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# EFFICACY OF ENDOVASCULAR INTERVENTIONS IN INTRACRANIAL DURAL ARTERIOVENOUS FISTULAS: A SYSTEMATIC REVIEW

ABDULLAH ALI ALQARNI
ASSISTANT PROFESSOR OF RADIOLOGY, DEPARTMENT OF INTERNAL MEDICINE, COLLEGE OF MEDICINE, UNIVERSITY OF BISHA, KINGDOM OF SAUDI ARABIA.
EMAIL: almohsen@ub.edu.sa; ORCID ID: 0009-0003-1923-4026

**Objectives:** To evaluate the efficacy and safety of endovascular interventions for the treatment of intracranial intracranial dural arteriovenous fistulas (DAVFs). **Methods:** A thorough search across four databases identified 881 relevant publications. After removing duplicates using Rayyan QCRI and screening for relevance, 475 full-text articles were reviewed, with 7 studies ultimately meeting the criteria for inclusion. **Results:** We included seven studies with a total of 455 patients and less than half of them 213 (46.8%) were females. Endovascular therapy can effectively block DAVFs, with rates ranging from 57.6% to 97.8%. The review emphasizes the relative safety of endovascular treatments for dural arteriovenous fistulas, with multiple studies showing low mortality rates. Despite this, concerns about procedure-related morbidity in certain cases, particularly where mortality is higher, highlight the risks linked to the technical and anatomical complexities of these procedures. Nonetheless, endovascular therapy is still considered a preferred initial treatment when surgery is not viable, advocating for continued improvements and tailored approaches to maximize safety and effectiveness. **Conclusion:** Endovascular treatment for intracranial DAVFs is a promising surgical alternative, demonstrating high success rates in obliteration and low mortality. However, the variability in morbidity rates highlights the need for enhanced techniques and better patient selection. Future studies, including prospective and randomized controlled trials, are essential to refine the use of endovascular therapies, improve patient outcomes, and reduce healthcare burdens.

**Keywords:** Endovascular approach; Intracranial; Cerebral; Dural; Arteriovenous fistulas; Systematic review.

## INTRODUCTION

DAVFs represent abnormal linkages between dural arteries and either a dural venous sinus or a cortical (leptomeningeal) vein, making up 10–15% of all intracranial vascular abnormalities [1], [2]. These account for approximately 6% of arteriovenous malformations (AVMs) above the tentorium and 35% below it [2]. Typically fueled by meningeal arteries, DAVFs may also involve the recruitment of pial vessels as the fistula enlarges, leading to enhanced shunting [3]. The fistulous connections generally occur within the dura mater's leaflets, located either in a venous sinus or plexus, with potential for transdural, backward flow into cortical and/or leptomeningeal veins [4]. Occasionally, the primary drainage of the fistula is through a channel likely situated within the dural wall of the sinus, with subsequent flow into the main sinus and/or cortical veins [5], [6].

The origins of DAVFs are diverse, with potential causes including trauma, surgical interventions, complications following aneurysmal ruptures, spontaneous occurrences, congenital factors, and unknown reasons [7]. While initially thought to be congenital, evidence accumulated over the past three decades suggests that DAVFs may develop as acquired conditions due to venous outflow impairments [8]. The predominant theory is that most DAVFs arise due to venous thrombosis or stenosis. Additionally, hormonal influences are also considered potential contributing factors [4].

Recent enhancements in endovascular methods now permit initial exploration of DAVFs via endovascular approaches, primarily aiming for embolization to achieve complete obliteration [9]. Endovascular embolization has emerged as the primary treatment strategy for all patients with high-risk DAVFs, with surgical interventions considered only when endovascular options are ineffective or not possible. The objective of transarterial embolization is to reduce blood flow, which aids in defining the lesion’s angioarchitecture and the draining arterialized veins, setting the stage for potential surgery or transvenous embolization [9, 10]. Moreover, transvenous

embolization, especially using coiling at the most proximal venous outlet, is recognized as a safe and definitive endovascular treatment for aggressive DAVFs [11, 12].

The evolution of endovascular techniques has transformed the treatment landscape, offering potentially less invasive and more effective interventions. Despite these advances, there remains a need to systematically evaluate the efficacy and safety of endovascular treatments for DAVFs. Given the variability in treatment outcomes and the critical nature of these lesions, a comprehensive review of recent and past studies can provide valuable insights into optimal therapeutic strategies and improve patient outcomes. The objective of this systematic review is to evaluate the efficacy and safety of endovascular interventions for the treatment of intracranial DAVFs.

## METHODS

The PRISMA and GATHER criteria were met by the systematic review.

### SELECTION CRITERIA:

### INCLUSION CRITERIA

1. Peer-reviewed research articles, including randomized controlled trials, cohort studies, case-control studies, retrospective analyses, cross-sectional studies, and case-series that evaluate the efficacy and safety of endovascular interventions for intracranial DAVFs.
2. Studies involving patients diagnosed with intracranial DAVFs, irrespective of age, sex, or severity of condition.
3. Articles detailing endovascular treatment modalities such as embolization, coiling, and stenting specifically for DAVFs.
4. Studies must report on one or more of the following outcomes: obliteration rates, symptomatic relief, and long-term patient follow-up.
5. Studies published within the last 20 years, to ensure the review incorporates contemporary endovascular techniques and outcomes.
6. Articles published in English.

### EXCLUSION CRITERIA

1. Abstracts, conference presentations, editorials, and expert opinions that have not undergone peer review.
2. Studies that do not specifically address endovascular interventions for DAVFs or include a broad spectrum of vascular malformations without separately analyzing DAVFs.
3. Studies that do not provide specific outcome measures related to the efficacy and safety of the endovascular treatments, such as those lacking follow-up or detailed complication rates.
4. Research involving animal models, as the focus is on clinical outcomes in human patients.
5. Multiple publications reporting the same patient cohorts or overlapping datasets, where only the most comprehensive or recent study will be included to avoid data redundancy.

### SEARCH STRATEGY

A thorough search was undertaken to locate relevant studies on the efficacy and safety of endovascular interventions for the treatment of intracranial DAVFs. The reviewers looked at four electronic databases: PubMed, Cochrane, Web of Science, and SCOPUS. We uploaded all of the titles and abstracts identified through electronic searches into Rayyan, removing any duplicates. All texts from papers that met the inclusion criteria based on title or abstract were collected and thoroughly inspected. Two reviewers independently evaluated the appropriateness of the extracted publications and resolved any contradictions through discussion.

## DATA EXTRACTION

Two unbiased reviewers retrieved data from studies that met the inclusion criteria in a consistent and established format. The following information was retrieved and recorded: (i) First author (ii) Year of publication, (iii) Study design, (iv) Country, (v) Sample size, (vi) Gender, (vii) Age (viii) Complete occlusion (CO) rate, (ix) Mortality rate, (x) Main outcomes (effectiveness and safety).

## RISK OF BIAS ASSESSMENT

We utilized the ROBINS-I technique to evaluate the risk of bias because it allows for extensive assessment of confounding, which is significant because bias owing to omitted variables is common in studies in this field. The ROBINS-I tool is intended to evaluate non-randomized investigations and can be applied to cohort designs in which participants exposed to various staffing levels are monitored over time. Two reviewers separately assessed the risk of bias for each paper, and disagreements were resolved through group discussion [13].

# RESULTS

The specified search strategy yielded 881 publications **(Figure 1).** After removing duplicates (n = 406), 475 trials were evaluated based on title and abstract. Of these, 397 failed to satisfy eligibility criteria, leaving just 74 full-text articles for comprehensive review. A total of 8 satisfied the requirements for eligibility with evidence synthesis for analysis.

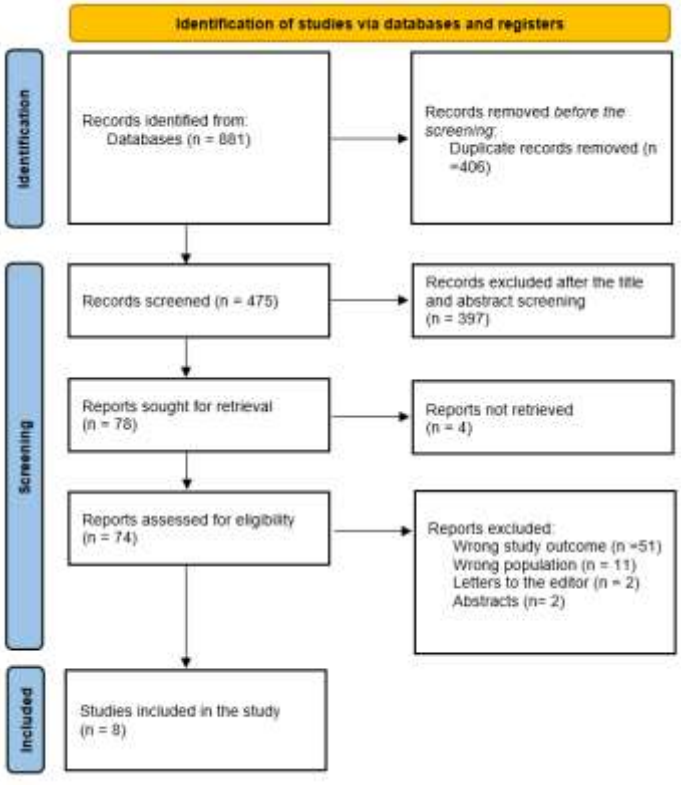


**Figure (1): PRISMA flowchart [14].**

## SOCIODEMOGRAPHIC AND CLINICAL OUTCOMES

We included seven studies with a total of 455 patients and less than half of them 213 (46.8%) were females. Regarding study designs, seven were retrospective cohorts [15-19, 21, 22], and one was a case-series [20]. The earliest study was conducted in 2014 [15, 21, 22] and the latest in 2024 [17].

Several studies highlighted high CO rates, indicating that endovascular therapy can effectively block DAVFs, with rates ranging from 57.6% [16] to 97.8% [21]. Moreover, the safety profile of these interventions is notable, with several studies reporting low mortality rates, emphasizing the reduced risk associated with endovascular procedures compared to more invasive methods [15, 18, 22].

However, the review also notes considerable procedure-related morbidity in some cases, particularly in studies with higher mortality rates [16]. This underscores the potential risks of endovascular treatments, which may include complications due to the nature and location of the fistula, as well as the technical aspects of the intervention. Despite these risks, the overall trend suggests that endovascular treatment is a viable first-line therapy for managing DAVFs, particularly when surgery is not feasible. The findings support the continued use and refinement of endovascular techniques, ideally tailored to the specifics of each case to maximize safety and efficacy [15, 16, 18, 21, 22].

TABLE (1): Outcome measures of the included studies.

| Study ID | Country | Study design | Sociodemographic | CO rate (%) | Mortality rate (%) | Safety and effectiveness |
|---|---|---|---|---|---|---|
| Rangel-Castilla et al., 2014 [15] | USA | Retrospective cohort | Participants: 53<br>Mean age: 56<br>Females: 17 (32%) | 92.1% | 3.8% | An initial angiographic cure can be achieved safely and effectively with endovascular Onyx embolization, according to preliminary data. |
| Kim et al., 2022 [16] | Korea | Retrospective cohort | Participants: 33<br>Mean age: 60.1<br>Females: 27 (81.8%) | 57.6% | 27.3% | In the treatment of patients with symptomatic cavernous sinus DAVF without ophthalmological emergency, we found that EVT is effective, though there is a high procedure-related morbidity and mortality rate. |
| Nedeljkovic et al., 2024 [17] | Serbia | Retrospective cohort | Participants: 19<br>Mean age: 54<br>Females: 6 (31.6%) | 68.4% | NM | This study adds to the increasing amount of data demonstrating the effectiveness and security of endovascular therapies for DAVF. |
| Maus et al., 2020 [18] | Germany | Retrospective cohort | Participants: 50<br>Median age: 61<br>Females: 28 (44%) | 92% | 0 | With high rates of CO, endovascular treatment of intracranial DAVFs is practical, secure, and efficient. After a single surgery, the DAVF was fully blocked in almost half of the patients. However, it was more common to need more than one session for tentorial DAVFs. |
| Sorteberg et al., 2022 [19] | Norway | Retrospective cohort | Participants: 67<br>Mean age: 54.4<br>Females: 32 (48%) | 60% | NM | EVT was the primary treatment for most DAVFs in the study, comprising 91% of kinds I/II and 79% of non-hemorrhagic cases. |
| Kortman et al., 2019 [20] | Netherlands | Case-series | Participants: 14<br>Mean age: 61<br>Females: 12 (85.7%) | 71.4% | NM | All patients' symptoms were resolved after receiving endovascular therapy and care for DAVFs with antegrade sinus leakage. |
| Pashapour et al., 2014 [21] | Iran | Retrospective cohort | Participants: 46<br>Mean age: 36.1<br>Females: 16 (35%) | 97.8% | 2.2% | For patients who were not eligible for conservative therapy, endovascular care of DAVF is safe and effective in producing both an initial angiographic cure and a long-term clinically cure. |

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|---|---|---|---|---|---|---|
| Baltsavias & Valavanis, 2014 [22] | Switzerland | Retrospective cohort | Participants: 173<br>Mean age: 56.3<br>Females: 75 (43.4%) | 85.8% | 0 | For DAVFs, endovascular embolization is the preferred treatment. Few embolization procedures per patient are necessary to produce a high percentage of anatomical cure or subtotal-extensive occlusion of the lesion with even greater rates of outstanding clinical results and a very low surgical complication rate. |

TABLE (2): RISK OF BIAS ASSESSMENT USING ROBINS-I

| Study ID | Bias due to confounding | Bias in the selection of participants into | Bias in the classification of interventions | Bias due to deviations from the intended interval | Bias due to missing data | Bias in the measurement of outcomes | Bias in the selection of reported result | Overall bias |
|---|---|---|---|---|---|---|---|---|
| Rangel-Castilla et al., 2014 [15] | Low | Low | Mod | Low | Low | Low | Mod | Low |
| Kim et al., 2022 [16] | Mod | Low | Low | Low | Low | Mod | Low | Low |
| Nedeljkovic et al., 2024 [17] | Low | Low | Mod | Low | Low | Low | Mod | Low |
| Maus et al., 2020 [18] | Low | Low | Mod | Low | Low | Low | Mod | Low |
| Sorteberg et al., 2022 [19] | Mod | Mod | Low | Low | Low | Mod | Mod | Moderate |
| Kortman et al., 2019 [20] | Mod | Mod | Mod | Low | Mod | Mod | Low | Moderate |
| Pashapour et al., 2014 [21] | Mod | Mod | Low | Low | Low | Mod | Mod | Moderate |
| Baltsavias & Valavanis, 2014 [22] | Mod | Mod | Low | Low | Low | Mod | Mod | Moderate |

## DISCUSSION

The systematic review underscores the general effectiveness and safety of endovascular treatments for intracranial DAVFs, with obliteration rates reported between 57.6% to 97.8%. These interventions also show a favorable safety profile, with low mortality rates highlighting their advantages over more invasive surgical methods. However, there is notable variability in procedure-related morbidity, especially in studies that report higher mortality rates. Despite these risks, endovascular treatments are recommended as a primary treatment option for DAVFs, especially when surgical approaches are not viable. The findings advocate for ongoing refinement and careful tailoring of endovascular techniques to optimize both safety and efficacy.

Alexandre et al., reported that the most popular endovascular procedure is transvenous coiling, which has a very low risk of complications and a high proportion of radiological and clinical resolution [23]. Selective transarterial embolization involves positioning the microcatheter into the distal part of the feeding artery to ensure that the embolic material effectively reaches the nidus and is pushed into the most proximal venous outlet. The aim of this process is to seal the shunt at the fistula site, with the embolic material extending into the venous side [24]. If the embolization is performed too proximally, it can allow ongoing arterial flow and the recruitment of collateral circulation, increasing the likelihood of recanalization. Conversely, if the embolization is too distal, it risks causing venous occlusion which can exacerbate venous hypertension [25]. Additionally, the most aggressive types of DAVFs, especially those with exclusively leptomeningeal drainage, receive blood from numerous feeders, including pachymeningeal branches from cerebral vessels. Occluding these vessels could potentially lead to a stroke, as they also supply normal brain tissue [26, 27].

As endovascular therapies have improved due to technological advancements, so too has the treatment of dural AVFs. Transarterial and transvenous embolization of dural AVFs are now the standard initial treatments due to the availability of novel endovascular therapies like Onyx, adhesive, and more navigable microcatheters. Although additional research is needed to further refine their specifications and indications, covered stents have recently emerged as a promising therapeutic approach to treat CCFs [28].

Clinically, these findings underscore the importance of advancing endovascular techniques and training to enhance safety and outcomes. The efficacy of endovascular treatment in achieving obliteration of DAVFs suggests that with appropriate technological and procedural developments, these methods could further diminish the need for invasive surgery. Medical professionals should consider endovascular treatment as a primary approach, particularly in patients at higher surgical risk or where DAVFs are located in anatomically challenging positions.

### STRENGTHS

The strengths of this review include a comprehensive aggregation of data from multiple studies across different populations and geographic locations, which provides a broad perspective on the outcomes of endovascular treatment for DAVFs. This approach allows for a nuanced understanding of how these treatments perform in diverse clinical settings.

### LIMITATIONS

However, the review also has limitations. Most of the included studies are retrospective and cohort-based, which could introduce selection bias and limit the generalizability of the findings. The variation in study designs and methodologies also makes it challenging to perform a meta-analysis, which could provide more definitive conclusions about the effectiveness and safety of these treatments.

## CONCLUSION

In conclusion, endovascular treatment for intracranial DAVFs offers a promising alternative to surgery, with high rates of success in terms of obliteration and generally low mortality rates. However, the significant variability in morbidity rates associated with these procedures calls for ongoing improvements in technique and patient selection criteria. Future research should focus on prospective studies and randomized controlled trials to better define the optimal use of endovascular therapies in the management of DAVFs, enhancing patient outcomes and reducing healthcare burdens.

## REFERENCES:

1. Luessenhop A. Dural arteriovenous malformations and intracranial hemorrhage. In: Wilkins RHRSe, editor. Neurosurgery. New York: McGraw-Hill; 1986. p. 1473–7.
2. Newton TH, Cronqvist S. Involvement of dural arteries in intracranial arteriovenous malformations. Radiology 1969;93(November (5)):1071–8.
3. Lawton MT, Jacobowitz R, Spetzler RF. Redefined role of angiogenesis in the pathogenesis of dural arteriovenous malformations. Journal of Neurosurgery 1997;87(August (2)):267–74.
4. Nishijima M, Takaku A, Endo S, Kuwayama N, Koizumi F, Sato H, et al. Etiological evaluation of dural arteriovenousmalformations ofthe lateral and sigmoid sinuses based on histopathological examinations. Journal of Neurosurgery 1992;76(April (4)):600–6.
5. Caragine LP, Halbach VV, Dowd CF, Ng PP, Higashida RT. Parallel venous channel as the recipient pouch in transverse/sigmoid sinus dural fistulae. Neurosurgery 2003;53(December (6)):1261–6, discussion 6–7.
6. Sarma D,terBruggeK.Management ofintracranialdural arteriovenous shunts in adults. European Journal of Radiology 2003;46(June (3)):206–20.
7. Friedman A. Dural arteriovenous malformations. Park Ridge, IL: AANS; 1993.
8. Aboian MS, Daniels DJ, Rammos SK, Pozzati E, Lanzino G. The putative role of the venous system in the genesis of vascular malformations. Neurosurgical Focus 2009;27(November (5)):E9.

9. Woo HH, Masaryk TJ, Rasmussen PA. Treatment of dural arteriovenous malformations and fistulae. In: Levy EI, Guterman LR, Hopkins NL, editors. Neurosurgery clinics of North America, vol. 16, no. 2. Philadelphia: W.B. Saunders; 2005. p. 381–93.
10. Liu JK, Dogan A, Ellegala DB, Carlson J, Nesbit GM, Barnwell SL, et al. The role of surgery for high-grade intracranial dural arteriovenous fistulas: importance of obliteration of venous outflow. Journal of Neurosurgery 2009;110(May (5)):913–20.
11. Defreyne L, Vanlangenhove P, Vandekerckhove T, Deschrijver I, Sieben G, Klaes R, et al. Transvenous embolization of a dural arteriovenous fistula of the anterior cranial fossa: preliminary results. American Journal of Neuroradiology 2000;21(April (4)):761–5.
12. Kallmes DF, Jensen ME, Cloft HJ, Kassell NF, Dion JE. Percutaneous transvenous coil embolization of a Djindjian type 4 tentorial dural arteriovenous malformation.AmericanJournal of Neuroradiology 1997;18(April(4)):673–6.
13. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, Henry D, Altman DG, Ansari MT, Boutron I, Carpenter JR. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. bmj. 2016 Oct 12;355.
14. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA, Prisma-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic reviews. 2015 Dec;4:1-9.
15. Rangel-Castilla L, Barber SM, Klucznik R, Diaz O. Mid and long term outcomes of dural arteriovenous fistula endovascular management with Onyx. Experience of a single tertiary center. Journal of NeuroInterventional Surgery. 2014 Oct 1;6(8):607-13.
16. Kim MJ, Hong SW, Kim DJ, Kim BM, Kim YB, Chang WS, Park KY. Efficacy and safety of stereotactic radiosurgery versus endovascular treatment for symptomatic cavernous sinus dural arteriovenous fistula without ophthalmological emergency: a single-center 10-year experience. Journal of neurosurgery. 2022 Dec 2;139(1):139-49.
17. Nedeljkovic Z, Vukasinovic I, Petrovic M, Nedeljkovic A, Nastasovic T, Bascarevic V, Micovic M, Milicevic M, Milic M, Jovanovic N, Stanimirovic A. Comparison of a Novel Liquid Embolic System with Commonly Used Embolic Agents in the Endovascular Treatment of Intracranial Dural Arteriovenous Fistulas: A Single-Center Experience. Journal of Clinical Medicine. 2024 Oct 2;13(19):5899.
18. Maus V, Drescher F, Goertz L, Weber A, Weber W, Fischer S. Endovascular treatment of intracranial dural arteriovenous fistulas: a German single-center experience. Cerebrovascular Diseases Extra. 2020 Sep 1;10(2):84-93.
19. Sorteberg W, Sorteberg A, Jacobsen EA, Rønning P, Nome T, Eide PK. Endovascular versus surgical treatment of cranial dural arteriovenous fistulas: a single-center 8-year experience. Acta Neurochirurgica. 2022 Jan 1:1-1.
20. Kortman H, Boukrab I, Sluzewski M, van Rooij WJ, Peluso JP, Majoie C. Endovascular treatment of dural arteriovenous fistulas with sinus drainage: Do we really need to protect the sinus?. Interventional Neuroradiology. 2019 Jun;25(3):315-21.
21. Pashapour A, Mohammadian R, Salehpour F, Sharifipour E, Mansourizade R, Mahdavifard A, Salehi M, Mirzaii F, Sariaslani P, Ardalani GF, Davaraltafi GF. Long-term endovascular treatment outcome of 46 patients with cavernous sinus dural arteriovenous fistulas presenting with ophthalmic symptoms: a non-controlled trial with clinical and angiographic follow-up. The Neuroradiology Journal. 2014 Aug;27(4):461-70.
22. Baltsavias G, Valavanis A. Endovascular treatment of 170 consecutive cranial dural arteriovenous fistulae: results and complications. Neurosurgical review. 2014 Jan;37:63-71.
23. Alexandre AM, Sturiale CL, Bartolo A, Romi A, Scerrati A, Flacco ME, D'Argento F, Scarcia L, Garignano G, Valente I, Lozupone E. Endovascular treatment of cavernous sinus dural arteriovenous fistulas. Institutional series, systematic review and meta-analysis. Clinical Neuroradiology. 2022 Sep;32(3):761-71.
24. van Rooij WJ, Sluzewski M, Beute GN. Intracranial dural fistulas with exclusive perimedullary drainage: the need for complete cerebral angiography for diagnosis and treatment planning. American Journal of Neuroradiology 2007;28(February (2)):348–51.

25. HalbachVV,HigashidaRT,Hieshima GB,WilsonCB,HardinCW,KwanE. Treatment of dural fistulas involving the deep cerebral venous system. American Journal of Neuroradiology 1989;10(March–April (2)):393–9.
26. Halbach VV, Higashida RT, Hieshima GB, Hardin CW. Embolization of branches arising from the cavernous portion of the internal carotid artery. American Journal of Neuroradiology 1989;10(January–February (1)): 143–50.
27. Picard L, Bracard S, Islak C, Roy D, Moreno A, Marchal JC, et al. Dural fistulae of the tentorium cerebelli Radioanatomical, clinical and therapeutic considerations. Journal of Neuroradiology 1990;17(3): 161–81.
28. Santillan A, Nanaszko M, Burkhardt JK, Patsalides A, Gobin YP, Riina HA. Endovascular management of intracranial dural arteriovenous fistulas: a review. Clinical neurology and neurosurgery. 2013 Mar 1;115(3):241-51.