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RESEARCH

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Conventional and old endovascular techniques for vertebral aneurysms still work in the era of flow diversion

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Abstract

Background Endovascular management for vertebral artery dissecting aneurysms (VADA) is quite intricate which thereby necessitate different strategies per case. Our current study described various optimal strategies available for endovascular management of VADA other than flow diverter (FD).

Results 14 Patients presented with acute SAH and 4 patients with symptoms of mass effect. VADA were classified in 3 groups, viz contralateral vertebral artery is dominant group A ($n=5$), co-dominant group B ($n=8$) or group C hypoplastic ($n=5$). Group A and B ($n=13$) was further subdivided into three subtypes depending on location of aneurysm with respect to posterior inferior cerebellar artery (PICA), aneurysm proximal to the PICA, type I ($n=5$); involving the PICA, type II ($n=1$); and distal to the pica, type III ($n=4$). Treatment strategy varied with type whether deconstructive or reconstructive methods using stents and coils in different fashion.

Conclusion Preprocedural angiographic work up delineating the anatomical location of the aneurysm, contralateral vertebral artery dominancy and nearby perforator status along with location of PICA is imperative in selecting the safest and optimal endovascular therapy option.

Keywords Subarachnoid hemorrhage, Vertebral artery dissecting aneurysm, Flow diverter, Parent vessel occlusion

Background

Internal carotid artery or vertebral artery (VA) dissection is responsible for up to 2.5% of all strokes in the general population, but is the most prominent (up to 5–20%) causative factor of stroke in young patients [1]. Intradural VA dissection is the most common among posterior circulation dissections with annual incidence of spontaneous vertebral arterial dissections being around 1 to 1.5 per 100,000 [2–4]. VA dissection has increasingly been acknowledged as a source of stroke and subarachnoid hemorrhage (SAH). VA dissection can be categorized into aneurysmal and steno-occlusive types as per angiographic appearance. Vertebral artery dissecting aneurysm (VADA) of intradural segment presenting with hemorrhage bear a dismal outcome, with evidence of early (within 24 h) repeat hemorrhage being ~ 70% and high mortality of up to ~ 46.7% in patients with repeat rupture [5], emphasizing the necessity of early and aggressive treatment [6, 7].

Treatment strategy is exclusively determined and individualized according to the angio-architecture of the aneurysm and it's relation to major vessels like posterior inferior cerebellar artery (PICA) and anterior spinal artery (ASA). Endovascular therapy is the preferred treatment albeit surgical treatments for VADA like proximal

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occlusion or trapping with or without bypass surgery do exist [8–10]. Surgical procedures are also known to be associated with recurrence, re-bleeding along with ischemic complications and lower cranial nerve palsy. Under emergent circumstances, surgical interventions may carry a relatively high risk of treatment-related morbidity and mortality [11, 12].

Endovascular management for ruptured VADA consists of two major techniques: A reconstructive technique, including stent-assisted coiling (SAC), stent only therapy (SOT) with single or multiple stents & flow diversion (FD), and a Deconstructive technique which includes proximal occlusion of the parent artery and internal coil trapping (Figs. 1 and 2). Reconstructive techniques are favored in patients with a dominant VADA, as these preserve the antegrade blood flow in the involved (dominant) parent artery and perforating vessels. In patients with a non-dominant VADA with or without involving the orifice of the PICA, either reconstructive or deconstructive endovascular treatment could be performed. If

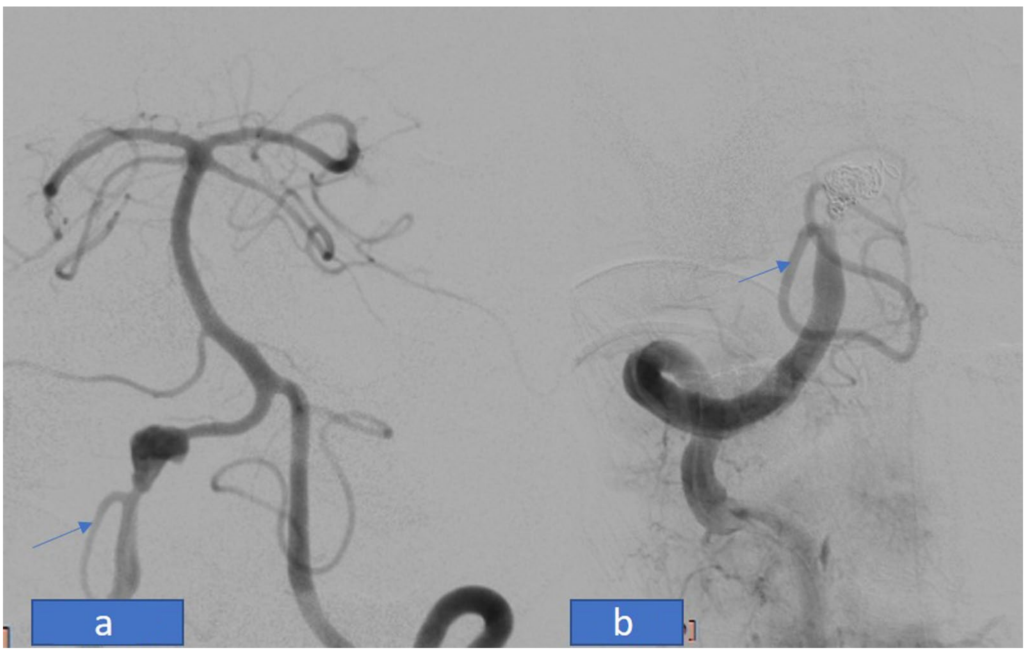


Fig. 1 Dissecting vertebral artery aneurysm (**a**) with PICA (arrow) arising proximal to it was treated with aneurysm coiling and trapping (**b**). PICA is well preserved (arrow in **b**)

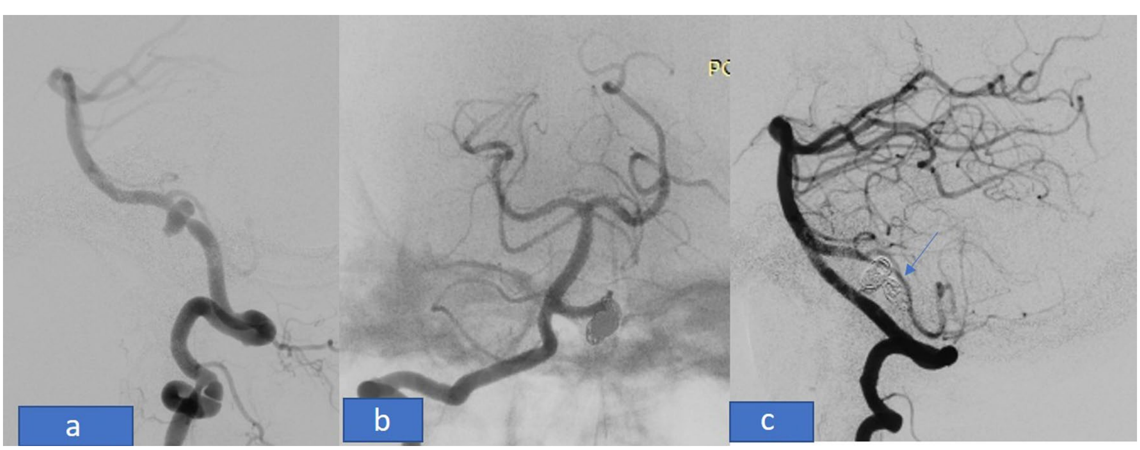


Fig. 2 Co-dominant VA with left VA dissecting aneurysm. PICA origin is distal to the aneurysm (**a**), treated with aneurysm coiling with trapping of parent vessel (**b** and **c**) and PICA origin is well preserved (arrow in **c**)

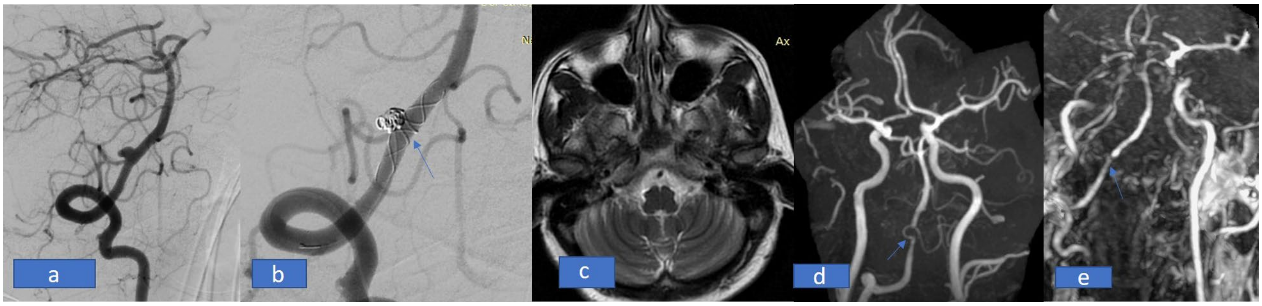


Fig. 3 PICA origin was very close to neck of the aneurysm (**a**), so stent-assisted coiling was done (**b**. with arrow showing stent). Follow-up MRI after 1 year showed no parenchymal changes in cerebellum or brainstem (**c**). TOF MRA shows patent PICA (arrow in **d**). Metallic susceptibility artifact obscuring the flow within the stent but distal VA appears patent and normal (**d**). Contrast MRA showing patent stent (arrow in **e**)

ipsilateral PICA origin is spared then internal trapping with coils is a preferred approach (Figs. 1 and 2). If the ipsilateral PICA origin is involved, then SAC or FD is said to be the preferred technique to preserve the PICA origin (Fig. 3). In treating a non-dominant VADA involving the orifice of the ASA or PICA, SOT with multiple stents or FD could be performed to preserve the antegrade flow of the anterior spinal artery (ASA) and PICA [13]. Treatment options for some particular vascular morphology are not very well addressed in literature viz. where PICA is not seen on the involved side which might be due to hypoplasia, occlusion during dissection or compression due to hematoma.

Endovascular treatment (EVT) with parent vessel occlusion or trapping of VA does also carry a small risk of ischemia but contemporary surgical arm has higher risk. Recent attempts and trials have shown the superiority in post-procedural outcomes in the endovascular treatment cohorts [14].

Current literature suggests good clinical and angiographic outcome with FD for dissecting aneurysm in some particular settings. However it is necessary to adjudge and evaluate all other available endovascular options for managing VADA in variable settings. We, in this study, present the imaging features of intradural VA dissection (with emphasis on angiographic findings), clinical correlation with preferred and feasible neurointerventional treatment options other than FD.

Methods

Retrospective analysis of patients was done from our departmental records for patients with vertebral artery dissecting aneurysm who came to our department between 2013 and 2019. In total, 18 Patients (8 males and 10 females) with VADA were referred to our department for imaging and management. SAH was confirmed by computed tomography (CT) scans in 14 patients. CT angiography (CTA) was performed to assess cerebral vasculature anatomy and to rule out any underlying vascular anomalies in all patients. Presenting symptoms were headache, vomiting, drowsiness and cranial nerve palsy (Table 1). The clinical status of the patients at admission was recorded using Hunt-Hess grading (HHG) system. Fisher grading (FG) system was used to evaluate subarachnoid hemorrhage on CT. All patients underwent 4-vessel digital subtraction angiography (DSA) for confirmation. The diagnosis of dissection was based on classical angiographic findings, such as fusiform dilatation, the "pearl and string" appearance, subintimal flap and irregular luminal narrowing.

Treatment options were based on the morphologic appearance of the aneurysms. Endovascular embolization was done with detachable coils (Axium; medtronics USA, Microplex; Microvention USA and Target; Stryker USA) with or without a stent. We used both laser cut stents like Enterprise by Codman (Johnson and Johnson; USA) and detachable stents like Solitaire (ev3; USA), in telescopic or overlapping fashion (Fig. 4). Braided stents (Baby Leo; Balt, France), were also used adopting both 'stent only' and 'stent-assisted coiling' approach (Fig. 3).

Clinical features

Among the 18 patients, 10 were females and 8 were males. In total, 14 patients among them, presented with acute subarachnoid hemorrhage, and 4 with an acute-onset headache. The clinical status of the patients was documented as per modified Hunt and Hess (H and H) grading system. Four patients were in H and H grade 0, four patients in grade I, three in grade II and seven patients in grade III (Table 1).

Table 1 Table showing clinical features, grading of SAH with angiographic features of vertebral artery dissecting aneurysms in the included patients

S.no.	Age in years /Sex	VA dominancy	Relation to PICA	Treatment done	Angiographic outcome	Clinical outcome	Follow-up period	Complications
1	62/M	contralateral hypoplastic	Distal to pica	Stent assisted coiling	Complete	0	3 and half years	NA
2	17/F	co-dominant	Pica not seen	Parent vessel occlusion, after balloon occlusion test	Incomplete	0	3 months then lost to follow-up	NA
3	39/F	co-dominant	Pica not seen	Overlapping stent-assisted coiling	Complete	0	6 yr	
4	62/M	contralateral VA dominant	Pica proximal to aneurysm	Aneurysm with parent vessel stenting	Complete	1	5 And half yrs	
5	45/F	co-dominant	Pica at same level of aneurysm	Loose packing of aneurysm along with parent artery occlusion	Incomplete	1	3 months then lost to follow-up	
6	60/F	contralateral VA hypoplastic	Pica just proximal to aneurysm	Overlapping stent-assisted coiling	Complete	I	3 yrs	Thrombus within stent, resolved after tirofiban injection
7	45/M	contralateral dominant	Not seen	Trapping of the aneurysm with parent vessel occlusion	Complete	VI, died	3 days after procedure	Thromboembolism in left pca, died after 24 h
8	51/M	co-dominant	Pica Proximal to aneurysm	Aneurysm with parent vessel occlusion	Complete	I	4 and half yrs	Nil
9	72/M	Contralateral VA hypoplastic	Pica distal to aneurysm	Stent assisted coiling	Complete	0	2 years	Nil
10	38/M	co-dominant	Distal to aneurysm	Aneurysm with parent vessel occlusion	Complete	0	2 and half year	Nil
11	54/F	co-dominant	Distal to aneurysm	Overlapping stent-assisted coiling	Complete	0	3 years	Nil
12	42/F	contralateral hypoplastic	Pica just proximal to aneurysm	Stent (leo) assisted coiling	Complete	0	1 and half years	Nil
13	42/M	Codominant	PICA just proximal	1st sitting: only stent	Complete	I	5 Years from 1st sitting	Initially 1st time, stent only was placed, 2nd sitting: as there was regrowth of the aneurysm; aneurysm along with parent vessel was occluded
				2nd sitting trapping of aneurysm with parent vessel occlusion			3 years 2nd sitting	
14	55/F	contralateral dominant	Distal to aneurysm	Only aneurysm coiling	Complete	0	2 years	Nil
15	60/F	contralateral dominant	Pica is distal to aneurysm	Aneurysm with parent vessel occlusion	Complete	0	18 months	Nil

Table 1 (continued)

S.no.	Age in years /Sex	VA dominancy	Relation to PICA	Treatment done	Angiographic outcome	Clinical outcome	Follow-up period	Complications
16	43F	Co dominant	PICA proximal to aneurysm	Aneurysm with parent vessel occlusion	Complete	0	1 yr	Nil
17	59M	Contralateral hypoplastic	PICA just distal to aneurysm	Stent across luminal irregularity	Incomplete	0	3 months	Nil
18	49 F	Contralateral dominant	PICA distal to aneurysm	Aneurysm with parent vessel occlusion	Complete	0	3 months	Nil

Fig. 4 Non-contrast CT head showing sub arachnoid hemorrhage (**a**) with left VADA shown on volumetric CT cranial angiography (arrow in **b**). DSA showing left VADA (**c**) and non-visualization of ipsilateral PICA. Overlapping stent (arrow in **d**) assisted coiling done (**d**). Follow-up DSA after 6 months (**e**) and 2 year (**f**) showed no residual aneurysmal filling

Angiographic results and classification

VADAs were classified into three types depending upon whether contralateral VA is dominant (A), co-dominant (B) or hypoplastic (C). In type A and B, dominant/co-dominant contralateral VA would provide satisfactory cross flow in posterior circulation following ipsilateral VA occlusion. Type A and B aneurysms were further divided into three subtypes depending upon the location of aneurysm in relation to the origin of PICA as follows: aneurysm proximal to the PICA origin (Type I), involving the PICA origin (Type II), and distal to the PICA origin (Type III). Type C included hypoplastic contralateral VA, which is less likely to provide adequate posterior circulation cross flow after an ipsilateral VA occlusion (Tables 2 and 3). In some cases, PICA was not seen at the involved side, which also affected the treatment strategy.

Endovascular therapy

All embolization procedures were performed under general anesthesia. The treatment approach was chosen considering the type of aneurysms as per aforementioned classification. In reconstructive endovascular treatment with a stent, a loading dose of double antiplatelets [300 mg aspirin + 300 mg clopidogrel/60 mg prasugrel] was given via Ryle's tube in Cath Laboratory, before stent deployment. During deconstructive treatment using internal trapping, detachable coils were used to achieve adequate packing with occlusion of adjoining proximal and distal few millimeters of the parent artery.

Results

Out of total 18 patients, 8 were male and 10 were female with mean age of 48 years (12–72 years). The clinical presentations leading to imaging were neurologic deficit ($n=8$), headache ($n=18$), dizziness ($n=6$) and altered behavior ($n=7$). Hypertension was found in 10 patients. No patients had a history of any trauma.

Only aneurysm coiling was done in 1 patient, stent-assisted coiling with single & overlapping stents was done in 3 patients each, parent vessel occlusion was done in 8 patients and stent only treatment was done in 2 cases. On follow-up, one patient underwent trapping of the aneurysm where only stent therapy was done initially and in one patient trapping was done as first-line management (Table 2).

No intra-operative complication was encountered in any of the 18 cases. In 3 patients, PICA was not seen so these could not be classified into type I, II or III (in Table 3). Non-visualization of PICA also affected the treatment strategy.

One patient who underwent overlapping stent-assisted coiling developed thrombus within the stent, which resolved after tirofiban injection (Table 3).

One of the patient treated with stent only approach developed enlargement of the aneurysm on follow-up, who underwent trapping of the aneurysm in second sitting(Figs. 5, 6 and 7).

One patient, in whom trapping of aneurysm was done as the first line of management, deteriorated after 24 h and died. Post-operative NCCT head did not show any evidence of new bleed in that patient (Fig. 8).

One patient presented with additional ICA-Pcom (posterior communicating artery) aneurysm, which was coiled in the same sitting.

One patient had significant (more than 90%) internal carotid artery (ICA) stenosis in the cervical segment, which was treated with carotid angioplasty and stenting after 3 months.

Follow-up protocols

Imaging follow-up was individualized according to each patient's treatment method. Patients managed with a reconstructive technique were followed up with DSA after 3–6 months and 1–2 years of initial treatment.

Table 2 Relationship of vertebral artery aneurysm to ipsilateral PICA, treatment done along with angiographic outcome, complications and follow-up

S.No	Age in years /Sex	Chief complaint	Hunt and Hess grade	Location	Characteristic features	Other findings
1	62/M	Headache, drowsy	III	Left	Luminal irregularity	c/l vertebral hypoplastic, ASA origin at level of aneurysm
2	17/F	Headache and vomiting	0	Right	Fusiform dilatation	Partially thrombosed
3	39/F	Drowsy	III	Left	Luminal irregularity	Preaneurysmal narrowing
4	62/M	Drowsy	III	Right	Luminal irregularity with distal fusiform dilatation	Dual origin of pica
5	45/F	Headache, vomiting	0	Right	Large right V4 aneurysm	
6	60/F	Severe headache	II	Left	Luminal irregularity with fusiform dilatation	ICA stenosis
7	45/M	Drowsy, hemiparesis	III	Left	Fusiform dilatation, left V4 large dissecting aneurysm	Proximal basilar ectatic dilatation
8	51/M	Headache	I	Right V4 dissecting aneurysm	Luminal irregularity with fusiform dilatation	
9	72/M	Headache	I	left	Luminal irregularity	
10	38/M	Headache	I	Left (dissecting flap noted)	Irregularity with dissecting flap	
11	54/F	Severe headache with neck rigidity	II	Right V4	Luminal irregularity with	Additional Right ICA-Pcom aneurysm
12	42/F	Severe headache	II	Right V4	Irregularity with outpouching	
13	42/M	Headache, vomiting, vertigo	0	Left	Fusiform dilatation	
14	55/F	Drowsy	III	Right	Irregularity with our pouching	
15	60/F	Drowsy, focal deficit	III	Left	Luminal irregularity	
16	43F	Headache, drowsy	III	rt	Fusiform dilatation	
17	59M	Headache	I	rt	Luminal irregularity	
18	49 F	Headache	0	rt	Fusiform dilatation	

Table 3 Classifying according to vertebral artery dominance and location of PICA

	Type a and Type b			Type c
	I	II	III	
No of patients	5	1	4	5
Treatment	Aneurysm coiling in 1 case, telescoping stent with coils in 1 case, and parent vessel occlusion in 3 cases	Loose packing of aneurysm with coils and parent vessel occlusion	Aneurysm coiling with parent vessel occlusion in all 4 cases	Stent assisted coiling in 3, telescoping stent with coils and only braided stent in 1 each
Complication	Nil	Nil	Nil	Thrombus within telescoping stent immediate resolved after tirofiban injection in 1 case
Clinical outcome	mRS 0	mRS 1	mRS 1 in 2 and mRS 0 in 1	

Contralateral VA is dominant (A), co-dominant (B) or hypoplastic (C). Aneurysm is proximal to the PICA origin (type I), involving the PICA origin (type II), and distal to the PICA origin (type III). There were total 13 patients in type A and B but in 3 cases PICA was not seen so not included in type I–III classification

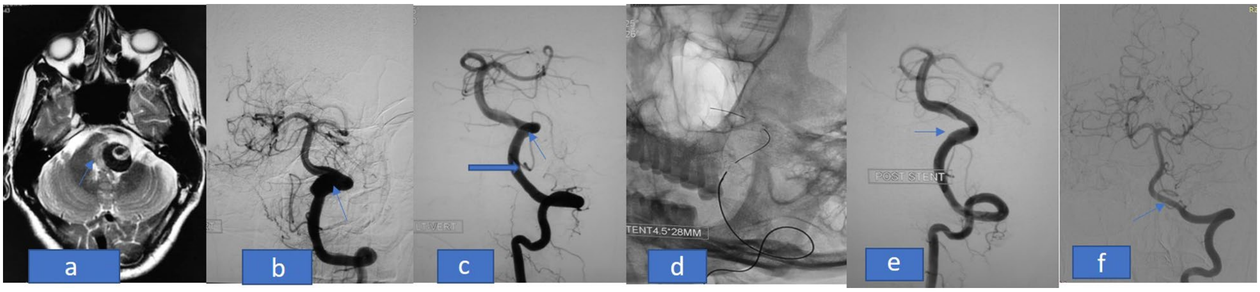


Fig. 5 MRI shows a large partially thrombosed left vertebral artery aneurysm (**a**) exerting loco regional mass effect and adjacent vasogenic edema over the brain stem (arrow in **a**). DSA showed a dissecting fusiform left vertebral artery aneurysm (arrow in **b**). Repeat DSA after 2 weeks showed no filling of the aneurysm (arrow in **c**) with PICA arising proximally to aneurysm (thick arrow in **c**). Patient was treated with stent only approach using Enterprise stent of size 4.5 × 28 mm (**d**) with no residual filling of aneurysm (arrow in **e**). Follow-up DSA after 1 month (**f**) showed no filling of the aneurysm (arrow in **f**)

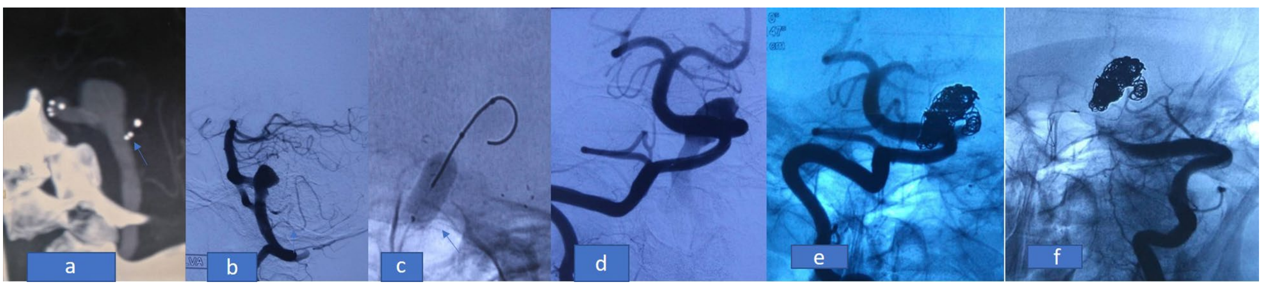


Fig. 6 2 year follow-up of patient shown in Fig. 5. CTA showed enlarged aneurysm with stent embedded within the thrombosed aneurysm (**a**). DSA showed enlarged aneurysm (**b**) and PICA arising just proximal to it (arrow in **b**). Balloon occlusion test (**c**) done with Scepter C balloon of dimension 4 × 15 mm (arrow in **c**). Contralateral VA was co-dominant (**d**), so trapping of the aneurysm done (**e**) with sparing of PICA (**f**)

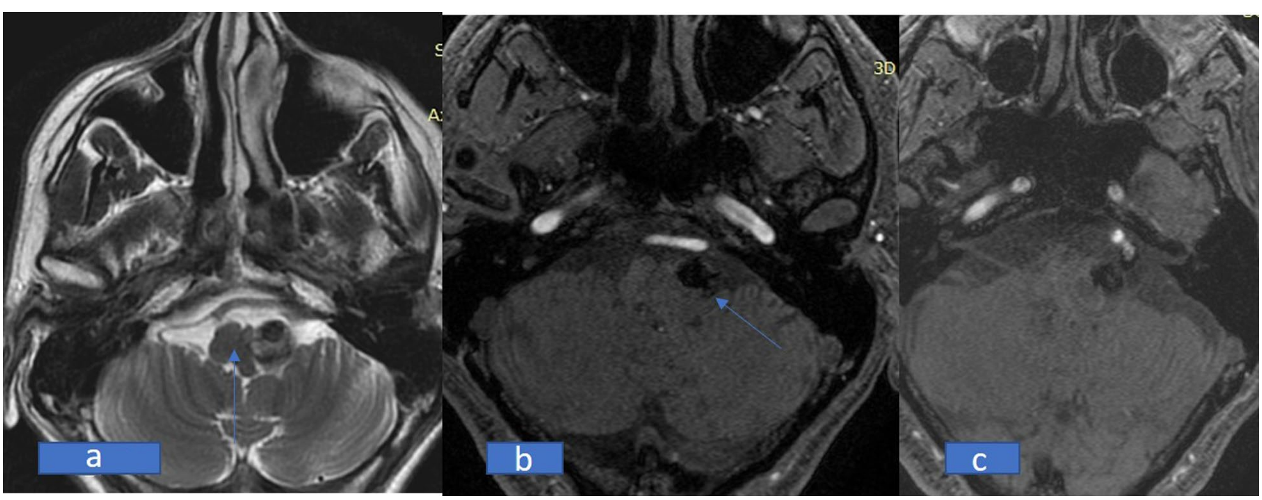


Fig. 7 Follow-up MRI of same patient shown in Fig. 5 and 6. Follow-up MRI after 3 year of aneurysm trapping, showed no obvious mass effect or edema (**a**) as seen earlier. TOF MRA showed coil mass within aneurysm (arrow in **b**) with no residual filling (**c**). No PICA territory infarct noted

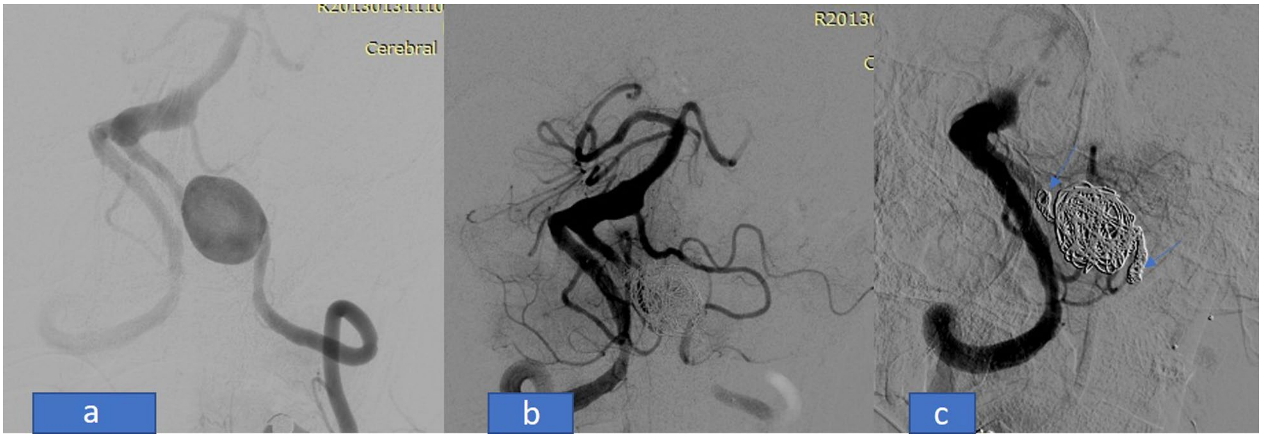


Fig. 8 Large left VADA with non-visualization of left PICA (**a**). Patient was treated with coiling of aneurysm (**b**) along with trapping and parent vessel occlusion (arrow in **c**)

Follow-up magnetic resonance (MR) angiography was performed for patients treated with a deconstructive technique at 6 months and 1 year after treatment. DSA follow-up was reserved for patients treated with a deconstructive technique with suspicious recanalization of the obliterated parent artery on follow-up MR angiography. Imaging follow-up results were classified into two categories: (**1) Stable occlusion,** in which complete obliteration of the dissecting aneurysm was maintained and the residual sac showed no internal change in size and configuration, and (**2) Recurrence**, in which there was evidence of re-bleeding, recanalization after complete obliteration, or increase in the size of the residual sac after partial obliteration. In-stent stenosis or occlusion, and patency of antegrade flow of the parent artery along with perforating vessels covered by stents, were evaluated on follow-up imaging studies. The clinical follow-up results were assessed with a modified Rankin Scale (mRS) during the follow-up period at one year and subsequently. A score of 0–2 on the mRS, indicating that the patient can live an independent life, was categorized as a favorable outcome; while, a mRS score of 3–6 (suggesting dependency) at one year after the procedure was categorized as a poor outcome.

Discussion

Spontaneous VA dissection most frequently involves extradural VA, even though intradural and combined intradural–extradural involvements may also be seen [15–17]. Intradural VA dissection is more likely to develop a pseudoaneurysm with or without subarachnoid hemorrhage than the extradural VA dissection due to absence of external elastic lamina, thinner adventitia and fewer elastic fibers in media [18]. In contrast, steno-occlusive lesions are more common in extradural VA dissection as the subintimal extravasation is usually limited by the thick external elastic lamina. [19, 20].

Imaging and clinical features

CT angiography and MR angiography are non-invasive imaging techniques used in suspected case of arterial dissection. MR angiography has shown promising results in demonstrating imaging signs of dissection such as aneurysmal dilatation, intimal flap, irregular luminal narrowing or occlusion [21]. DSA is the gold standard and demonstrate all imaging features of dissection including pearl and string sign.

Clinical presentation depends on the location of dissection. Extradural VA dissection usually presents with luminal narrowing leading to cerebellar and brainstem ischemic changes while intradural VA dissection frequently presents with subarachnoid hemorrhage (SAH). Vascular dissection can also lead to intraluminal clot formation which can undergo thrombo-embolic episode, occluding distal posterior circulation branches. Classically the extradural VA dissection present as a single neurological event with gradual recovery over a few weeks. Progression, if occurs, is thought to be from thromboembolic episodes. Hence antiplatelet and antithrombotic treatments are recommended in case of an extradural VA dissection [22–24].

Anticoagulation is, however, contraindicated in patients with hemorrhagic infarction or SAH due to intradural VA dissecting aneurysms because the clinical course in these cases may worsen following anticoagulation [25].

Intradural dissection commonly presents with subarachnoid bleed and is associated with high mortality and morbidity due to its ischemic or hemorrhagic complications requiring urgent surgical or endovascular interventions [18, 26, 27].

Management options

Most dissecting aneurysms have ill-circumscribed neck with a fragile aneurysmal wall leading to technical difficulties and risks of rupture when applying a microsurgical neck clip or performing endovascular coil embolization. Conventional surgical clipping is often not effective in obliterating these kinds of aneurysms and is associated with high surgical morbidity due to high incidence of lower cranial nerve involvement. The endovascular intervention has shown promising results as a primary option for treating VA dissecting aneurysms with both **deconstructive and reconstructive** strategies. To prevent the ruptured VADA from re-bleeding, surgical or endovascular proximal occlusion or internal trapping are safe and effective management strategies (Figs. 1 and 2). However, these deconstructive techniques increase the risk of ischemic complications resulting from occlusion of the VA, PICA and perforating arteries, which might have a deleterious effect on the clinical outcome. Revascularization and reconstructive treatments, including bypass surgery, stent-assisted coiling, (Fig. 3) and multiple overlapping stents (in a telescoping fashion) (Fig. 4) are necessary to prevent and minimize ischemic complications. For achieving the best treatment results, which include complete obliteration with preserved distal blood flow, precise individualized treatment planning after careful inspection of angio-architecture in each case is done. We considered the angio-architecture of VADA with respect to the PICA location, VA dominancy and bilateral lesions before planning the treatment strategy [28].

Deconstructive strategies and PICA

Parent vessel trapping is a feasible technique in patients with a contralateral dominant/co-dominant vertebral artery, with possible associated challenges being coil migration, coil under-packing, re-bleed and infarction. Symptomatic infarction in the occluded territory due to the procedure has been reported in 5.3% of patients, with repeat hemorrhage rate of 3.1% [29, 30].

In our experience, for precisely selected patients, trapping appears to be a safe and effective option. One of our patients, whose ipsilateral PICA was not visualized in the pre embolization angiographic images, died suddenly in the post-operative period after 24 h. He underwent coiling of the aneurysm along with trapping of the adjoining vertebral artery segment. Post-operative NCCT did not reveal any evidence of bleed. Tentative cause for the sudden mortality was supposed to be the medullary area infarct. This led us to believe that we should be cognizant of the ipsilateral PICA, which gives medullary perforators. Non-visualization of the PICA is a difficult case scenario, as medullary perforators arising from the proximal part of PICA would be supplied directly from the VA which if occluded can lead to medullary infarcts. Reconstructive option should be preferred in these particular VADA cases where ipsilateral PICA is not seen, presuming its involvement in dissection.

In another similar case where the patient presented with fusiform partially thrombosed VADA with non-visualization of ipsilateral PICA, we did the balloon occlusion test initially, which was very well tolerated by the patient. The patient underwent parent vessel occlusion subsequently. Post embolization angiographic runs from contralateral vertebral artery showed non filling of the aneurysm. The patient is under our regular follow-up without evidence of any morbidity or complication. Flow diverter placement is a feasible option in these particular cases, but this is a costly alternative and requires lifelong oral antiplatelets with long-term imaging follow ups, which also adds to the cost of treatment.

Another interesting case, which needs special mention, presented with fusiform shaped partially thrombosed V4 (intradural) segment aneurysm with mass effect and edema over the brain stem (Fig. 5a). Ipsilateral PICA was arising just proximal to the aneurysmal segment (Fig. 5b). Patient was posted for stent-assisted coiling after 2 weeks, but angiographic runs showed partial resolution of dissection, so only stent was placed across the aneurysm without coiling (Fig. 5c). The patient remained asymptomatic and came for follow-up after 2 years. Follow-up CT angiography showed interval growth of aneurysm with partial thrombosis. Stent was seen embedded within the thrombosed aneurysmal segment (Fig. 6a). Balloon occlusion test was done to look for collateral adequacy from contralateral side which was well tolerated by the patient, followed by trapping of the aneurysmal segment (Fig. 6c). PICA originating proximally to the aneurysmal segment was cautiously salvaged during trapping (Fig. 6f). Follow-up MRI showed resolution of mass effect with no parenchymal infarct (Fig. 7).

Risks associated with deconstructive methods

Trapping the parent vessel should be refrained if the contralateral vertebral artery is hypoplastic or any critical artery such as a PICA, anterior spinal artery (ASA) or medullary perforators arise from or are close to the dissected segment. In one of our patients, where the dissected segment was near the vertebrobasilar junction in close proximity to the origin of the ASA, stent-assisted coiling was done (Tables 1 and 2 in case 1) with a good outcome as trapping of the aneurysm with adjoining arterial segment can lead to catastrophic results due to occlusion of ASA.

Symptomatic infarction is documented in about 38% of patients undergoing parent vessel trapping if PICA arises from the dissected segment [29, 30]. We deliberately avoided trapping the aneurysm with proximate PICA, except in one case where PICA was not seen which ultimately resulted in mortality after trapping. So we suggest reconstructive procedures in these situations to avoid risk of occluding brainstem perforators.

Reconstructive techniques

Reconstructive techniques are befitting in the aforementioned patient category where vital vessel is arising from the dissected segment or dominant VA is dissected. Endoluminal reconstruction also appears to be the most appropriate strategy in unruptured aneurysms, due to the reduced risk of acute bleeding. Meta-analysis shows sac occlusion is better with trapping; however, peri-operative morbidity, mortality, recurrence, retreatment rates and long-term clinical outcomes were similar with both deconstructive and reconstructive techniques [31].

Reconstructive techniques that maintain the blood flow through the parent artery are indicated if vital vessels such as PICA take off from the diseased segment, or if the contralateral VA is insufficient to supply the posterior circulation independently. For all patients in group A (with a contralateral dominant VA), we advised internal trapping of the parent vessel except when the aneurysm involved the PICA origin (subtype II) or when PICA is not seen. PICA occlusion can result in a clinically symptomatic lateral medullary infarct; hence, proximal arterial occlusion could be done in these cases (type 1) so that retrograde flow from the contralateral dominant VA could provide enough blood to the ipsilateral PICA. Proximal coil occlusion carries the risk of post-treatment re-bleeding (type 3) because of the retrograde blood flow into the aneurysm from the contralateral VA with outflow into the ipsilateral PICA [32, 33]. If in type 1 and 3, there is space between PICA and the aneurysm its always better to coil the aneurysm then trap or do proximal vessel occlusion but if the distance is not within safe limits then reconstructive techniques like stent-assisted coiling or overlapping stents or flow diversion should be done as described in literature [34]. The decision to choose between deconstructive versus reconstructive techniques depends upon the local need and interventionist experience and is not very well described in the literature.

According to some previous reports, stent-assisted coiling in dissecting aneurysms, may appears to be less effective than parent vessel trapping given long-term aneurysmal occlusion rates and some of these patients may need additional treatment after the primary procedure [35]. We, in our study, did not found any significant recurrence in stent-assisted coiling.

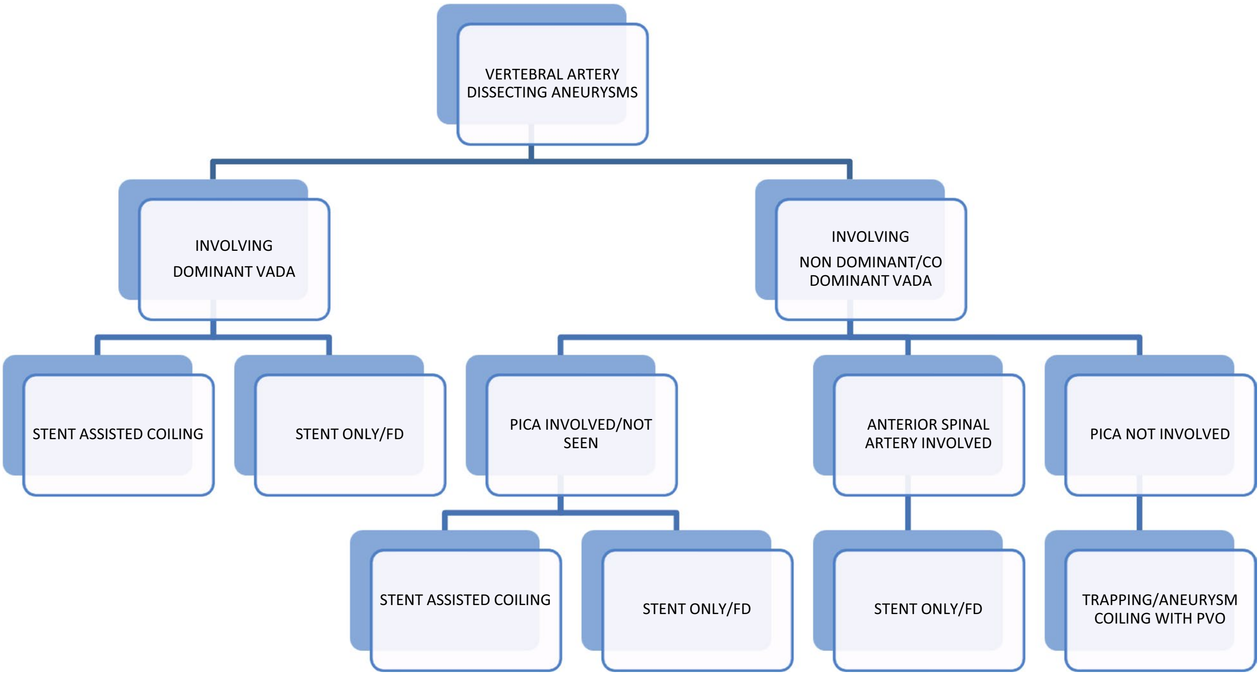
Another feasible option is to use overlapping stents, which provide adequate flow diversion by promoting thrombosis and thus enhances sac occlusion. Braided stents are likely to offer superior redirection of flow as compared to laser cut stents as has been demonstrated in a few experimental models [36]. In our study overlapping stents were employed while using laser cut stents, but braided stents like baby Leo or Leo (Balt, France) were used in isolation as single stent. No recurrence was noted using either type of stents and techniques (Figs. 3 and 4). In one case where stent only therapy was employed using Enterprise stent (laser cut stent, Codman, Johnson and Johnson USA), there was evidence of interval growth of the aneurysm in 2 year follow-up (Figs. 5, 6 and7) which ultimately required a second procedure in form of trapping and parent artery occlusion. Another case in which Leo (Balt, France) has been used as a single stent in isolation, long-term follow-up is still awaited, however early follow-up showed adequate stasis within the aneurysm.

Despite providing better flow diversion, braided stents has less radial force compared to laser cut stent, which is thought to allow for tracking down of intimal flap and straightening of the arterial segment [37, 38].

Current literature has shown promising results with flow diversion with decreased peri-procedural ischemic complications and re-treatment chances [39]. Placing and opening FD in the dissected segment is sometimes very challenging and its use in posterior circulation is still off label.

Dual antiplatelet drugs are necessary with reconstructive techniques to ensure long-term stent patency and to prevent thrombo-embolic complications. Aspirin in combination with clopidogrel, prasugrel or ticagrelor can be used. Patient can be given loading dose on the operating table or over a few days before procedure depending upon the urgency of the procedure [40].

We suggest using the following algorithm in deciding suitable treatment according to vascular and aneurysmal morphology in the patient.



Conclusions

Ruptured VADA should be treated as soon as possible to reduce the chances of re-bleeding and mortality. VADA should be treated with an endovascular technique, based on the status of the contralateral VA and the relation of the aneurysm to the ipsilateral PICA. Both endovascular trapping (deconstructive) and reconstructive techniques are good options for treating ruptured VADA. Parent artery occlusion is a preferred technique in patients with ruptured aneurysms, provided the contralateral vertebral artery has the good caliber and any critical artery (PICA) is not arising from the aneurysmal segment. Stent assisted coiling and flow diverter placement appears promising in dissecting aneurysms where PICA or any significant perforator is seen arising from that segment. PICA should be presumed to be involved if not seen separately adjacent to dissected segment, and these particular cases should be treated with reconstructive techniques. Treatment strategies should be individualized for all cases of VADA as the use of FD is not appropriate and recommended for all cases.

	VS	GC	RVP	SNP	ZN
Concepts	√		√		
Design	√	√			
Definition of intellectual content	√				
Literature search		√		√	
Clinical studies					
Experimental studies					
Data acquisition	√		√	√	
Data analysis	√			√	√
Statistical analysis				√	√
Manuscript preparation	√	√			
Manuscript editing	√	√			√
Manuscript review	√	√	√		
Guarantor	√				

Abbreviations

VADA	Vertebral artery dissecting aneurysm
CTA	Computed tomography angiography
MRA	Magnetic resonance angiography
TOF	Time of flight
DSA	Digital subtraction angiography

MRS	Modified Rankin score
PICA	Posterior inferior cerebellar artery
FD	Flow diverter
VA	Vertebral artery
SAH	Sub-arachnoid hemorrhage
SOT	Stent only therapy
SAC	Stent-assisted coiling
ASA	Anterior spinal artery
EVT	Endovascular therapy
HHG	Hunt and Hess grading
FG	Fisher grading
ICA	Internal carotid artery
PCOM	Posterior communicating
PVO	Parent vessel occlusion

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Declarations

Ethics approval and consent to participate
Ethical approval not required for retrospective analysis, written consent for teaching and publication purposes is obtained before the procedure.

Consent for publication
Not applicable.

Competing interests
Nil.

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