Neuroimaging

Occlusion of a clival dural arteriovenous fistula using a novel approach through the foramen ovale

Alfonso Urdaneta-Moncada,¹ Lei Feng,^{1,2} Joseph Chen²¹Diagnostic Radiology, Kaiser Permanente—Los Angeles Medical Center, Los Angeles, California, USA²Department of Neurosurgery, Kaiser Permanente Medical Center, Los Angeles, California, USA

Correspondence to Dr Alfonso Ricardo Urdaneta-Moncada, Alfonso.R.Urdaneta@kp.org

Summary

Dural arteriovenous fistulas (DAVFs) are abnormal connections between arteries and veins that are classified by location, morphology or direction of venous drainage. Treatment of DAVFs is undertaken in patients with severe symptoms or those with retrograde cortical venous drainage and/or venous ectasia. Much is written regarding the treatment of DAVFs involving the transverse sigmoid sinuses, cavernous sinus and tentorium, but little is written concerning the treatment of clival DAVFs. We demonstrate a novel transforaminal percutaneous approach through the foramen ovale as a viable method to occlude a clival vein. Specialised software was used to create a safe trajectory to the DAVF via the foramen ovale. The patient then underwent successful occlusion of the clival DAVF, thus further increasing the neurointerventionalist's armamentarium when attempting to treat difficult to reach clival DAVFs.

BACKGROUND

Dural arteriovenous fistulas (DAVFs) are abnormal connections between arteries and veins in the dura mater that account for 10–15% of all intracranial arteriovenous malformations.^{1–4} The nidus that results in DAVFs arises from previous head trauma, cranial surgery, dural sinus or cortical venous thrombosis, previous infections or tumours.^{5–8} DAVFs are classified by location, morphology or direction of venous drainage.^{5–9–13} The important features associated with morbidity and mortality are the presence of retrograde cortical venous drainage and venous ectasia.^{2–5–9–11–13} The decision to treat a DAVF depends on its signs, symptoms and classification. Patients with mild symptoms and without evidence of retrograde cortical venous drainage can be managed expectantly, while those with severe symptoms or with retrograde cortical venous drainage and/or venous ectasia require surgical resection or endovascular therapy.

There is ample literature regarding the treatment of DAVFs of the transverse sigmoid sinuses, cavernous sinus and tentorium.^{2–14–16} Literature involving the treatment of DAVFs arising within the anterior cranial fossa, straight sinus, posterior fossa, inferior petrosal sinus, superior petrosal sinus, marginal sinus and deep venous system involve mostly case reports.^{13–16–20} There is sparse literature concerning treatment of DAVFs involving the clivus.

The clivus is a part of the cranium behind the dorsum sellae that slopes obliquely backwards. The blood supply to the interconnected venous plexus within the clivus is variable and can derive from branches of both the internal and external carotid arteries. This complexity requires that a neurointerventionalist closely examines the angioarchitecture to determine the best route for treatment since occlusion of a receiving sinus without occlusion of the nidus can direct flow into other sinuses or cortical veins. A case series by Viñuela *et al*¹² found that the optimal treatment was transarterial embolization

through the clival branches of the ascending pharyngeal artery without need for occlusion of the cavernous sinus.¹³

CASE PRESENTATION

A 69-year-old right-handed woman with dilated cardiomyopathy presented with 9 months of progressive proptosis, chemosis, ophthalmoplegia and visual loss in the right eye. She had initially been seen by an ophthalmologist and received treatment for suspected glaucoma. When the symptoms did not improve with eye drops and steroids, the patient underwent a CT angiogram of the head and neck, MRI of the brain and a cerebral angiogram at an outside hospital and was found to have a DAVF.

INVESTIGATIONS

Cerebral angiography at our hospital demonstrated a high-grade clival DAVF near the left posterior clinoid process supplied by meningeal branches of the bilateral meningohypophyseal trunks with minimal contribution from the bilateral external carotid artery (ECA) branches (figure 1A,B).

The receiving veins travelled through the dorsum of the clivus to the right side, connecting to the cortical veins and right superior ophthalmic vein (SOV) through small dural channels. The right cavernous sinus, right facial vein and bilateral inferior petrosal sinuses were occluded (figure 2). The left cavernous sinus was patent but did not receive any drainage from the clival DAVF.

TREATMENT

As there was no direct access to the left clival vein, an attempt was made to recanalize the left inferior petrosal sinus via the left internal jugular vein. A Marathon catheter was advanced to about 2 mm from the venous pouch receiving the arteriovenous shunt but no channel to the fistula could be found by venography or by probing with microguidewires.

Figure 1 (A) Anteroposterior and (B) lateral right internal carotid artery injection demonstrating a clival dural arteriovenous fistula (DAVF) dorsal and medial to the Meckle's cave. The clival DAVF was supplied by bilateral meningohipophyseal trunks with small collateral supplies from the bilateral middle meningeal arteries.

Onyx-34 was injected with the plug-and-push technique in the hope that the high pressure would open a channel to the venous pouch, but this was unsuccessful. Various right facial vein branches were then catheterized without evidence of connection to the right SOV. Direct puncture of the right SOV was considered a poor approach as there was a severe stenosis at the junction of the right SOV with the clival veins. It was deemed too difficult to navigate a microcatheter from the right SOV to the left clival vein to treat the fistula. Occlusion of the right SOV alone could alleviate her eye symptoms but would increase the risk of intracranial hemorrhage by forcing all the venous drainage to the cortical veins.

Transarterial embolization was then attempted. The meningohipophyseal trunks of the bilateral internal carotid arteries (ICAs) were catheterized and embolized

Figure 2 Right internal carotid artery injection, early venous phase, demonstrating the clival fistula vein (arrowhead), cortical venous reflux to the preseptal region (open arrow) and reflux to the right superior ophthalmic vein (solid arrow) through small invisible channels in the wall of the right cavernous sinus. The right cavernous sinus is occluded. The fistula had no communication with the left cavernous sinus. Although the fistula was on the left side, this peculiar venous drainage pattern explained the patient's right eye symptoms.

with Onyx-34. Post-embolization angiograms demonstrated marked reduction of arteriovenous shunting, although residual arteriovenous shunting was noted from the recurrent lacerum branch of the left ICA and small dural branches of the bilateral middle meningeal arteries.

Figure 3 Three-dimensional reconstruction of 0.6 mm axial images of CT angiogram using the Brainlab iPlan 4.1 workstation. The left foramen ovale (purple), cavernous carotid artery (red) and targeted residual dural arteriovenous fistula (DAVF) (opal) were manually contoured on axial images. The iPlan software was then used to perform a surface segmentation. The image was manipulated to superimpose the foramen ovale over the DAVF target.

The procedure was terminated and the patient was observed to see if the rest of the fistula would progress to complete thrombosis. When her symptoms persisted, she was brought back 1 month later for embolisation of the left middle meningeal artery.

The anterior division of the left middle meningeal artery was catheterized. The orbital branches were protected with a detachable coil. An Echelon-10 catheter was placed into the origin of a dural branch that ran posteriorly along the lateral wall of the left cavernous sinus to the fistula and Onyx-34 was injected with the plug-and-push technique. As Onyx was just approaching the site of the

fistula, reflux into the orbital vessels including the left ophthalmic artery was noted. The procedure was stopped and the patient was kept on heparin and started on intravenous abciximab. Acetazolamide was added after the procedure to reduce intraocular pressure and, after 2 days, the patient was switched to aspirin and warfarin. With these treatments, vision was preserved in her left eye.

After 1 month the patient demonstrated some improvement in her right ptosis and chemosis but she continued to have ophthalmoplegia and minimal vision in her right eye. As transarterial embolization failed to cure the fistula and alleviate her symptoms, we explored the options of percutaneous access to the recipient vein.

Her original CT angiogram was uploaded to a radiosurgery planning workstation and the 0.6 mm axial images were transferred to a Brainlab iPlan 4.1 workstation (Brainlab AG, Heimstetten, Germany). The left foramen ovale, cavernous carotid artery and targeted residual DAVF were manually contoured on axial images. The iPlan software was used to perform a surface segmentation and to superimpose the foramen ovale over the DAVF target (figure 3). This demonstrated a safe trajectory to the DAVF via the foramen ovale.

The patient was brought back for the third treatment under general anesthesia. A three-dimensional rotational angiogram of left ICA injections was obtained and reconstructed to CT format to select the angle to align the anteroposterior (AP) projection with the trajectory from the left foramen ovale to the DAVF. The left ICA was placed medial to the foramen ovale on the AP projection and the lateral view was used to determine the depth of the needle. A 20 gauge 6 inch spinal needle was inserted through the left foramen ovale into the left Meckel's cave and then into the venous pouch under biplane digital subtraction road mapping (figures 4 and 5). A venogram was performed to confirm the needle position after the target vein was reached on both AP and lateral views and there

Figure 4 (A) Left anterior oblique angiographic road map demonstrating the clival fistula vein lateral to the left internal carotid artery. A 20 gauge spinal needle is seen through the foramen ovale with the tip terminating in the clival fistula vein. The position of the needle tip is confirmed on the lateral view (B). Onyx from prior embolization is seen in the left inferior petrosal sinus, bilateral meningohypophyseal trunks and left orbital and ophthalmic arteries from the left middle meningeal injection.

Figure 5 Left anterior oblique digital subtraction angiogram through the 20 gauge spinal needle demonstrating the clival fistula pouch.

Figure 6 (A) Anteroposterior and (B) lateral radiographs demonstrating Onyx cast in the fistula.

was blood return from the needle. The fistula was embolized with Onyx-34 until reflux was seen in the main feeding artery (figure 6).

OUTCOME AND FOLLOW-UP

A post-embolization angiogram showed complete obliteration of arteriovenous shunting. The patient had immediate improvement in her eye symptoms after the procedure. Her proptosis, ophthalmoplegia and chemosis completely resolved within 2 months and she recovered most of the vision in her right eye. A follow-up angiogram at 3 months showed durable occlusion of the DAVF (figure 7).

DISCUSSION

The clival dura has a complex blood supply,^{13 21–23} making transarterial embolization of limited effectiveness and high risk. Although the meningohypophyseal trunks

Figure 7 Three-month follow-up right (A) and left (B) internal carotid artery injection demonstrating durable occlusion of the clival dural arteriovenous fistula.

of the ICAs were embolized in this case, the inability to penetrate the fistula with Onyx allowed for the recruitment of secondary feeder vessels. Embolization of these dural branches with Onyx using plug-and-push techniques carries a high risk of ischemic cranial nerve palsies or inadvertent occlusion normal cerebral arteries.^{24–27} The patient in this case was fortunate to preserve her vision despite occlusion of her left ophthalmic artery, probably because of collateral vessels that developed in the presence of the DAVE.

Treatment of clival DAVFs can be directed at cure or symptom relief. If the clival vein or the connecting venous sinus can be catheterized via the arterial or venous routes, curative therapy may be considered. Palliative transarterial embolization may be considered in cases without access to the clival vein. The various supplies to the cranial nerves and anastomosis with the cerebral arteries must be kept in mind when performing transarterial

embolization to minimize complications. Embolization of venous sinuses without occlusion of the clival vein should be avoided.

The transforaminal approach has been used by neurosurgeons to access the temporal lobe in epilepsy, to treat trigeminal neuralgia or to biopsy cavernous sinus tumors.^{28–31} The foramen ovale is a bony defect in the base of the skull that allows for the accessory meningeal artery, small venous plexus and the mandibular branch of the trigeminal nerve to pass through the skull.^{28–29} It opens into the Meckel's cave intracranially. The medial wall of the Meckel's cave is the clivus and its roof is the inferior lateral wall of the posterior cavernous sinus. Using CT angiography and stereotactic localisation software, a trajectory to the cavernous sinus and clival veins may be obtained without violating vital structures such as the ICA. Once a needle is placed into the target vein, a DAVF in this region can be treated with Onyx embolization.

Complications from using a percutaneous foramen ovale route are described in the literature and include dysesthesias; transient bradycardia; carotid-cavernous fistula; ICA, middle meningeal artery or maxillary artery puncture; aneurysm formation; cranial nerve II, III, IV injury; or hemorrhage.²⁸ Many of these risks can be avoided or reduced when a rotational angiogram with CT reconstruction is used for intraoperative imaging guidance.

A review of the literature did not reveal any case studies or case series in which the foramen ovale was traversed in order to directly puncture the venous pouch of a DAVE. The successful occlusion of the clival vein using a transcatheter foramen ovale approach increases the neurointerventionalist's armamentarium when attempting to treat clival and posterior cavernous sinus DAVFs.

Learning points

- ▶ Clival dural arteriovenous fistulas (DAVFs) usually involve aberrant connections between branches of the ascending pharyngeal and internal carotid arteries and the clival venous plexus.
- ▶ Although connections to the cavernous, inferior petrosal and superior petrosal sinuses may arise, the clival DAVF is a separate entity.
- ▶ Percutaneous embolization via the foramen ovale is safe and feasible in treating clival DAVF.

Contributors LF and JC did the planning for and performed the surgeries and also assisted in editing the manuscript. AU assisted with the surgeries and wrote and edited the manuscript.

Competing interests None.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. Kim MS, Han DH, Kwon OK, et al. Clinical characteristics of dural arteriovenous fistula. *J Clin Neurosci* 2002;**9**:147–55.
2. Cognard C, Gobin YP, Pierot L. Cerebral dural arteriovenous fistulas: clinical and angiographic correlation with a revised classification of venous drainage. *Radiology* 1995;**194**:671–80.
3. Davies MA, Terbrugge K, Willinsky R, et al. The validity of classification for the clinical presentation of intracranial dural arteriovenous fistulas. *J Neurosurg* 1996;**85**:830–7.
4. Kiyouse H, Hori Y, Okahara M, et al. Treatment of intracranial dural arteriovenous fistulas: current strategies based on location and hemodynamics, and alternative techniques of transcatheter embolization. *Radiographics* 2004;**24**:1637–53.
5. Haithcock JA, Pride GL. Dural arteriovenous fistulas: review of imaging findings and endovascular treatment strategies. *Neurographics* 2011;**01**:31–8.
6. Chaudhary MY, Sachdev VP, Cho SH. Dural arteriovenous malformation of the major venous sinuses: an acquired lesion. *Am J Neuroradiol* 1982;**3**:13–19.
7. Sakaki T, Morimoto T, Nakase H. Dural arteriovenous fistula of the posterior fossa developing after surgical occlusion of the sigmoid sinus: report of five cases. *J Neurosurg* 1996;**84**:113–18.
8. Horinaka N, Nonaka Y, Nakayama T. Dural arteriovenous fistula of the transverse sinus with concomitant ipsilateral meningioma. *Acta Neurochir* 2003;**145**:501–04.
9. Awad I, Little J, Akrawi W, et al. Intracranial dural arteriovenous malformations: factors predisposing to an aggressive neurological course. *J Neurosurg* 1990;**72**:839–50.
10. Borden JA, Wu JK, Shucart WA. A proposed classification for spinal and cranial dural arteriovenous fistulous malformations and implications for treatment. *J Neurosurg* 1995;**82**:166–79.
11. Lasjaunias P, Chiu M, ter Brugge K, et al. Neurological manifestations of intracranial dural arteriovenous malformations. *J Neurosurg* 1986;**64**:724–30.
12. Viñuela F, Fox AJ, Pelz DM, et al. Unusual clinical manifestations of dural arteriovenous malformations. *J Neurosurg* 1986;**64**:554–8.
13. Shi ZS, Ziegler J, Gonzalez NR, et al. Transarterial embolization of clival dural arteriovenous fistulae using liquid embolic agents. *Neurosurgery* 2008;**62**:408–15.
14. Debrun GM, Viñuela F, Fox AJ, et al. Indications for treatment and classification of 132 carotid-cavernous fistulas. *Neurosurgery* 1988;**22**:285–9.
15. Halbach VV, Higashida RT, Hieshima GB, et al. Transvenous embolization of dural fistulas involving the transverse and sigmoid sinuses. *Am J Neuroradiol* 1989;**10**:385–92.
16. Malek AM, Halbach VV, Dowd CF, et al. Diagnosis and treatment of dural arteriovenous fistulas. *Neuroimaging Clin N Am* 1988;**8**:445–68.
17. Arat A, Inci S. Treatment of a superior sagittal sinus dural arteriovenous fistula with Onyx: technical case report. *Neurosurgery* 2006;**59**(Suppl 1):169–70.
18. Barnwell SL, Halbach VV, Dowd CF, et al. Dural arteriovenous fistulas involving the inferior petrosal sinus: angiographic findings in six patients. *Am J Neuroradiol* 1990;**11**:511–16.
19. Kincaid PK, Duckwiler GR, Gobin YP, et al. Dural arteriovenous fistula in children: Endovascular treatment and outcomes in seven cases. *Am J Neuroradiol* 2001;**22**:1217–25.
20. McDougall CG, Halbach VV, Dowd CF, et al. Dural arteriovenous fistulas of the marginal sinus. *Am J Neuroradiol* 1997;**18**:1565–72.
21. Martins C, Yasuda A, Campero A, et al. Microsurgical anatomy of the dural arteries. *Neurosurgery* 2005;**56**(Suppl 2):S211–51.
22. Ayberk G, Ozveren MF, Aslan S, et al. Subarachnoid, subdural and interdural spaces at the clival region: an anatomical study. *Turk Neurosurg* 2011;**21**:372–7.
23. Ozveren MF, Uchida K, Aiso S, et al. Meningovenous structures of the petroclival region: clinical importance for surgery and intravascular surgery. *Neurosurgery* 2002;**50**:829–36.
24. Liu HM, Huang YC, Wang YH, et al. Transarterial embolisation of complex cavernous sinus dural arteriovenous fistulae with low-concentration cyanoacrylate. *Neuroradiology* 2000;**42**:766–70.
25. Nelson PK, Russell SM, Woo HH, et al. Use of a wedged microcatheter for curative transarterial embolization of complex intracranial dural arteriovenous fistulas: Indications, endovascular technique, and outcome in 21 patients. *J Neurosurg* 2004;**98**:498–506.
26. Rezende MT, Piotin M, Mounayer C, et al. Dural arteriovenous fistula of the lesser sphenoid wing region treated with Onyx: technical note. *Neuroradiology* 2006;**48**:130–4.
27. Iizuka Y, Maehara T, Hishii M, et al. Successful transarterial glue embolisation by wedged technique for a tentorial dural arteriovenous fistula presenting with a conjunctival injection. *Neuroradiology* 2001;**43**:677–9.
28. Tubbs RS, Dixon J, Loukas M, et al. Regional vascular relationships to the foramen ovale: an anatomical study with application to approaches to the external skull base with an emphasis on transcatheter procedures for the treatment of trigeminal neuralgia. *J Neurosurg* 2010;**113**:493–7.
29. Kaplan M, Erol FS, Ozveren MF, et al. Review of complications due to foramen ovale puncture. *J Clin Neurosci* 2007;**14**:563–8.
30. Bowsher D. Trigeminal neuralgia: an anatomically oriented review. *Clin Anat* 1997;**10**:409–15.
31. Sindou M, Chavez JM, Pierre Saint G, et al. Percutaneous biopsy of cavernous sinus tumors through the foramen ovale. *Neurosurgery* 1997;**40**:106–11.

Copyright 2012 BMJ Publishing Group. All rights reserved. For permission to reuse any of this content visit <http://group.bmj.com/group/rights-licensing/permissions>.

BMJ Case Report Fellows may re-use this article for personal use and teaching without any further permission.

Please cite this article as follows (you will need to access the article online to obtain the date of publication).

Urdaneta-Moncada A, Feng L, Chen J. Occlusion of a clival dural arteriovenous fistula using a novel approach through the foramen ovale. *BMJ Case Reports* 2012;10.1136/bcr-2012-010475, Published XXX

Become a Fellow of BMJ Case Reports today and you can:

- ▶ Submit as many cases as you like
- ▶ Enjoy fast sympathetic peer review and rapid publication of accepted articles
- ▶ Access all the published articles
- ▶ Re-use any of the published material for personal use and teaching without further permission

For information on Institutional Fellowships contact consortiasales@bmjgroup.com

Visit casereports.bmj.com for more articles like this and to become a Fellow