Interdisciplinary Neurosurgery: Advanced Techniques and Case Management 36 (2024) 101910

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery: Advanced Techniques and Case Management

journal homepage: www.elsevier.com/locate/inat

Review Article

Surgical management of anterior cranial fossa dural arteriovenous fistulas: Illustrative case series and review of surgical approaches

M. Vanloon [a,*], ARPKM van Renterghem [a,b], V. Raymaekers [c,d], T. Menovsky [c,d], S. Achahbar [e,h], S. Heye [f], M. Plazier [e,g,h]

[a] Faculty of Health, Medicine and Life Sciences, Maastricht University, the Netherlands
[b] Zuyderland Hospital Urology, the Netherlands
[c] Department of Neurosurgery, University Hospitals Antwerp, Belgium
[d] Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium
[e] Department of Neurosurgery, Jessa Hospital, Hasselt, Belgium
[f] Department of Radiology, Jessa Hospital, Hasselt, Belgium
[g] Faculty of Medicine and Life Science, Hasselt University, Hasselt, Belgium
[h] Study and Educational Center for Neurosurgery, Virga Jesse, Hasselt, Belgium

ARTICLE INFO

Keywords:
Dural arteriovenous fistula
Anterior cranial fossa
Surgical approaches

ABSTRACT

Background: Dural arteriovenous fistulas (DAVF) within the anterior cranial fossa (ACF) are of particular concern due to their higher hemorrhage rates. Surgical intervention is typically the most effective treatment for ACF DAVFs, although recent advancements suggest increasing use of endovascular techniques. It has consistently shown effectiveness, with minimal thromboembolic risks.

Case description: We present two cases of ACF DAVF graded Cognard type IV. A successful pterional and frontotemporal approach was performed, respectively. Postoperative angiography confirmed complete DAVF occlusions, and the patients had an uneventful recovery.

Conclusion: ACF DAVFs can be exposed through direct or indirect approaches, with advantages and drawbacks for each method. The anterior interhemispheric approach is widely recognized for its safety and efficacy. Limited studies have advocated for the use of the pterional approach, showing feasibility and potential benefits such as avoiding frontal sinus reconstruction and providing an excellent view of the fistula. Furthermore, pterional approach offers sufficient exposure and favorable cosmetic outcomes, making it a viable option for ACF DAVFs. The presented cases exemplify the efficacious surgical management of ACVF DAVFs through distinct approaches, underscoring the significance of personalized treatment strategies and the effectiveness of surgical interventions in accomplishing total obliteration of the fistulas.

1. Introduction

Dural arteriovenous fistulas (DAVF) are arteriovenous malformations that occur within the dura mater. While only constituting 5% of all DAVFs, those situated in the anterior cranial fossa (ACF) demand particular attention due to their increased rates of hemorrhage [1–3]. Based on the existing knowledge of the disease, the process of neovascular growth is believed to be triggered by a dual mechanism. Firstly, it involves the presence of a preexisting fistula located in proximity to a venous sinus within the dura. This is followed by a substantial reduction in peripheral vascular resistance, resulting in increased blood flow. Secondly, the development of a thrombus within the venous vascular structures further contributes to this process [4–6]. Given the potential for CNS parenchymal damage due to venous hemorrhage, active treatment options should be carefully considered for DAVFs presenting with cortical venous drainage. Irrespective of the presence of intracranial hemorrhage, the shunt itself can give rise to neurological symptoms. Therefore, the assessment of these fistulas holds significant importance, particularly in the context of anterior cranial fossa DAVFs, which exhibit a remarkably high incidence of intracranial hemorrhage ranging from 62% to 91% [7,8]. In addition, it is worth noting that fistulas situated within the lateral epidural space, encompassing the lamina cribrosa, exhibit a pronounced male predominance and display an aggressive clinical course [9]. In most cases, DAVFs in the ACF are primarily

* Corresponding author.
E-mail address: maarten_vanloon@hotmail.com (M. Vanloon).

https://doi.org/10.1016/j.inat.2023.101910
Received 12 November 2023; Accepted 19 November 2023
Available online 20 November 2023

supplied by the ethmoidal branches of the ophthalmic artery, with subsequent venous drainage occurring through the frontal cortical veins into the superior sagittal sinus.

Despite the ongoing advancements in endovascular techniques and their broader applicability, ACF DAVFs have been recognized as an exception to the prevailing trend favoring endovascular management. Surgical intervention has consistently demonstrated the highest efficacy in treating anterior cranial fossa DAVFs.[10,11]. Yet, recent advancements in technology indicate that endovascular treatment is believed to become a more extensively employed technique for managing anterior cranial fossa DAVFs as well [12–16]. The primary objective in treating DAVFs is the complete obliteration of the arteriovenous shunt. While endovascular treatment alone is effective in most cases, anatomical complexities in our cases necessitated surgical obliteration. This approach was chosen due to its safe and easily accessible nature, particularly in high-volume centers like ours, with low associated morbidity rates. Typically, a frontobasal craniotomy is performed for this purpose, as it offers a direct path and excellent visualization of the fistula. However, it should be noted that this technique involves a large skin incision, extensive bone exposure, and the opening of the frontal sinus [7,10,17–19].

In this study, we present two cases of ACF DAVF. The first case involved an asymptomatic patient who underwent surgical treatment using a pterional approach. Subsequently, our second case presented several months later with an active hemorrhagic ACF DAVF, which was initially stabilized and subsequently treated with surgical obliteration. Furthermore, we will discuss the treatment options available for DAVFs, including a detailed exploration of various exposure techniques. Specifically, we will highlight the pterional approach as one of the methods utilized in managing these vascular abnormalities.

2. Case presentation

A 40-year-old Moroccan male was seen at the emergency department following a high energetic trauma car accident. He was known to have chronic rhinosinusitis and took no medication at the time of admission. The patient was stable at the time of presentation with a maximal Glasgow Coma Scale at our emergency department and was subjected to a cerebral MRI scan. Emergent MRI revealed flow void signs, which suggested a DAVF (Fig. 1). This incidental finding was described by the radiologist and confirmed by a digital subtraction angiography (Fig. 2). The radiologist classified the DAVF as Cognard type IV (Borden III). Furthermore, the DAVF was located in the ACF. The patient was then seen at the neurosurgical outpatient clinic. The patient had no symptoms from the incidental finding of the DAVF. After multidisciplinary consultation, an elective surgical treatment was considered. The patient was installed in a supine position, with the head slightly elevated and fixated in a Mayfield skull clamp. A pterional incision was performed,

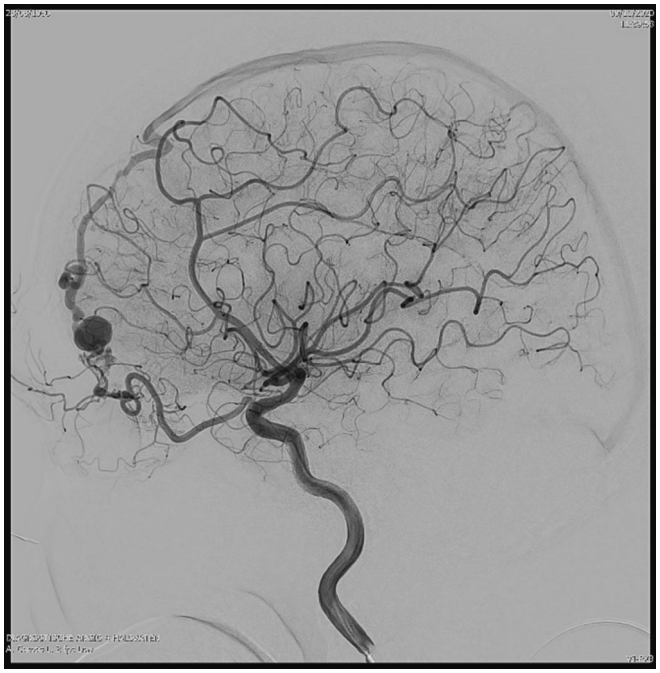

Fig. 2. A digital subtraction angiograph showing the left carotid artery and a dural arteriovenous fistula located in the anterior cranial fossa.

and burr holes were drilled in between the superior sagittal sinus and frontal sinus. A frontal bone flap of about 3x3 centimeters was made using the craniotome and a U-shaped opening of the dura was made. Subsequently the arterialized vein was identified as well as the fistula. The feeding branches to the fistula (originating out of the skull base) were coagulated as well as the fistula itself. The arterialized vein was closed. The dura was closed after meticulous hemostasis. The bone flap was replaced, and the skin was closed in multiple anatomical layers. The surgery lasted 3 h in which the fistula was successfully closed. Fig. 3 shows the surgical field during surgery with a direct visualization of the fistula. Postoperative angiography indicated complete DAVF occlusion. There were no adverse events during and after the surgery. The postoperative condition of the patient was uneventful. The patient had a headache and a slight swelling of the wound which resorbed spontaneously after a few days of the intervention. The patient complained about a slight discomfort of the masticatory muscles at a checkup of 6 weeks.

Our second case consists of 68-years old Caucasian man, presenting with acute headache, nausea, and neck pain for 5 days. His medical history reported a laparoscopic gastric bypass and total knee

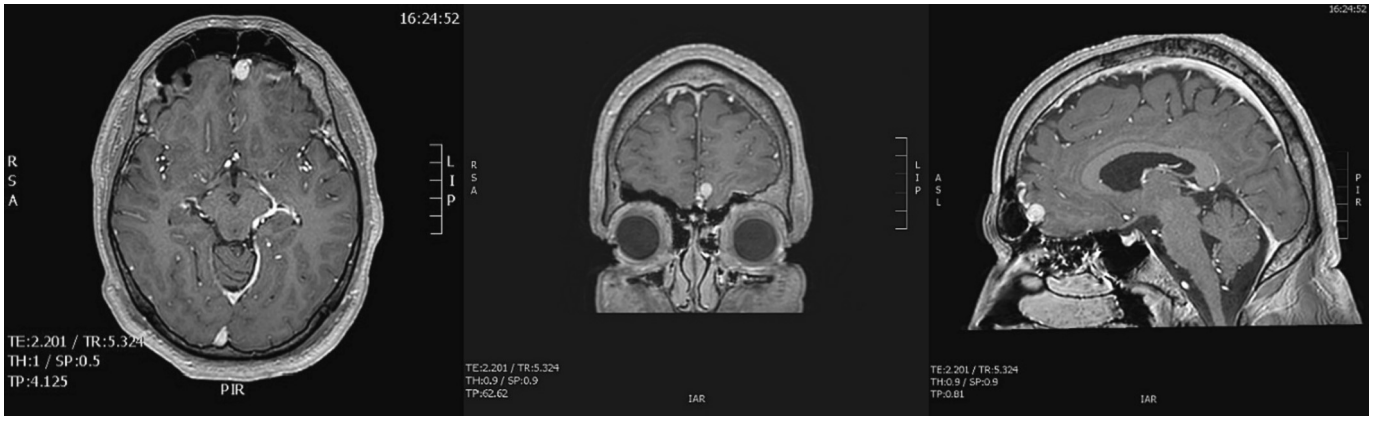

Fig. 1. An MRI scan at time of admission, showing a dural arteriovenous fistula at the left frontal cerebral hemisphere.

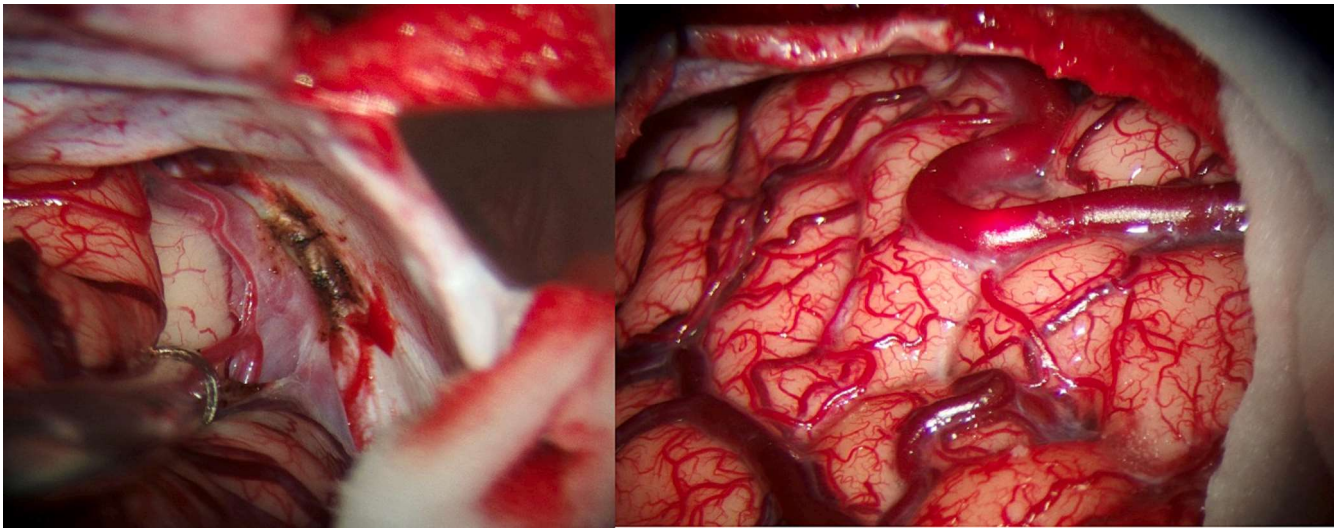

Fig. 3. Intraoperative images of the first case showing a dural arteriovenous fistula in the anterior cranial fossa. Left image shows the post-procedural venous circulation, characterized by the transportation of relatively deoxygenated blood, resulting in a brighter red appearance, as it returns to the systemic circulation. Right image showing revascularization of the veins with less oxygenated, darker blood due to arterial supply coagulation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

replacement. Current medication consisted of paracetamol and diclofenac. The patient was referred by his general practitioner to our emergency department when these symptoms were accompanied by horizontal diplopia. Apart from discrete oculomotor and facial nerve paresis on the right side, lateralization nor neurological manifestations were seen. A computed tomography was performed and showed a right sided basofrontal internal parenchymatous bleeding accompanied with cerebral edema. Dilated veins were objectified in the arterial phase of the scan with drainage to the frontal cortex and temporal cortex. A ruptured venous aneurysm from a DAVF was suspected. An urgent digital subtraction angiography was made and confirmed a Borden III DAVF (Cognard IV). The fistula had arterial supply from the ophthalmic artery, branches of the infraorbital artery, the sphenopalatine artery, the anterior meningeal artery and one branch of the superficial temporal artery. Venous drainage took place via the frontal cortical veins, on the right side. A focal aneurysmatic dilatation to the superior sagittal sinus was seen on one hand and to the cavernous sinus on the right, on the other hand. Further neurological examination was normal. The patient was admitted to the intensive care unit for observation and monitored for 1 day before being transferred to the neurology ward for 3 days. A final CT scan 3 days after the acute presentation showed diminished intracranial bleeding density without active bleeding. No new bleeding focus was objectified. After profound consideration of several treatment techniques by several authors mentioned above, a surgical treatment was recommended. Arguments for this approach were that our patient was neurologically intact with a stable sub-acute intracranial bleeding, secondary to a ruptured arteriovenous malformation. Adequate closure of the fistula would be complicated due to edema and therefore increased the chance of complications. Urgent, though not acute surgery is recommended within 2–3 weeks after presentation. Deterioration or rebleeding would need reconsideration of this approach. Shared decision making with our patient was made. Our patient was admitted to the surgery room 2 weeks later. Our patient was installed in a supine position, with the head slightly elevated and fixated in a Mayfield skull clamp. A frontotemporal incision was made. Precise arachnoidal dissection was performed until the DAVF was properly in sight and arterialized veins were subsequently coagulated. There were no complications perioperative. There were no adverse events during postoperative hospital stay. Postoperative neurological controls were normal. The patient was seen after 6 weeks postoperative at our outpatient clinic and showed good clinical recovery without any symptoms. Postoperative angiography indicated complete DAVF occlusion.

3. Discussion

Fistulas can be addressed through various treatment modalities, including endovascular, stereotactic, or surgical techniques. Notably, DAVFs located at the base of the anterior cranial fossa pose a significant risk of intracranial hemorrhage, distinguishing them from DAVFs involving the transverse, sigmoid, or cavernous sinuses. As a result, they are of particular concern and interest to neurosurgeons [1–3,9].

Treating ACF DAVFs with endovascular techniques can be challenging due to the predominant origin of these DAVFs from the ophthalmic artery. While endovascular approaches have shown feasibility in certain cases with small-caliber feeders and less accessible DAVFs, catheterizing the ophthalmic artery branches can be problematic. Additionally, embolization carries an increased risk of occlusion of the central retinal artery, further complicating the procedure [9,11]. Recent advancements in endovascular technology and techniques have led to improved outcomes in the treatment of DAVFs. These developments have demonstrated enhanced efficacy and success rates, as indicated by recent studies [15,16]. Moreover, surgical management has consistently demonstrated a high level of effectiveness in achieving complete obliteration of the DAVF, with a minimal risk of thromboembolic complications such as ophthalmic artery occlusion [8,13,19]. Consequently, surgical intervention is generally the preferred treatment approach for ACF DAVFs, particularly in younger patients without comorbidities. Furthermore, findings from hospital-based case series indicate a relatively low risk of unfavorable outcomes in patients who experience intracranial hemorrhage resulting from DAVF rupture, similar to the presentation observed in our second case [20]. Endovascular treatment of ACF DAVFs may be considered in patients who carry a higher surgical risk or when distal catheterization can be safely accomplished through either a transarterial or a retrograde transvenous approach. This alternative treatment modality provides a viable option for select cases where surgical intervention presents greater challenges or risks.

Multiple surgical approaches can be utilized to expose ACF DAVFs. Direct exposure methods include unilateral frontobasal, bilateral frontobasal, unilateral orbitozygomatic, and transfrontal sinus approaches, all of which involve frontal sinus exposure. Indirect exposure can be

achieved through anterior interhemispheric, supraorbital, pterional, or high frontal approaches. Among these, frontobasal craniotomy, anterior interhemispheric, and transfrontal sinus approaches are commonly employed for ACF DAVF exposure. In recent years, there has been a slight decline in the use of large frontobasal craniotomies, thanks to advancements in surgical techniques that are based on a better understanding of DAVF pathophysiology [18,21]. The direct approach offers the advantage of providing the shortest route to the fistula, thereby enabling the preservation of neuronal structures with minimal to no manipulation of the brain. However, this approach is associated with several drawbacks that have been extensively reported in the literature. These include frontal sinus destruction, which can lead to issues such as infection, cerebrospinal fluid leakage, and mucocele formation. Additionally, the direct approach is associated with a higher risk of blood loss and may result in less favorable cosmetic outcomes [22,23].

Another frequently employed indirect exposure technique is the anterior interhemispheric approach. This approach involves a bicoronal skin incision, followed by a bifrontal craniotomy and subsequent medial frontal dissection toward the location of the fistula. The anterior interhemispheric approach is widely acknowledged for its safety and effectiveness in treating ACF DAVFs [17,24]. The anterior interhemispheric approach offers several potential advantages, including the preservation of olfaction, unobstructed visualization of the midline anterior skull base, early access and control of the optic nerve and cerebral anterior arteries, and favorable cosmetic outcomes. However, it should be noted that comprehensive surgical studies assessing the feasibility and limitations of this approach, as well as those of the pterional approach, are currently lacking. Further research is needed to evaluate the efficacy and potential drawbacks associated with these techniques on a larger scale.

To the best of our knowledge, there are only a limited number of studies that have advocated for the use of a pterional approach in the management of ACF DAVFs. Some studies have suggested that this approach may not be feasible for larger vascular lesions [25], while others have provided evidence supporting its effectiveness [26]. A two-center study conducted by Meneghelli et al. demonstrated that a pterional approach, with a relatively low inferior limit on the frontal bone, was effective in providing sufficient exposure of the anterior cranial fossa in most patients (93%, 13 out of 14 patients). In cases where there was bilateral supply to the fistula, the study suggested that the incision of the falx cerebri could be performed to visualize the contralateral half of the olfactory groove region. These findings indicate the feasibility and potential benefits of utilizing a pterional approach in the surgical management of ACF DAVFs [3,9]. Except for the study by Meneghelli et al. and the focus video by Wicks et al., there is a scarcity of recent reports specifically discussing the use of the pterional approach for ACF DAVFs [27]. Based on our own experience, we have observed several advantages of utilizing a pterional approach compared to a frontal sinus approach for ACF DAVFs. Firstly, there was no need for frontal sinus reconstruction, resulting in fewer cosmetic consequences for the patient. Additionally, the exposure of the surgical site was sufficient and easily achievable. The pterional route provided an excellent perpendicular view of the fistula located on the cribriform plate. Furthermore, as previously described by Jang et al., evacuating the cerebrospinal fluid naturally causes the frontal brain lobe to move dorsally from the frontal skull base, thereby creating a larger working space [2]. These advantages highlight the potential benefits and favorable outcomes associated with the pterional approach in the surgical management of ACF DAVFs.

4. Conclusion

Anterior cranial fossa DAVFs continue to present a significant surgical indication due to their high risk of hemorrhage. While endovascular embolization is often considered the standard of care for fistulas, the complex arterial supplies and anatomical variations associated with ACF DAVFs make surgery an important treatment modality to consider. Given the available treatment options, we believe that surgical management should be regarded as the primary therapy for comparable ACF DAVFs, primarily due to its low complication risks and high rates of fistula obliteration. Traditionally, extensive frontal sinus exposure has been employed to directly access the cribriform plate and anterior cranial fossa lesions. However, we present a case where a minimally invasive indirect pterional approach to the fistula proved to be a safe surgical option with reduced complications and risks. Both cases demonstrate successful surgical management of ACF DAVFs using different approaches, highlighting the importance of individualized treatment decisions and the effectiveness of surgical interventions in achieving complete obliteration of the fistula.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] M. Soderman, et al., Natural history of dural arteriovenous shunts, Stroke 39 (6) (2008) 1735–1739.
[2] J.H. Jang, et al., Surgical Obliteration of Anterior Cranial Fossa Dural Arteriovenous Fistulas via Unilateral High Frontal Craniotomy, World Neurosurg. 130 (2019) 89–94.
[3] L. Mayfrank, et al., Microsurgical interhemispheric approach to dural arteriovenous fistulas of the floor of the anterior cranial fossa, Minim Invasive Neurosurg. 39 (3) (1996) 74–77.
[4] I. Wanke, D.A. Rufenacht, The Dural AV-Fistula (DAVF), the Most Frequent Acquired Vascular Malformation of the Central Nervous System (CNS), Clin. Neuroradiol. 25 (Suppl 2) (2015) 325–332.
[5] D. Varnagy, N. Labropoulos, The issue of spontaneous arteriovenous fistulae after superficial thrombophlebitis, endovenous ablations, and deep vein thrombosis: an unusual but predictable finding, Perspect. Vasc. Surg. Endovasc. Ther. 18 (3) (2006) 247–250.
[6] M. Nishijima, et al., Etiological evaluation of dural arteriovenous malformations of the lateral and sigmoid sinuses based on histopathological examinations, J. Neurosurg. 76 (4) (1992) 600–606.
[7] V.V. Halbach, et al., Dural arteriovenous fistulas supplied by ethmoidal arteries, Neurosurgery 26 (5) (1990) 816–823.
[8] M. Kohama, et al., Anterior cranial fossa dural arteriovenous fistula with bilateral cortical drainers–case report, Neurol. Med. Chir. (Tokyo) 50 (3) (2010) 217–220.
[9] P. Meneghelli, et al., Surgical treatment of anterior cranial fossa dural arteriovenous fistulas (DAVFs): a two-centre experience, Acta Neurochir. (Wien) 159 (5) (2017) 823–830.
[10] J.M. Abrahams, et al., Alternative management considerations for ethmoidal dural arteriovenous fistulas, Surg. Neurol. 58 (6) (2002) 410–416, discussion 416.
[11] R. Agid, et al., Management strategies for anterior cranial fossa (ethmoidal) dural arteriovenous fistulas with an emphasis on endovascular treatment, J. Neurosurg. 110 (1) (2009) 79–84.
[12] A.M. Spiotta, et al., Transfemoral venous approach for Onyx embolization of anterior fossa dural arteriovenous fistulae, J. Neurointerv. Surg. 6 (3) (2014) 195–199.
[13] W.J. Mack, et al., Endovascular management of anterior cranial fossa dural arteriovenous malformations. A technical report and anatomical discussion, Interv. Neuroradiol. 17 (1) (2011) 93–103.
[14] X. Lv, et al., Endovascular embolization of dural arteriovenous fistulas of the anterior cranial fossa: three case reports, Neurol. Res. 30 (8) (2008) 852–859.
[15] J.P. Deng, et al., Embolization of dural arteriovenous fistula of the anterior cranial fossa through the middle meningeal artery with Onyx, Clin. Neurol. Neurosurg. 117 (2014) 1–5.
[16] L. Defreyne, et al., Transvenous embolization of a dural arteriovenous fistula of the anterior cranial fossa: preliminary results, AJNR Am. J. Neuroradiol. 21 (4) (2000) 761–765.
[17] D. Ding, et al., Interhemispheric approach for endoscopic ligation of an anterior cranial fossa dural arteriovenous fistula, J. Clin. Neurosci. 22 (12) (2015) 1969–1972.
[18] U.K. Kakarla, et al., Surgical treatment of high-risk intracranial dural arteriovenous fistulae: clinical outcomes and avoidance of complications. Neurosurgery 61(3) (2007) 447-457; discussion 457-9.
[19] M.T. Lawton, et al., Ethmoidal dural arteriovenous fistulae: an assessment of surgical and endovascular management, Neurosurgery 45(4) (1999) 805-810; discussion 810-1.

[20] J. van Beijnum, et al., Outcome after spontaneous and arteriovenous malformation-related intracerebral haemorrhage: population-based studies, Brain 132 (Pt 2) (2009) 537–543.
[21] E. Magro, D. Engel, M.W. Bojanowski, Transfrontal sinus approach for an anterior cranial fossa, ethmoidal, dural arteriovenous fistula, Surg. Neurol. Int. 5 (2014) 172.
[22] J.R. Linzey, et al., Frontal Sinus Breach During Routine Frontal Craniotomy Significantly Increases Risk of Surgical Site Infection: 10-Year Retrospective Analysis, Neurosurgery 81 (3) (2017) 504–511.
[23] K. Meetze, J.N. Palmer, R.J. Schlosser, Frontal sinus complications after frontal craniotomy, Laryngoscope 114 (5) (2004) 945–948.
[24] D. Mielke, et al., The anterior interhemispheric approach: a safe and effective approach to anterior skull base lesions, Acta Neurochir. (Wien) 156 (4) (2014) 689–696.
[25] D.V. White, E.H. Sincoff, S.I. Abdulrauf, Anterior ethmoidal artery: microsurgical anatomy and technical considerations, Neurosurgery 56(2 Suppl) (2005) 406-410; discussion 406-10.
[26] S. Terasaka, et al., Anterior interhemispheric approach for tuberculum sellae meningioma, Neurosurgery 68(1 Suppl Operative) (2011) 84-88; discussion 88-9.
[27] R.T. Wicks, et al., Mini-pterional approach for clip ligation of ethmoidal dural arteriovenous fistula, Neurosurg. Focus 46 (Suppl_2) (2019) V9.