

REFERENCES

1. Angevine PD, Connolly ES Jr. Pseudoaneurysms of the superficial temporal artery secondary to placement of external ventricular drainage catheters. Surg Neurol 2002;58:258-60.
2. Brain Trauma Foundation; American Association of Neurological Surgeons; Congress of Neurological Surgeons; Joint Section on Neurotrauma and Critical Care, AANS/CNS, Bratton SL, Chestnut RM, Ghajar J, McConnell Hammond FF, Harris OA, Hard R, et al. Guidelines for the management of severe traumatic brain injury. VI. Indications for intracranial pressure monitoring. J Neurotrauma 2007;24 Suppl 1:S37-44.
3. Brownlee RD, Dold ON, Myles ST. Intraventricular hemorrhage complicating ventricular catheter revision: Incidence and effect on shunt survival. Pediatr Neurosurg 1995;22:315-320.
4. Desai K, Nadkarni T, Muzumdar D, Goel A. Rupture of a giant posterior inferior cerebellar artery aneurysm in an infant following a ventriculoperitoneal shunt. Case report. Neurol Med Chir (Tokyo) 2001;41:127-30.
5. Dey M, Jaffe J, Stadnik A, Awad IA. External ventricular drainage for intraventricular hemorrhage. Curr Neurol Neurosci Rep 2012;12:24-33.

6. Field M, Branstetter BF 4th, Levy E, Yonas H, Jungreis CA. Dural arteriovenous fistula after ventriculostomy. Case illustration. J Neurosurg 2002;97:227.

7. Gaberel T, Magheru C, Emery E. Management of non-traumatic intraventricular hemorrhage. Neurosurg Rev 2012;35:485-94.

8. Gardner PA, Engle J, Attebery D, Moossy J. Hemorrhage rates after external ventricular drain placement. J Neurosurg 2009;110:1021-5.

9. Ghajar JB. A guide for ventricular catheter placement. Technical note. J Neurosurg 1985;63:985-6.

10. Gigante P, Hwang BY, Appelboom G, Kellner MA, Bellinger DL, Kellner CP. External ventricular drainage following aneurysmal subarachnoid hemorrhage. J Neurosurg 2010;120:625-32.

11. Gutierrez-Gonzalez R, Boto GR, Perez-Zamarron A. Cerebrospinal fluid diversion devices and infection. A comprehensive review. Eur J Clin Microbiol Infect Dis 2012;31:889-97.

12. H. Tillmanns. Something about puncture of the brain. BMJ 1908;2:983-4.

13. Horowitz M, Albright AL, Jungreis C, Levy EI, Stevenson K. Endovascular management of a basilar artery false aneurysm secondary to endoscopic third ventriculostomy: Case report. Neurosurgery 2001;49:1461-4.

14. Horowitz M, Sharts M, Levy E, Albright AL, Pollack I. Endovascular management of ventricular catheter-induced anterior cerebral artery false aneurysm: Technical case report. Neurosurgery 2005;57:E374.

15. Jenkinson MD, Basu S, Broome JC, Eldridge PR, Buxton N. Traumatic cerebral aneurysm formation following ventriculoperitoneal shunt insertion. Childs Nerv Syst 2006;22:193-6.

16. Keen WW. Surgery of the lateral ventricles of the brain. Lancet 1890;136:553-5.

17. Kim JH, Desai NS, Ricci J, Stieg PE, Rosengart AJ, Hartl R, et al. Factors contributing to ventriculostomy infection. World Neurosurg 2012;77:135-40.

18. Kosty J, Pukenas B, Smith M, Storm PB, Zager E, Stiefel M, et al. Iatrogenic vascular complications associated with external ventricular drain placement: A report of 8 cases and review of the literature. Neurosurgery 2013;72 (2 Suppl Operative):ons208-213.

19. Kuwamura K, Kokunai T. Intraventricular aneurysm secondary to a ventriculoperitoneal shunt. Neurosurgery 1982;10:384-6.

20. Li LM, Timofeev I, Czosnyka M, Hutchinson PJ. Review article: The surgical approach to the management of increased intracranial pressure after traumatic brain injury. Anaesth Intensive Care 2010;38:736-48.

21. Mahan M, Spetzler RF, Nakaji P. Electromagnetic stereotactic navigation for external ventricular drain placement in the intensive care unit. J Clin Neurosci 2013;20:1718-22.

22. Matsumura A, Shinohara A, Munekata K, Maki Y. Delayed intracerebral hemorrhage after ventriculoperitoneal shunt. Surg Neurol 1985;24:503-6.

23. McLaughlin MR, Wahlig JB, Kaufmann AM, Albright AL. Traumatic basilar aneurysm after endoscopic third ventriculostomy: Case report. Neurosurgery 1997;41:1400-3.

24. Misaki K, Uchiyama N, Hayashi Y, Hamada J. Intracerebral hemorrhage secondary to ventriculoperitoneal shunt insertion-four case reports. Neurol Med Chir (Tokyo) 2010;50:76-9.

25. O’Leary ST, Kole MK, Hoover DA, Hysell SE, Thomas A, Shaffrey CL. Efficacy of the Ghajar Guide revisited: A prospective study. J Neurosurg 2000;92:801-3.

26. Pare L, Delfino R, Leblanc R. The relationship of ventricular drainage to aneurysmal rebleeding. J Neurosurg 1992;76:422-7.

27. Quigley MR, Reigel DM, Kortyna R. Cerebrospinal fluid shunt infections. Report of 41 cases and a critical review of the literature. Pediatr Neurosurg 1989;15:111-20.

28. Rehman T, Rehman Au, Ali R, Rehman A, Bashir H, Ahmed Bhimani S, et al. A radiographic analysis of ventricular trajectories. World Neurosurg 2013;78:173-8.

29. Rezende MT, Spelle L, Piotin M, Mouneyer C, Lucas Cde P, Abud DG, et al. Selective endovascular treatment of a traumatic basilar aneurysm after endoscopic third ventriculostomy. Neuroradiology 2008;50:443-6.

30. Savitz MH, Bobroff LM. Low incidence of delayed intracerebral hemorrhage secondary to ventriculoperitoneal shunt insertion. J Neurosurg 1999;91:32-4.

31. Schroeder HW, Niendorf WR, Schweginger G, Gaab MR. Fatal tumor hemorrhage after ventriculoperitoneal shunting: Case report. Neuropediatrics 1995;26:177-9.

32. Schuette AJ, Blackburn SL, Barlow DL, Cawley CM. Pial arteriovenous fistula resulting from ventriculostomy. World Neurosurg 2012;77:785 e1-2.

33. Shirane R, Kondo T, Yoshida YK, Furuta S, Yoshimoto T. Ruptured cerebral pseudoaneurysm caused by the removal of a ventricular catheter: Case report. J Neurosurg 1999;91:1031-3.

34. Srinivasan VM, O’Neill BR, Jho D, Whiting DM, Oh MY. The history of external ventricular drainage. J Neurosurg 2014;120:228-36.

35. Sundbarg G, Nordstrom CH, Soderstrom S. Complications due to prolonged external ventricular drain placement. J Neurosurg 2009;110:1021-5.

36. Suri A, Pandey P, Mehta VS. Subarachnoid hemorrhage and intracerebral aneurysm following lumboperitoneal shunt for pseudotumor cerebri: A rare complication. Neuroradiology 2002;50:508-10.

37. Tubbs RS, Acakpo-Satchivi L, Blount JP, Oakes WJ, Wellons JC 3rd. Pericallosal artery pseudoaneurysm secondary to endoscopic-assisted ventriculoperitoneal shunt placement. Case report. J Neurosurg 2006;105 (2 Suppl):S140-2.