Endovascular Treatment and Computed Imaging Follow-up of 14 Anterior Condylar Dural Arteriovenous Fistulas

YU-HONE HSU[1], CHUNG-WEI LEE[2], HON-MAN LIU[2,3], YAO-HUNG WANG[2], YA-FANG CHEN[2]

[1] *Department of Neurosurgery, Cheng-Hsin General Hospital; Taipei, Taiwan*
[2] *Department of Medical Imaging,* [3] *Department of Radiology, National Taiwan University Hospital; Taipei, Taiwan*

Key words: hypoglossal canal, anterior condylar vein, arteriovenous fistula, clivus, endovascular treatment, coiling

Summary

We report our experience in treating the anterior condylar dural arteriovenous fistula (DAVF) and confirm the location of the coils in the follow-up images after successful endovascular treatment.

We retrospectively reviewed the 14 patients with anterior condylar DAVF treated successfully in our institute. Twelve of them had CT or MR follow-up images. All the patients had intravascular coiling of the fistula. Seven of our patients had retrograde drainage to different sinuses. Three had ocular symptoms as a clinical manifestation. We treated nine patients with coils alone (eight transvenous, one transarterial), four with adjuvant transarterial treatment with particles or liquid embolic for minimal residual after coiling packing. One patient had failed onyx treatment and successful treatment by following transvenous packing. All patients had total obliteration of the DAVF fistula on immediate post-procedure angiogram or on the follow-up images and no evidence of recurrence clinically. The mean follow-up period was 34.2 months (standard deviation=39.8). Twelve patients had computed images (CT alone in four, MR alone in five, both CT and MR in three). These findings were analyzed by four certified neuroradiologists. We found 100% of the coils at the anterior condylar veins inside the hypoglossal canal, 54.2% at the lateral lower clivus, and only 14.2% at the anterior condylar confluence which is ventrolateral to the anterior orifice of the hypoglossal canal.

Intravascular coiling is the treatment of choice in patients with anterior condylar DAVF. All the coils were found at the anterior condylar veins inside the hypoglossal canal after successful treatment.

Introduction

Intracranial dural arteriovenous fistulas (DAVFs) are shunts between the meningeal arteries and intracranial dural sinus, subarachnoid veins, or cortical veins. The incidence of DAVF is 0.16 per 100,000 persons per year in the adult population, and they accounts for 10%-15% of all intracranial shunts [1]. The clinical features of DAVF are closely related to its venous drainage pattern. A DAVF without cortical venous reflux usually has a benign course, but those with reflux into the cortical vein or perimedullary venous plexus are considered aggressive lesions because they might give rise to clinical features such as focal neurological deficit, intracranial hemorrhage, myelopathy, or dementia. The nomenclature of the DAVF is usually based on the location of the sinus or affected veins where the shunting occurred. Inside the hypoglossal canal, vascular structures include a meningeal branch of the ascending pharyngeal artery and the anterior condylar vein. We defined anterior condylar DAVF as shunting occurring inside the hypoglossal canal. Anterior condylar DAVF is rare and its shunting occurs entirely within the skull base and the venous drainage usually does not involve the dural sinuses. The inci-

Table 1 **Demography, clinical course, angioarchitecture, treatment, and follow-up images of 14 patients with hypoglossal dural arteriovenous fistula.**

No.	Side	Symptom	DOS (m)	Feeding arteries	Drainage	Tx	Immediate Image result	Clinical outcome	Complication
1	R	Pulsatile tinnitus	72	LAPA	RIJV	TVE	Complete occlusion	Resolved	None
2	L	Pulsatile tinnitus	2	BAPA, RVA	LIJV	TVE	Complete occlusion	Resolved	None
3	R	Pulsatile tinnitus	6	ROA, RVA, RAPA	RIJV	TVE+ aTAE	Complete occlusion	Resolved	None
4	R	Pulsatile tinnitus	6	BOA, BAPA, BIMA, BMMA	RIJV	TVE+ aTAE	Complete occlusion	Resolved	None
5	R	Pulsatile tinnitus, R eye conjestion	6	RIMA, RAPA	RIPS, retrograde to RCS to SOV	TVE	Complete occlusion	Resolved	None
6	L	Pulsatile tinnitus	12	LVA, LIMA, LMMA, BAPA	Vertebral plexus, L IJV	TVE	Complete occlusion	Resolved	None
7	R	Pulsatile tinnitus	48	ROA, BAPA	RIJV	TVE+ aTAE	Complete occlusion	Resolved	None
8	L	Pulsatile tinnitus	2	LVA, LOA, BAPA	LIPS, L upper neck veins, LCS	TAE with Onyx 18 + TVE	Complete occlusion	Resolved	None
9	L	Pulsatile tinnitus	3	LOA, BVA, RAPA	LIPS, retrograde flow to L TS sinus	TVE+ aTAE	Complete occlusion	Resolved	None
10	R	Pulsatile tinnitus	1	BVA, LAPA, ROA	RIPS, retrograde to basilar plexus	TVE	Complete occlusion	Resolved	None
11	R	Pulsatile tinnitus, R eye proptosis	24	BAPA, LICA	RIPS, retrograde to RCS to cortical veins	TAE coil packing	Complete occlusion	Resolved	None
12	R	Pulsatile tinnitus	6	RVA, BAPA	RIJV	TVE	Complete occlusion	Resolved	None
13	L	Pulsatile tinnitus, L eye congestion	12	BAPA, LMMA, LVA, LICA	LIPS, retrograde to LCS to RCS and RIPS	TVE	Complete occlusion	Resolved	None
14	R	Pulsatile tinnitus, diplopia, R tongue twitching	2	BAPA, BICA, RVA	RIPS, retrograde to RCS to SOV	TVE	Complete occlusion	Resolved	None

ACC, *anterior condylar confluence;* APA, *ascending pharyngeal artery;* aTAE, *adjuvant transarterial embolization;* B, *bilateral;* CS, *cavernous sinus;* DOS, *duration of symptoms;* Hypo, *hypoglossal canal;* ICA, *internal carotid artery;* IJV, *internal jugular vein;* IMA, *internal maxillary artery;* IPS, *inferior petrosal sinus;* L, *left;* m, *months;* MMA, *middle meningeal artery n/a, not available;* OA, *occipital artery;* R, *right;* SOV, *superior ophthalmic vein;* TS, *transverse-sigmoid;* TVE, *transvenous embolization;* Tx, *treatment;* VA, *vertebral artery;* y, *years;* *, *additional bone involved also noted in the follow-up images.*

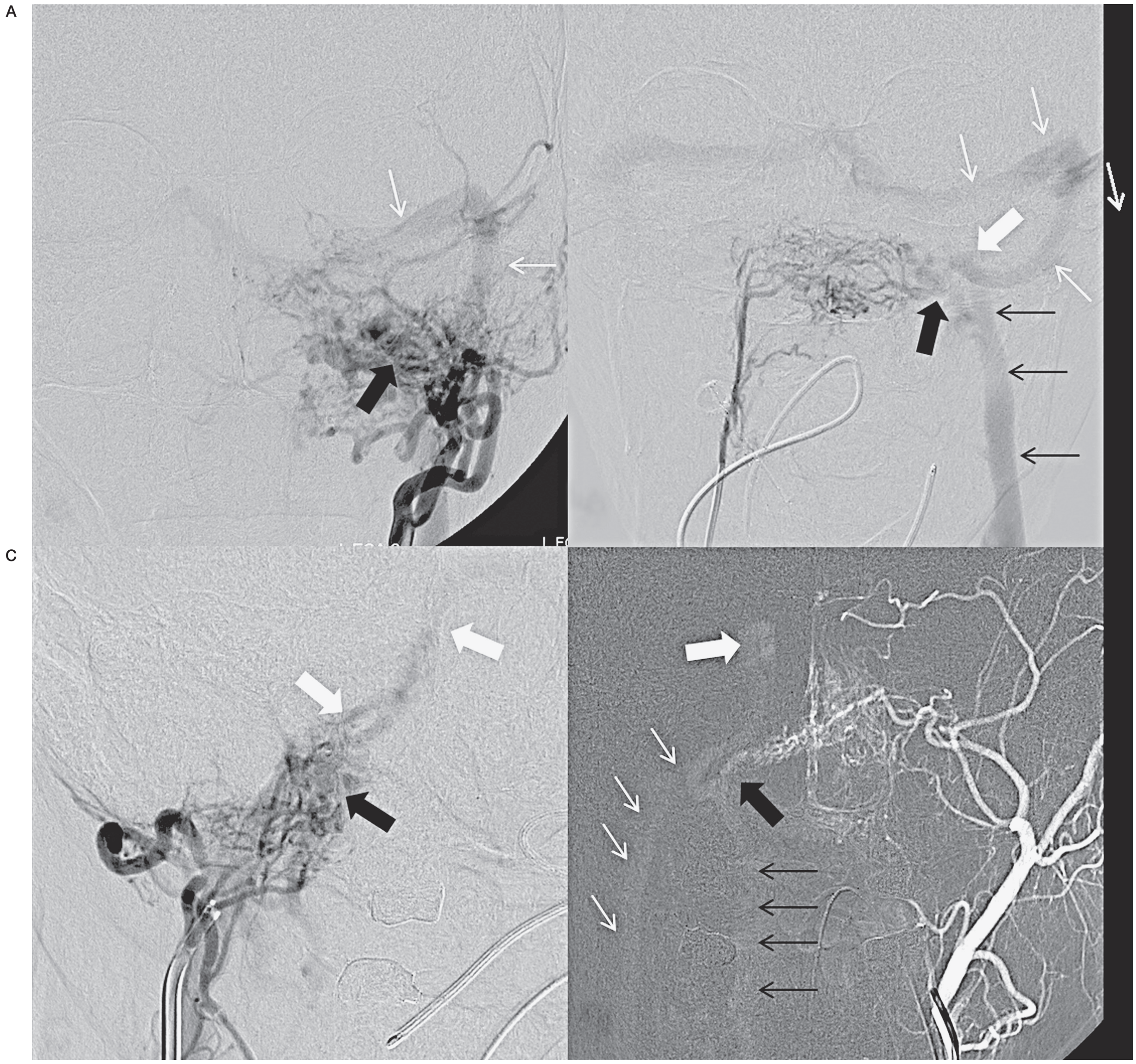

Figure 1 Frontal views of 3 patients of anterior condylar DAVF in the hypoglossal canal with retrograde flow. The fistula site is shown with large black arrows (A-D). On the left external (A) and right ascending pharyngeal (B) angiograms (patient 9), the antegrade flow refluxes into the left inferior petrous sinus then to jugular bulb (large white arrow). It shows retrograde flow to the transverse-sigmoid sinus (small white arrows) and antegrade flow to the internal jugular vein (small black arrows). C) (patient 10, occipital artery angiogram) Reflux into the cavernous sinus through the internal petrous sinus (white arrows). D) (patient 5, left external carotid) Fistula on the right side with antegrade flow to the internal jugular vein (small white arrows), internal paraspinal venous plexus (small black arrows), and retrograde flow into the cavernous sinus (large white arrow).

dence was reported as 3.6%-5.1% of all DAVF [2,3]. The nomenclature on anterior condylar DAVF is controversial due to the complex anatomy in the skull base and the lack of correlated imaging studies. Anterior condylar DAVF has been confused in the literature with marginal sinus DAVF [4], inferior petrosal sinus DAVF [5], anterior condylar vein DAVF [6,7], hypoglossal canal DAVF [2,3,8,9], and clival DAVF [10]. Recently, most papers have used anterior condylar confluence DAVF to describe such lesions [11-14]. For a successful treatment of neurovascular disorders with microscopic neurosurgery, stereotactic radiosurgery, and neurointerventional treatment, precise localization and extent evaluation of the lesion are the important factors [15]. Herein, we report our experience of 14 anterior condylar DAVFs treated with endovascular management, and the follow-up CT or MR imaging study.

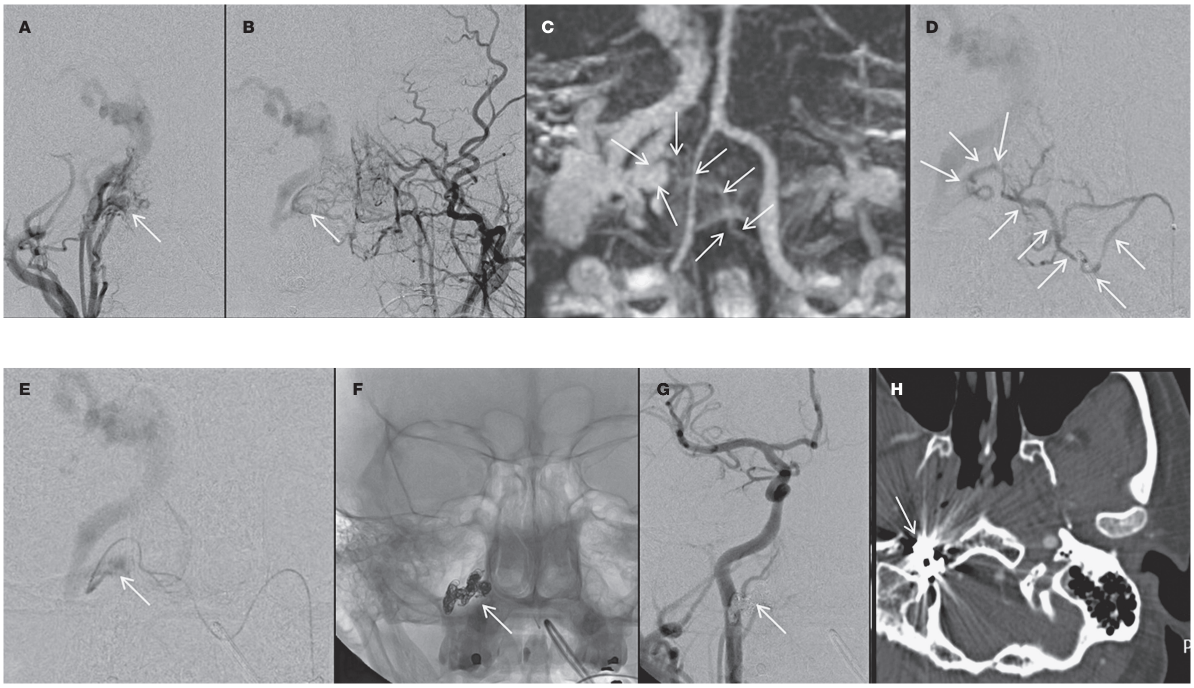

Figure 2 Case 11. A patient had pulsatile tinnitus for 2 years and right proptosis recently. Diagnostic angiographies of the external carotid on the right (A) and left (B) show a dural arteriovenous fistula (DAVF) (arrow) in the right anterior condylar veins. The inferior petrosal sinus was occluded in below. Retrograde flow to the cavernous sinus and superior ophthalmic vein are noted. Maximal intensity projection view (C) of CT angiogram shows a prominent artery (arrows) from the left side communicating to the venous sac which is confirmed on the superselective angiogram (D) at the clival branch of the left ascending pharyngeal artery (arrows). Embolization was performed with a microcatheter navigating into the venous sac (E) and coil packing (F, arrow). Immediate post-procedure angiogram (G) shows the complete obliteration of the fistula (arrow) and follow-up CT scan shows the coil mass in the hypoglossal canal and anterior condylar confluence (arrow).

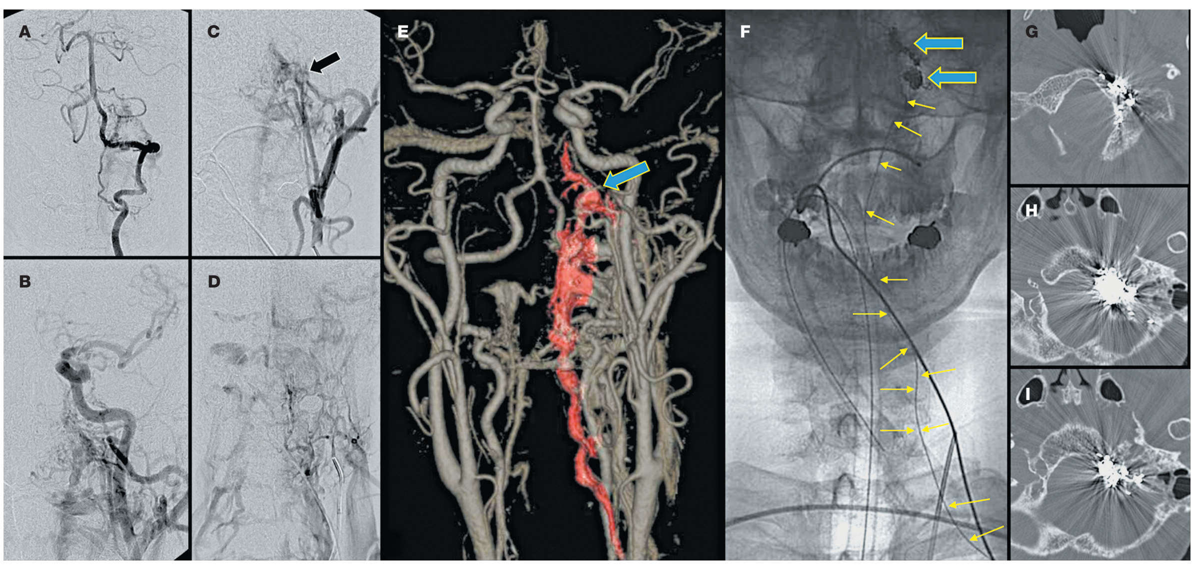

Figure 3 Case 6. A patient suffered from vascular tinnitus for 1 year. Diagnostic angiographies of left vertebral (A), left common carotid (B), left external carotid (C) show a DAVF in the left hypoglossal canal. The drainage is mainly to the internal paraspinal venous plexus (D). On virtual reality images (E) of the CT angiogram, the fistula (arrow) and drainage are identified. The inferior petrosal sinus is not visualized in the above studies. The fistula is obliterated by paraspinal venous approach (small yellow arrows) with coil packing (large blue arrows). The follow-up CT study shows the coil mass inside the occipital condyle (G), hypoglossal canal (H), and lateral lower clivus (I).

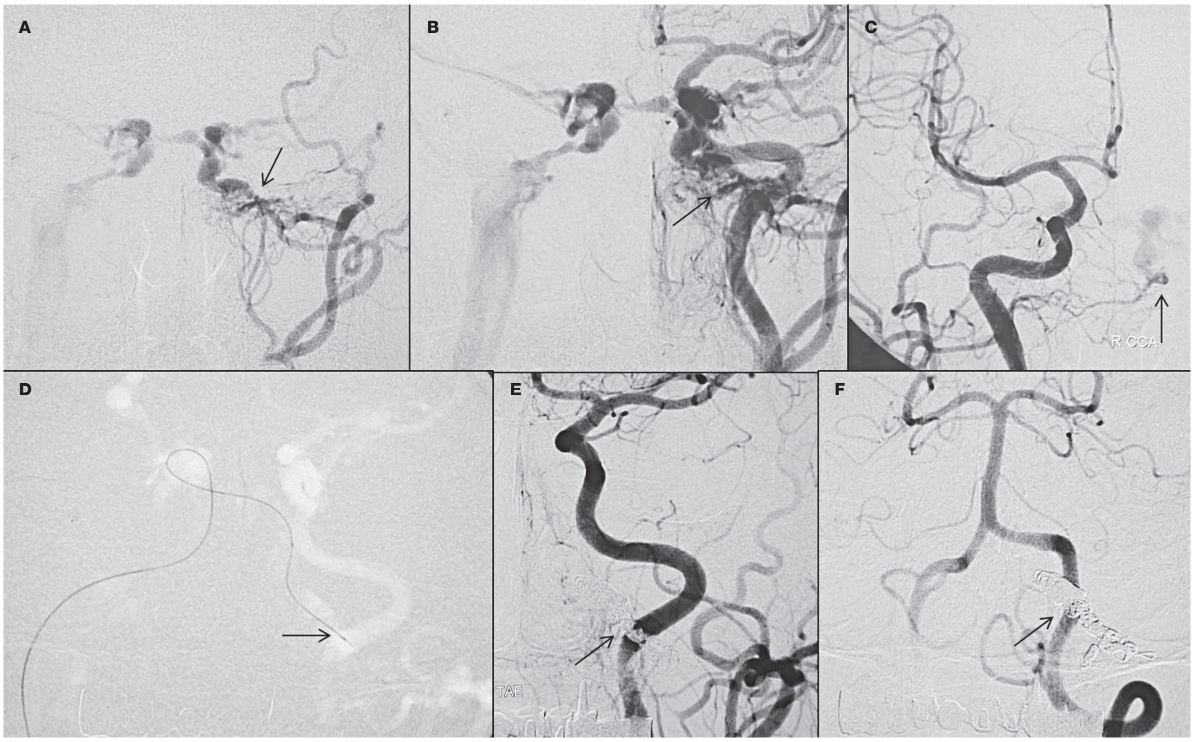

Figure 4 Case 13. A patient had pulsatile tinnitus and left eye congestion for 1 year. Diagnostic angiography of left external (A), left common (B), and right common carotid arteries (C) show a DAVF in the left hypoglossal canal with obstruction of the lower inferior petrosal sinus. Retrograde flow shows reflux to the right cavernous sinus and right inferior petrosal sinus. The microcatheter was navigated from right inferior petrosal sinus to left inferior petrosal sinus and then the anterior condylar DAVF through the communication between both cavernous sinuses (D). Immediate post-procedure angiogram shows no residue on left common carotid (E) and left vertebral artery (F) injection.

Materials and Methods

Seventeen patients with anterior condylar DAVF were found in the databank of neurointerventional surgery at our institute between 1998 and 2012.

The incidence of anterior condylar DAVF is 1.8% of the total 908 cases of all DAVF. We excluded three of them who had no treatment. Two of them resolved spontaneously and one had an asymptomatic DAVF involving the anterior condylar vein with coexisting transverse-sigmoid sinus DAVF with cortical vein reflux which was treated. A total of 14 patients were included in this study with their medical records and images reviewed. Pre-procedural image evaluation included CTA, MRA and DSA. Outcome was determined by immediate angiographic findings, clinical and imaging follow-up study. The clinical and follow-up imaging studies included either MR or CT angiography done at three, six, 12, and 24 months after the final embolization if possible. The locations of coil material were recorded and analyzed. These imaging findings were analyzed by four certified neuroradiologists who had 29, 15, 12 and six years' experience of diagnostic neuroradiology respectively.

Results

The demographic data, clinical presentation, fistula angiographic architecture, immediate post-procedure imaging, and clinical outcome are summarized in Table 1. Total 14 patients (seven males, seven females) were treated, with a mean age of 54.4 years (standard deviation =7.4, 43-67). Nine lesions were on the right side and five on the left. All patients were presented with pulsatile tinnitus. Four patients also presented with associated symptoms. Two patients had eye chemosis mimicking carotid-cavernous DAVF. One patient had tinnitus and transient proptosis. One had diplopia and right half tongue twitching. The duration of symptoms ranged from one to 72 months, with an average of 14.4 months (standard deviation =20.8, 1-72).

The main arterial feeders were bilateral ascending pharyngeal artery (n=9), vertebral artery (n=8), ipsilateral ascending pharyngeal artery (n=5), occipital artery (n=5), internal maxillary artery (n=3), middle meningeal artery (n=3), and internal carotid artery (n=2). The venous drainage pattern varied. Seven patients had retrograde venous drainage and four of them had retrograde venous drainage to the cavernous sinus then to superior ophthalmic vein, causing ocular symptoms; one had retrograde venous drainage to the cavernous sinus then to a dilated cortical vein, the remaining three had retrograde venous drainage including basilar plexus and transverse-sigmoid sinus. No obstruction in antegrade flow was noted in four of these seven patients (Figure 1).

The 14 patients received 16 sessions of endovascular treatment. All patients were treated by intravascular coil packing finally. The intravascular coil packing was performed by transvenous embolization (TVE) in eight patients, transarterial approach in one patient. One patient received TAE with liquid embolic agent (Onyx 18, Covidien, Irvine, CA, USA) but failed then by coiling in the second session (case 8). The remaining four patients received adjuvant transarterial embolization (TAE) with N-butyl cyanoacrylate (NBCA) or polyvinyl alcohol particles (Contour, Boston Scientific, Fremont, CA, USA) for minimal residual after TVE coil packing. All the coils deployed were ultrasoft detachable coils (Guglielmi or Matrix detachable coil, Boston Scientific, Fremont, CA, USA). The transarterial approach in one patient (case 11, Figure 2) was performed by navigating the microcatheter to the venous side of the fistula via a branch of the contralateral ascending pharyngeal artery. One patient (case 6, Figure 3) showed no obvious inferior petrosal sinus on the angiogram. We used a paraspinal approach through the anterior internal paraspinal venous plexus and packed the fistula with coils. One patient (case 13, Figure

Table 2 **Follow-up computed axial images and the extension of coil mass in 12 patients with successful coiling of hypoglossal dural arteriovenous fistula.**

No.	Imaging	Extension of coil mass				
		Hypoglossal canal	Ventral to hypoglossal canal	Central clivus	Lateral lower clivus (basiocciput)	Other sites
1	CT	+	–	–	+	Jugular condyle
3	MR	+	–	–	+	
4	CT	+	–	–	+	Border of Foramen Magnum, inferior petrosal sinus
5	CT/MR	+	–	–	+	Border of Foramen Magnum
6	CT	+	–	–	+	
7	CT/MR	+	–	–	+	
8	MR	+	–	–	+	Border of Foramen Magnum
9	CT/MR	+	–	–	–	Bone surrounding hypoglossal canal
10	MR	+	–	–	–	
11	CT	+	+	–	+	
12	MR	+	–	–	+	
14	MR	+	+	–	–	

CT, *computed tomography;* MR, *magnetic resonance.*

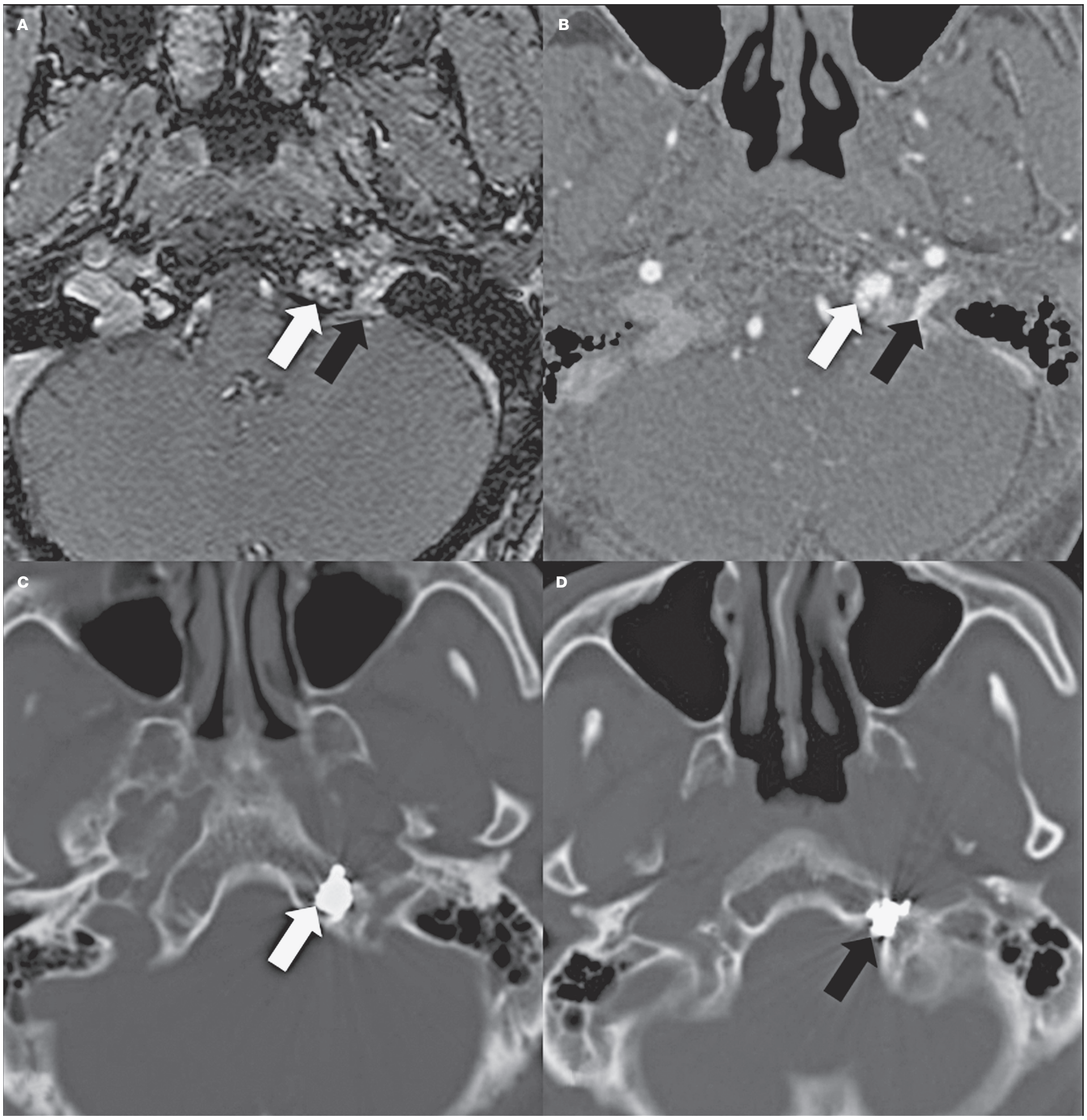

Figure 5 Case 6. Pre-embolization time of flight MR angiography source image at the level of the hypoglossal canal shows high flow inside the left hypoglossal canal (black arrow) and adjacent basiocciput (white arrow). It is also well depicted on the CT angiography source image (B). Post-embolization CT angiography shows a coil mass inside the basiocciput (C, white arrow) and hypoglossal canal (D, black arrow).

4) had a left lesion with retrograde flow to the right inferior petrosal sinus via the communication between the cavernous sinuses. We obliterated the fistula successfully by navigating the microcatheter from the right inferior petrosal sinus to the left anterior condylar vein.

The immediate post-procedure angiography of the 14 patients treated with intravascular coil packing showed complete obliteration of the fistula. There were no complications in all treated patients. Symptoms resolved and no clinical or computed imaging recurrence was observed in the follow-up period. The mean follow-up period was 34.2 months (standard deviation=39.8, four months - 132 months). Follow-up images (CT alone in four, MR alone in five, both CT and MR in three) were obtained in 12 patients treated with coil packing (Table 2). The coil mass (Figures 5 and 6) was depicted inside the hypoglossal canal in 12 patients (100%), in the lateral lower clivus (basiocciput) in eight patients (54.2%), and in the ventral to hypoglossal canal (anterior condylar confluence) in two patients (14.2%). Three patients also had coils found at the vicinity such as the border of the oramen magnum, the inferior petrosal sinus, and bone surrounding the hypoglossal canal. Nine of these 12 cases had bilateral ascending pharyngeal arteries supply. In the eight cases with lateral lower clivus involvement, five had bilateral ascending pharyngeal artery supply.

Discussion

We successfully treated 14 patients presenting anterior condylar DAVF without complications and with an excellent outcome. By the follow-up CT or MR angiographic imaging of patients treated by coiling, we could identify the coil mass mainly inside the hypoglossal canal (n=10, 100%) and the lateral clivus (54.2%) after successful embolization. They were comparable to the imaging studies (Figures 4 and 5) obtained before treatment. We propose that the anterior condylar venous plexus inside the hypoglossal canal should be the key target of treatment and many of them may involve the adjacent lateral lower clivus. This concept is important for the successful embolization of anterior condylar DAVF, and also for surgical planning or targeting in stereotactic radiosurgery with axial computed images.

Geibprasert et al. categorized the dural arteriovenous shunts according to the craniospinal epidural space compartments based on embryonic development of craniospinal structures [18]. Anterior condylar DAVF is one of the subcategory of ventral epidural (osteo[cartilaginous]-epidural) shunts in their classification. In this particular type of shunt, the lesion involves mainly the epidural space and is in direct contact with the adjacent osseous structures that may invade or recruit the blood supply from the spongy bone structures and has no primary role in the drainage of the central nervous system. Tubbs et al. reported that a communication was always found between the basilar venous plexus and the inferior petrosal sinuses in a cadaver study [19]. A cadaver study reported by Kunicki et al. showed 96% (47/50) of the basilar venous plexus drained into the inferior petrosal sinus [20]. Tubbs et al. found 35% of the basilar plexus communicated with veins draining into the anterior condylar veins inside the hypoglossal canal [19]. This explains that the anterior condylar DAVF in our series can extend along this communication to the clivus. The follow-up computed images confirmed the involvement of the spongy bone marrow structures (Figure 4C,D). We cannot entirely exclude the possibility of clivus involvement due to a secondary event such as venous reflex into the bone structures or just a secondary recruitment from the blood supply to the clivus. For successful treatment and complete obliteration of such a lesion, we suggest that adjacent bone involvement should be concerned during planning for the treatment of anterior condylar DAVF.

Seven of our patients were males (50%) and this is different from the paper by Geibprasert et al. [18], in which a female predominance (2.3:1) was considered in such a lesion. They also stated that there was no cortical vein reflux in such a lesion without extensive thrombosis of epidural drainage or high-flow shunts [18]. Seven of our patients had retrograde drainage to different sinuses. Four of them had occlusion at the lower inferior petrosal sinus. The remaining three patients revealed no major sinus thrombosis shown on angiography. We speculate the retrograde flow may be due to the insufficient normal antegrade flow or venous outflow venopathies. Miyachi et al. mentioned that DAVF involves the anterior condylar confluence particularly in cases supplied by both of the ascending pharyngeal arteries [11]. In our series, nine anterior condylar DAVF had feeders from the bilateral ascending pharyngeal arteries, only two of them (cases 11 and 14) showed a coil mass at the anterior condylar confluence. Three of our patients presented with ocular symptoms such as cranial nerve neuropathy and/or symptoms of increased intraocular venous pressure. They were associated with reflux to the superior ophthalmic vein through the inferior petrosal sinus that may be the presenting symptom in a significant percentage of patients [6,21,22]. In four of our seven patients associated with patent antegrade flow, the high flow of the shunt itself can cause marked venous hypertension leading to reflux into the cavernous sinus and then the superior ophthalmic veins.

The previously published paper reported 21 patients had DAVF in the hypoglossal canal area [2,3,8,9,21]. Four of them had spontaneous disappearance of the tinnitus without aggressive treatment. Among the 15 cases treated, success was achieved with TAE alone in one, TVE after failed TAE in four, and TVE alone in nine. One

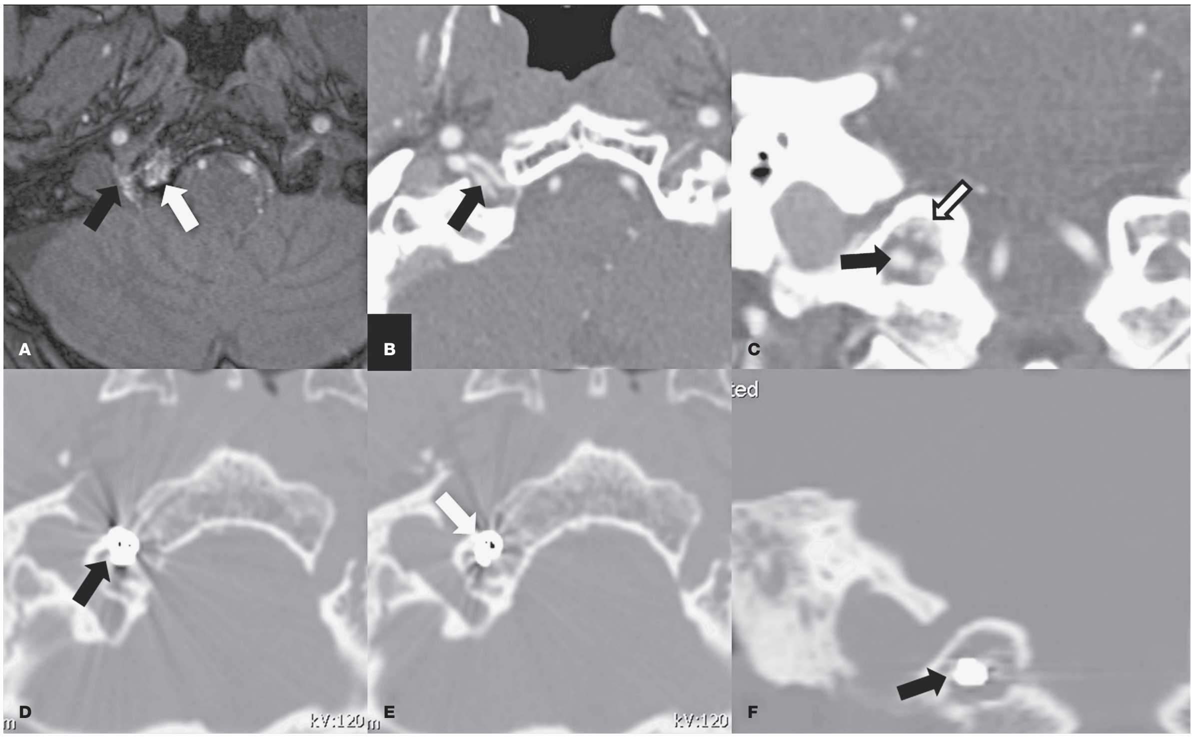

Figure 6 Case 7. Pre-embolization time of flight MR angiography source image at the level of hypoglossal canal shows high flow inside the right adjacent basiocciput (A, white arrow). The fistula (black arrow) is well depicted on CT angiography source (B) and coronal reconstruction images (C), on which the bone component is also shown (white arrow). Post-embolization CT angiography shows a coil mass inside the hypoglossal canal (D, F) and basiocciput (E, white arrow).

patient had a partial cure by TAE alone and one patient had permanent hypoglossal nerve palsy after TAE and TVE treatment [3]. The hypoglossal nerve palsy occurred after the second session of TVE treatment with interlocking detachable coils. No other complication was reported by the above papers. The successful rate of treatment of anterior condylar DAVFs predominantly by TAE with a liquid embolic agent was about 70% [10] but coiling was usually needed for complete obliteration [14]. The risk is high especially when the embolization was performed in the ascending pharyngeal artery. Tirakotai et al. reported four cases of intraosseous DAVF involving the jugular bulb treated successfully by surgical resection after failed endovascular treatment [23]. One of the patients needed occipitocervical fixation due to resection of bilateral lesions. In surgical resection of anterior condylar DAVF, the occipital condyle has to be resected partially and the jugular bulb has to be skeletonized and exposed. The potential risk includes injury to the vertebral artery, jugular bulb, and hypoglossal nerve. The more extensive the lesion is the higher possibility of damaging the stability of the occipito-atlantal joint by surgical resection. Radiosurgery plays some role in the treatment of DAVFs [24], but to our knowledge there are no reports on a treatment specific for anterior condylar DAVFs in the literature. We suggest that intravascular coil packing is still the treatment of choice for anterior condylar DAVF. It is always possible though the approach depends on the venous drainage pattern especially those with occlusion between the inferior petrosal vein occlusion and the jugular bulb. We successfully treated 14 patients presenting anterior condylar DAVF with intravascular coiling without complications. According to previous reports, transient or permanent hypoglossal nerve palsy could occur by coil packing inside the hypoglossal canal. We used only the softest detachable coil to avoid this complication. Although no complication was experienced in our case series, the warning for hypoglossal nerve palsy should always be considered. Though the patients were not followed by catheter angiography, all of them had multiple follow-up CTA/MRA, and a long-term resolution of the clinical symptoms, suggesting intravascular coiling is still the treatment of choice for anterior condylar DAVF.

Conclusion

We found that anterior condylar DAVF usually has an intraosseous component at the lateral lower part of clivus and adjacent bones. Both the anterior condylar vein inside the hypoglossal canal and its adjacent intraosseous extent should be the target of treatment during the management of anterior condylar DAVF.

Acknowledgements

Thanks to NSC support for the Center for Dynamical Biomarkers and Translational Medicine, National Central University, Taiwan (NSC 101-2911-I-008-001).

References

1 van Dijk JM, ter Brugge KG. Dural arteriovenous fistulas. J Neurosurg. 2002; 97 (6): 1486, author reply 1486-1487.
2 Okahara M, Kiyosue H, Tanoue S, et al. Selective transvenous embolization of dural arteriovenous fistulas involving the hypoglossal canal. Interv Neuroradiol. 2007; 13 (1): 59-66.
3 Manabe S, Satoh K, Matsubara S, et al. Characteristics, diagnosis and treatment of hypoglossal canal dural arteriovenous fistula: report of nine cases. Neuroradiology. 2008; 50 (8): 715-721. doi: 10.1007/s00234-008-0393-7.
4 McDougall CG, Halbach VV, Dowd CF. Dural arteriovenous fistulas of the marginal sinus. Am J Neuroradiol. 1997; 18 (8): 1565-1572.
5 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 (3): 511-516.
6 Ernst R, Bulas R, Tomsick T, et al. Three cases of dural arteriovenous fistula of the anterior condylar vein within the hypoglossal canal. Am J Neuroradiol. 1999; 20 (10): 2016-2020.
7 Tanoue S, Goto K, Oota S. Endovascular treatment for dural arteriovenous fistula of the anterior condylar vein with unusual venous drainage: report of two cases. Am J Neuroradiol. 2005; 26 (8): 1955-1959.
8 Kiyosue H, Tanoue S, Sagara Y, et al. Ocular symptoms associated with a dural arteriovenous fistula involving the hypoglossal canal: selective transvenous coil embolization. Case report. J Neurosurg. 2001; 94: 630-632. doi: 10.3171/jns.2001.94.4.0630.
9 Komiyama M, Ishiguro T, Matsuzaka Y, et al. [Intense pulse-synchronous tinnitus caused by dural arteriovenous fistula at the hypoglossal canal] [in Japanese]. No To Shinkei. 2002; 54: 830-831.
10 Shi ZS, Ziegler J, Gonzalez NR, et al. Transarterial embolization of clival dural arteriovenous fistulae using liquid embolic agents. Neurosurgery. 2008; 62 (2): 408-415. doi: 10.1227/01.neu.0000316007.34259.26.
11 Miyachi S, Ohshima Y, Izumi T, et al. Dural arteriovenous fistula at the anterior condylar confluence. Interv Neuroradiol. 2008; 14 (3): 303-311.
12 Abiko M, Ikawa F, Ohbayashi N, et al. Endovascular treatment for dural arteriovenous fistula of the anterior condylar confluence involving the anterior condylar vein. A report of two cases. Interv Neuroradiol. 2008; 14 (3): 313-317.
13 Liu JK, Mahaney K, Barnwell SL, et al. Dural arteriovenous fistula of the anterior condylar confluence and hypoglossal canal mimicking a jugular foramen tumor. J Neurosurg. 2008; 109 (2): 335-340. doi: 10.3171/JNS/2008/109/8/0335.
14 Takemoto K, Tateshima S, Rastogi S, et al. Onyx embolization of anterior condylar confluence dural arteriovenous fistula. J Neurointerv Surg. 2014; 6 (2): e13. doi: 10.1136/neurintsurg-2013-010651.rep.
15 Vougioukas VI, Coulin CJ, Shah M, et al. Benefits and limitations of image guidance in the surgical treatment of intracranial dural arteriovenous fistulas. Acta Neurochir (Wien). 2006; 148 (2): 145-153, discussion 153. doi: 10.1007/s00701-005-0656-6.
16 San Millán Ruíz D, Gailloud P, Rüfenacht DA, et al. The craniocervical venous system in relation to cerebral venous drainage. Am J Neuroradiol. 2002; 23 (9): 1500-1508.
17 Zhang W, Ye Y, Chen J, et al. Study on inferior petrosal sinus and its confluence pattern with relevant veins by MSCT. Surg Radiol Anat. 2010; 32 (6): 563-572. doi: 10.1007/s00276-009-0602-z.
18 Geibprasert S, Pereira V, Krings T, et al. Dural arteriovenous shunts: a new classification of craniospinal epidural venous anatomical bases and clinical correlations. Stroke. 2008; 39: 2783-2794. doi: 10.1161/STROKEAHA.108.516757.
19 Tubbs RS, Hansasuta A, Loukas M, et al. The basilar venous plexus. Clin Anat. 2007; 20 (7): 755-759. doi: 10.1002/ca.20494.
20. Kunicki J, Skadorwa T, Machura W. Microsurgical anatomy of basilar venous plexus in relation to transclival and transsphenoidal approaches to the posterior cranial fossa (abstract). Skull Base. 2009; 19 (01): A020. doi: 10.1055/s-2009-1222135.
21 Miropolsky V, da Costa LB, Marotta TR, et al. Endovascular therapy of hypoglossal canal AVFs presenting with orbital symptoms. Can J Neurol Sci. 2009; 36 (6): 745-750.
22 Liu HM, Shih HC, Huang YC, et al. Posterior cranial fossa arteriovenous fistula with presenting as carotico-cavernous fistula. Neuroradiology. 2001; 43 (5): 405-408. doi: 10.1007/s002340100551.
23 Tirakotai W, Benes L, Kappus C, et al. Surgical management of dural arteriovenous fistulas with transosseous arterial feeders involving the jugular bulb. Neurosurg Rev. 2007; 30 (1): 40-49, discussion 48-49. doi: 10.1007/s10143-006-0056-2.
24 Gandhi D, Chen J, Pearl M, et al. Intracranial dural arteriovenous fistulas: classification, imaging findings, and treatment. Am J Neuroradiol. 2012; 33 (6): 1007-1013. doi: 10.3174/ajnr.A2798.

Hon-Man Liu, MD, MBA
Department of Medical Imaging
National Taiwan University Hospital
No. 7, Chung-Shan South Road
Taipei, Taiwan, ROC 100
Tel.: +886-2-23123456x70329
Fax: +886-2-23224552
E-mail: inr.liu@gmail.com