An isolated ruptured spinal aneurysm presents with a thalamic infarct: case report

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Abstract

Background: Isolated spinal artery aneurysms are extremely rare, and their pathogenesis, clinical presentation, and treatment strategies are poorly established. We report only the second case of a patient with an isolated posterior spinal aneurysm and concurrent left thalamic infarct and review the literature to help clarify treatment strategies of isolated spinal aneurysms.

Case presentation: A 49-year-old patient presented with acute onset walking difficulty followed by diaphoresis, back and abdominal pain, and paraplegia. Imaging was notable for a hemorrhagic spinal lesion with compression at T12 through L4 and an acute left thalamic infarct. Surgical exploration revealed an isolated posterior spinal artery aneurysm. The aneurysm was surgically resected and the patient had partial recovery six months post-operatively.

Conclusions: Isolated posterior spinal artery aneurysms of the thoracolumbar region are rare lesions that commonly present with abdominal pain, radiating back pain, and lower extremity weakness. Imaging may not provide a definitive diagnosis. The three primary treatment strategies are conservative management, endovascular treatment, or surgical resection. In patients with symptomatic cord compression, immediate surgical intervention is indicated to preserve neurologic function. In all other cases, the artery size, distal flow, morphology, and location may guide management.

Keywords: Posterior spinal aneurysm, Subarachnoid hemorrhage, Thalamic infarct
concerning for conus medullaris syndrome. Additionally, the patient had right hemi-body sensory loss of light touch and pinprick in the face, upper torso, and arm.

**Imaging**

MRI with MRA of the complete spine demonstrated an intradural cystic and hemorrhagic mass along the left ventrolateral pial surface at the T11-12 level. This lesion was associated with extensive intradural hemorrhage with inferior extension into the lumbar spine (Fig. 1). The imaging findings were highly suggestive of subarachnoid and subdural hemorrhage initially thought to be due to a cavernous malformation vs. AVM. Brain MRI illustrated a T2 FLAIR hyperintense signal within the left thalamus consistent with an acute thalamic infarct. Conventional spinal angiography was negative for evidence of spinal aneurysm.

**Surgical Approach and Pathology**

The following day, a laminectomy was performed at levels T10- L1. The dura was opened and blood was immediately visualized and evacuated from the subdural space. The dura was retracted laterally with subarachnoid blood becoming apparent. The arachnoid was opened and the subarachnoid blood was irrigated and removed using suction. At the left lateral aspect of T11 and T12, there was a hematoma compressing the spinal cord in the subdural space, which was also evacuated with suction. After removal of the hematoma, a nodular vascular lesion at the posterolateral spinal cord likely emanating from the posterolateral spinal artery was visualized, excised, and sent to pathology (Fig. 1c).

Surgical pathology demonstrated a thin segment of vessel wall, positive trichrome stain, and several peripheral reticulin fibers confirming the diagnosis of a spinal aneurysm (Fig. 1d). Post-operatively, the patient had improved sensation and gradually regained strength in the lower extremities. The patient was discharged to the transferring hospital five days after surgery. Six months post-operatively, the patient's sensation and strength had improved but remained unable to walk with movement in the lower extremities limited to the toes.

**Left thalamic infarct**

The left thalamic infarct was treated with standard post-stroke management. The patient was kept permissively

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**Fig. 1** a Balanced steady-state gradient recalled echo sequences demonstrate a 1.7 cm intradural cystic and hemorrhagic mass within the spinal cord at thoracic levels 11 and 12 (arrow). There is associated intradural hemorrhage (arrowhead). b Spinal magnetic resonance angiogram shows a saccular aneurysm (arrow). c Surgical photograph reveals the posterior spinal aneurysm as an extrinsic mass lesion. d Histopathology of the resected aneurysm demonstrates positive reticulin staining.
hypertensive and Atorvastatin was initiated. HgbA1c was within normal range and Aspirin was started on post-operative day number 5; DAPT was not initiated given spinal SAH. The patient underwent a transthoracic echocardiogram and MRA of the neck, which were both unremarkable. The hemi-body sensory loss gradually improved and sensation was back to near baseline at discharge five days later.

Discussion and conclusion

We present a case of a ruptured posterior spinal artery aneurysm with a concurrent left thalamic infarct. This combination of pathologies led to cauda equina syndrome with hemibody sensory loss. To our knowledge, this is the second reported case of an isolated spinal artery aneurysm associated with a left thalamic infarct.

The pathophysiology of isolated spinal artery aneurysms is still under investigation. The majority are associated with vascular malformations, with increased flow through the vessel leading to aneurysm formation [2]. In the absence of a malformation (i.e. isolated spinal aneurysms), dissection has been a proposed mechanism proven by histopathology [3]. These dissections often arise in the setting of a condition that weakens the vessel, such as connective tissue disorders and autoimmune disease [2]. In our case, surgical examination revealed a ruptured thrombosed aneurysm without evidence of dissection on histopathology.

The natural history of isolated spinal aneurysms is unclear due to its rarity. Through a literature review, we found 39 cases of isolated spinal aneurysms from 2011 to 2019 (Table 1). Kim et al. previously found 43 cases as of 2010 [3], bringing the total number to 83 when including our case. Our patient initially presented with radiating back pain, abdominal pain, and lower extremity weakness. This is consistent with previous reports, as the most common symptoms in thoracolumbar spinal aneurysms are sudden onset back pain, weakness, meningism, and abdominal pain [3]. A hemorrhagic lesion was also present on initial imaging, which was confirmed to be a ruptured aneurysm on surgical examination. Hemorrhage occurs at a very high rate in patients with spinal aneurysms associated with AVMs, with one review finding a 100% incidence in 12 patients [4]. Although the data for isolated spinal aneurysms is limited, they are also likely to present with rupture and hemorrhage. In Kim et al.’s review, 36 (84%) presented with rupture [3].

The treatment strategy for spinal aneurysms is also controversial, with three primary strategies being used: (1) surgical resection, (2) endovascular treatment, or (3) conservative management [3]. Some authors have advocated for conservative management given their experience of spontaneous regression [5, 6]. They suggest that compression of the spinal cord from the aneurysm or surrounding blood should be the only indications for intervention. Karakama et al. presented a case of a ruptured anterior spinal artery aneurysm treated conservatively and recommended strict blood pressure control and follow-up imaging to monitor for progression [7]. This aneurysm was located in the anterior cervical region and conservative management was selected due to concern of disturbing blood flow of the parent artery. Longatti et al. presented a case of a patient with multiple anterior spinal artery aneurysms that were treated conservatively [8]. This strategy was selected due to the absence of cord compression, small artery size, and presence of distal flow. Dabus et al. presented a case series of four patients with dissecting spinal aneurysms that were treated conservatively, with the size of the parent artery and tissue supplied being the main determinants [9]. In these cases, the artery size, presence of distal flow, fusiform morphology, and surgical access were factors that favored a conservative approach.

Despite the successful cases with a wait-and-see approach, the overall occurrence of this condition is too limited to draw definite conclusions. There have been five reported cases of a patient dying without surgical intervention, with re-bleeding being the most common cause [10–14]. Early surgical intervention has been proposed for posterior spinal aneurysms due to its superficial location and ability to be resected safely, with all cases resulting in complete resolution [15]. Anterior spinal aneurysms are more difficult to access surgically and provide major blood supply to the spinal cord, which can lead to severe neurologic sequelae if interrupted. In our case, the patient presented with progressive symptoms of spinal cord compression, most notably paraplegia. Imaging did not provide a definitive diagnosis, so prompt surgical intervention was indicated to decompress the spinal cord and preserve neurologic function.

Whether the spinal aneurysm was the source of the left thalamic infarct or an incidental finding is difficult to determine. To the best of our knowledge, no cases in the literature have reported a spinal aneurysm as a cause of a cerebral infarct, although one case exists linking a subarachnoid hemorrhage with a spinal cord infarct [16]. This suggests that blood products in the subarachnoid space might lead to secondary ischemia at a distance, and indeed, multiple mechanisms have been postulated that connect subarachnoid blood with micro and macro circulatory failure. For example, release of intracellular material such as oxyhemoglobin from red blood cell lysis can lead to altered vessel dynamics through inactivation of nitric oxide, over-expression of endothelin peptides, and under-expression of...
### Table 1 Demographic and Clinical Data of Isolated Spinal Aneurysms (2011–2019)

| No. | Author/Year | Age/Sex | Co-morbidities | Location | Initial Presentation | Imaging Findings | Treatment | Outcome |
|-----|-------------|---------|----------------|----------|----------------------|------------------|-----------|---------|
| 1   | Iihoshi 2011 [17] | 60/F | - | T11 | Headache, back pain, nausea | Spinal and Intracranial SAH | Conservative | Resolution |
| 2   | Kim 2012 [3] | 52/M | Right acoustic neuroma, HTN, Meningoencephalitis | T7 | Abdominal pain, headache, back pain radiating to LE | T7 Intradural extradural enhancing lesion | Embolization | Resolution |
| 3   | Shankar 2012 [18] | 72/F | - | L2 | Back pain radiating to LE | T12-L1 Lesion | Embolization | Improved |
| 4   | Takashima 2012 [19] | 84/M | - | C1 | Quadriplegia | Intramedullary C1 Hematoma | N/A | Death from respiratory dysfunction |
| 5   | Tanweer 2012 [20] | 67/F | HTN, Atrial Fibrillation | T11 | Back pain, Acute paraplegia and sensory loss | Spinal and Intracranial SAH | Embolization | Improved |
| 6   | Seerangan 2012 [21] | 47/M | Intracranial aneurysms, ESRD, ADPKD | T7-T10 | Lower extremity weakness, bowel/bladder disturbances | Intracranial and Spinal SAH | Resection | Minimal Recovery |
| 7   | Sato 2012 [22] | 67/F | HTN, Dyslipidemia | T8 and T10 | Acute back pain, paraparesis | T8 and T10 intradural masses, spinal infarction, spinal SAH | Conservative | Resolution |
| 8   | Van Es 2013 [23] | 62/F | None | T12 | Headache, back pain, walking difficulty | Spinal SAH | Resection | - |
| 9   | Van Es 2013 [23] | 68/M | - | T4 | Intrascapular back pain radiating to lumbar region, Headache, Nausea | T4 Hyperdense nodular lesion | Conservative (patient refusal) | Resolution |
| 10  | Marovich 2013 [24] | 58/M | None | - | Cervico-thoracic back pain | C8-T6 Extradural Hemorrhagic Lesion | Resection | - |
| 11  | Yang 2013 [25] | 47/M | - | ASA-cervical region | Neck Pain | Cranial SAH, IVH, ASA aneurysm | Conservative | Death from End-Stage Bile Duct Cancer |
| 12  | Son 2013 [26] | 45/F | None | L1 | Headache, back pain, nausea | Spinal and Intracranial SAH | Conservative | Resolution |
| 13  | Santana-Ramirez 2013 [27] | 1/F | - | C3-C6 | Quadripareis, neck pain | C3-C6 intramedullary lesion | Resection | Improved |
| 14  | Pahl 2014 [28] | 43/F | None | - | Cervico-medullary junction | Headache and vomiting | Intracranial SAH, IVH | Conservative | Resolution |
| 15  | Romero 2014 [29] | 37/F | - | T4 | Thoracic/cervical pain, headache | Spinal and Intracranial SAH | Conservative | Resolution |
| 16  | Romero 2014 [29] | 72/F | HTN, DM, CRF | T10 | Cervical pain, headache, neck stiffness | Spinal and Intracranial SAH | Conservative | Improved |
| 17  | Bell 2014 [30] | 68/F | - | T5 | Severe back pain | Thoracic intradural lesion and lumbar SAH | Resection | - |
| 18  | Johnson 2015 [31] | Teenager/- | None | C5-C6 | Headache, neck pain, nausea | C5-C6 enhancing nodular lesion | Resection | Resolution |
| 19  | Ronchetti 2015 [32] | 51/F | - | T1-T4 | Neck pain, headache, bilateral leg numbness, difficulty waking | Thoracic extradural hemorrhage | Resection | Resolution |
| 20  | Ronchetti 2015 [32] | 68/M | - | T1 | Mid-back pain radiating to neck | Intracranial SAH, Cervico-Thoracic SAH | Embolization | Resolution |
| 21  | Sung 2015 [33] | 74/M | HTN, Ischemic Heart Disease | T1 | Chest pain radiating to neck/back | Intracranial and Spinal SAH | Resection | Resolution |
| 22  | Horio 2015 [1] | 84/M | Right Thalamic Infarct | T12 | Left Hemiplegia | Spinal SAH | Resection | Improved |
prostacyclin leading to platelet aggregation [17]. Should these mechanisms have contributed to the thalamic infarct observed in our patient, it is unclear why the arteriess supplying the thalamus would have been particularly susceptible. Along these lines, MRA of the head and neck did not reveal evidence of vasculopathy. An additional mechanism to link these two pathologies is hypertension. Hypertension is common following subarachnoid hemorrhage likely due to pain, anxiety, and sympathetic activation. Thalamic infarcts are most often caused by microvascular disease with hypertension accounting for ~ 68% of cases [18]. It is noteworthy that in the 83 cases of isolated spinal artery aneurysms reported in literature, two cases with concurrent thalamic infarcts have now been observed which is statistically unexpected. Further investigations are needed to

### Table 1 Demographic and Clinical Data of Isolated Spinal Aneurysms (2011–2019) (Continued)

| No. | Author/Year | Age/Sex | Co-morbidities | Location | Initial Presentation | Imaging Findings | Treatment | Outcome |
|-----|-------------|---------|----------------|----------|---------------------|-----------------|-----------|---------|
| 23  | Takata 2016 | 72/F    | None           | T9       | Acute back pain     | T4-T10 SAH      | Resection | Resolution |
| 24  | Dobenstein 2016 | 59/M  | Parkinson’s, T-cell lymphoma | T11 | Back spasms, walking difficulty | T6-L2 Hyperintensity | Conservative | Resolution |
| 25  | Ikeda 2016 | 54/M   | -              | T10      | Severe back pain, vomiting | Spinal SDH and SAH | Resection | Resolution |
| 26  | Hill 2016  | 53/M   | HBV, HCV       | T9       | Paraplegia          | C7-T1 intradural lesion | Resection | Death from medical complications |
| 27  | Roka 2016 | 30/F   | None           | Cervical | Headache, vomiting, vertigo | IVH             | Conservative | Resolution |
| 28  | Kogan 2017 | 58/F   | -              | T2       | Headache radiating to neck and upper back, nausea, vomiting | T1-T5 hyperintensity | Resection | Resolution |
| 29  | Dabus 2018 | 60 s/- | -              | Cervico-medullary Junction | Headache and neck pain | SAH             | Conservative | Resolution |
| 30  | Dabus 2018 | 30 s/- | -              | Cervical | Back Pain | SAH             | Conservative | Resolution |
| 31  | Dabus 2018 | 60 s/- | -              | Mid-Thoracic | Back pain and LE paresthesia | Intramedullary Hemorrhage | Conservative | Resolution |
| 32  | Dabus 2018 | 50 s/- | -              | Lower Thoracic | Back pain and LE paresthesia | SDH             | Conservative | Resolution |
| 33  | Aljuboori 2018 | 78/M  | HTN, PVD, HLD, CAD | T9       | Acute Back Pain, LE weakness | T9 aneurysm, cord compression | Resection | Resolution |
| 34  | Aguilar-Salinas 2018 | 54/F  | HTN             | T10      | Headache, back pain, nausea, vomiting | Spinal SAH with cord compression | Conservative | Improved |
| 35  | Ren 2018 | 57/F   | N/A            | C1       | Severe headache     | Intracranial SAH | Resection | Resolution |
| 36  | Ren 2018 | 27/F   | N/A            | L1       | Bilateral LE pain/ numbness | Lesion at Conus Medullaris | Resection | Resolution |
| 37  | Morozumi 2018 | 9/M  | None           | C7-T1    | Back pain, paralysis | C7-T1 Lesion with hemorrhage | Resection | Resolution |
| 38  | Simon-Gabriel 2018 | 65/M  | HTN, Hypercholesterolemia, Tachyarrhythmia | Cranio-cervical ASA | Neck stiffness | SAH with tamponade of 4th ventricle | Flow diverting stent | Resolution |
| 39  | Priola 2019 | 54/F  | None           | T3       | Upper thoracic back pain radiating to neck and head | Cervico-thoraco-lumbar spine Hematomas | Resection | Resolution |

*HTN Hypertension, DM Diabetes Mellitus, CRF Chronic Renal Failure, ESRD End Stage Renal Disease, ADPKD Autosomal Dominant Polycystic Kidney Disease, PVD Peripheral Vascular Disease, HLD Hyperlipidemia, CAD Coronary Artery Disease, HBV Hepatitis B Virus, HCV Hepatitis C Virus, LE Lower Extremities, SAH Subarachnoid Hemorrhage, IVH Intraventricular Hemorrhage, ASA Anterior Spinal Artery

Search Strategy:
- Google scholar: isolated AND spinal AND aneurysm
- Date range: 2011–2019
- 990 results reviewed
determine whether there is a mechanistic link between these two pathologies, and future cases may benefit by pursuing cerebral angiography at the same time of spinal angiography.

In conclusion, isolated spinal artery aneurysms are an exceedingly rare occurrence, particularly in the posterior axis of the spine. Imaging with MRI/CT and angiogram may not provide a definitive diagnosis. We agree with previous authors that in a patient with a posterior spinal aneurysm and symptoms of spinal cord compression, prompt surgical intervention is warranted. Finally, further studies are needed to understand the possible interaction between subarachnoid blood products and cerebral infarction.

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AT drafted and revised the manuscript. BH, AA, MA, and KM provided images and edited/reviewed the manuscript. All authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests.

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References
1. Horio Y, Katsuta T, Sumura K, et al. Successfully Treated Isolated Posterior Spinal Artery Aneurysm Causing Intracranial Subarachnoid Hemorrhage: Case Report. Neurol Med Chir (Tokyo). 2015;55(12):915–9.
2. Renier L, Raz E, Lanzino G, et al. Spinal artery aneurysms: clinical presentation, radiological findings and outcome. J Neurointerv Surg. 2018;10(7):644–8.
3. Kim HJ, Choi IS. Dissecting aneurysm of the posterior spinal artery: case report and review of the literature. Neurosurgery. 2012;71(3):E749–56.
4. Massand MG, Wallace RC, Gonzalez LF, Zabramski JM, Spetzler RF. Subarachnoid hemorrhage due to isolated spinal artery aneurysm in four patients. AJNR Am J Neuroradiol. 2005;26(6):2415–9.
5. Berlis AS, Scheufler KM, Schmahl C, Rauj S, Gotz M, Schumacher M. Spinal spinal artery aneurysms as a rare source of spinal subarachnoid hemorrhage: potential etiology and treatment strategy. AJNR Am J Neuroradiol. 2005;26(2):405–10.
6. Berlis A, Schumacher M. Subarachnoid hemorrhage due to isolated spinal arteries: Rare cases with controversy about the treatment strategy. AJNR Am J Neuroradiol. 2006;27(4):726–7.
7. Karakama J, Nakagawa K, Maehara T, Ohno K. Subarachnoid hemorrhage caused by a ruptured anterior spinal artery aneurysm. Neurol Med Chir (Tokyo). 2010;50(11):1015–9.
8. Longatti P, Squibb D, Di Faola P. Bleeding spinal artery aneurysms. J Neurosurg Spine. 2008;8(6):574–8.
9. Dabus G, Tosello RT, Pereira BJA. Infantile Intraspinal Dissection of a Spinal Artery Aneurysm: Conservative Management as a Therapeutic Approach. J Neurointerv Surg. 2018;10(5):451–4.
10. Garcia CA, Dulcey S, Dulcey J. Ruptured aneurysm of the spinal artery of Adamkiewicz during pregnancy. Neurology. 1979;29(3):394–8.
11. Koçak A, Öztepe Ö, Ceyi SR, Sarar K. Isolated postmenatal spinal artery aneurysm. Br J Neurosurg. 2006;20(4):241–4.
12. Yonas H, Patte S, White RJ. Anterior spinal artery aneurysm. Case report. J Neurosurg. 1980;53(4):570–3.
13. Hernon RA, Croft PB. Spontaneous spinal subarachnoid haemorrhage. Q J Med. 1956;25(77):53–66.
14. Rengachary SS, Duke OA, Tsiay FY, Kragel PJ. Spinal arterioplastic aneurysm: case report. Neurosurgery. 1993;33(1):125–9.
15. Geißbauer S, Krings T, Aptitzsch J, Reinges MH, Holte KF. Subarachnoid hemorrhage following posterior spinal artery aneurysm. A case report and review of the literature. Interv Neuroradiol. 2010;16(2):183–90.
16. Krishna V, Lazardis C, Eligteda D, Galzter S, Kindy M, Spampinato J, Chalela JA. Spinal cord infarction associated with subarachnoid hemorrhage. Clin Neurol Neurosurg. 2012;114(7):1030–2.
17. Khurana VG, Besier M. Pathophysiological basis of cerebral vasospasm following aneurysmal subarachnoid haemorrhage. J Clin Neurosurg. 1997;4(1):222–31.
18. Kumral E, Eyaplan D, Kütüluhan S. Pure thalamic infarction: Clinical findings. J Stroke Cerebrovasc Dis. 2003(3):287–97.
19. Ichikawa S, Miyata K, Murakami T, Kameko T, Koyanagi M. Dissection aneurysm of the radiculoomedullary branch of the artery of Adamkiewicz with subarachnoid hemorrhage. Neurol Med Chir (Tokyo). 2011;51(10):649–52.
20. Shankar JJ, Terbrugge K, Krings T. Subarachnoid hemorrhage following posterior spinal artery aneurysm rupture. Can J Neurol Sci. 2012;39(4):531–2.
21. Takashima N, Murali H, Hirano S, Oya M. Isolated intramedullary spinal artery aneurysm. Neurology. 2012;79(6):608–9.
22. Tanveer O, Woldenberg R, Wanvrey S, Setton A. Endovascular obliteration of a ruptured posterior spinal artery pseudoaneurysm. J Neurosurg Spine. 2012;17(4):334–6.
23. Sieverst A, Narayanan M. A Rare Case of Subarachnoid Hemorrhage due to Ruptured Isolated Anterior Spinal Artery Aneurysm in a Patient with Polycystic Kidney Disease. Case Rep Nephrol Urol. 2012;2012:5405.
24. Sato K, Roccatagliata L, Delpuydt S, Rodesch G. Multiple aneurysms of thoracic spinal cord arteries presenting with spinal infarction and subarachnoid hemorrhage: case report and literature review. Neurosurgery. 2012;71(3):E1053–8.
25. Van es AC, Brouwer PA, Willems PW. Management considerations in ruptured isolated radiculopial artery aneurysms. A report of two cases and literature review. Interv Neuroradiol. 2013;19(1):106–6.
26. Marovic P, Than I, Lu S, Bala A. Spinal subarachnoid hemorrhage secondary to rupture of an isolated radicular artery aneurysm. J Neurol Surg A Cent Eur Neurosurg. 2013;74(6):410–4.
27. Yang TK. A ruptured aneurysm in the branch of the anterior spinal artery. J Cerebrovasc Endovasc Neurosurg. 2013;15(1):126–9.
28. Son S, Lee SG, Park CW. Spinal ruptured aneurysm of the spinal artery of Adamkiewicz with subarachnoid hemorrhage. J Korean Neurosurg Soc. 2013;54(1):50–3.
29. Santos-Ramírez A, Farias-serratos F, Garzón-muñoz T, Quiróz-hinojosa A. A giant spinal arterial aneurysm in a child presenting as quadriparesis. BMJ Case Rep. 2013;2013.
30. Pahl FH, Dievele MF, Rotta MA, Dias GM, Rezende AL, Rotta JM. Spontaneous resolution of an isolated cervical anterior spinal artery aneurysm after subarachnoid hemorrhage. Surg Neurol Int. 2014;5:33.
31. Gutierrez Romero D, Batista AL, Centric JC, Raymond J, Roy D, Weill A. Ruptured isolated spinal artery aneurysms. Report of two cases and review of the literature. Interv Neuroradiol. 2014;20(6):774–80.
32. Bell DL, Stapleton CJ, Terry AR, Stone JR, Ogilvy CS. Clinical presentation and treatment considerations of a ruptured posterior spinal artery pseudoaneurysm. J Clin Neurosci. 2014;21(7):1273–6.
33. Johnson J, Patel S, Saraf-lavi E, Aziz-sultan MA, Yavagal DR. Posterior spinal artery aneurysm rupture after ‘Ecstasy’ abuse. J Neurointerv Surg. 2015;7(7):e23.
34. Ronchetti G, Morales-valero SF, Lanzino G, Wald JT. A cause of atypical intracranial subarachnoid hemorrhage: posterior spinal artery aneurysms. Neurocrit Care. 2015;22(2):299–305.
35. Sung TH, Leung WK, Lai BM, Kho J. Isolated spinal artery aneurysm: a rare culprit of subarachnoid hemorrhage. Hong Kong Med J. 2015;21(2):179–82.
36. Takata M, Takayama M, Yokoyama Y, Hayashi H, Kishida N. An Isolated Posterior Spinal Aneurysm Resection in Which Intraoperative Electrophysiological Monitoring Was Successfully Used to Locate the Lesion and to Detect the Possibility of Ischemic Complications. Spine. 2016;41(1):E46–9.
37. Doberstein CA, Bouley A, Silver B, Morrison JF, Jayaraman MV. Ruptured aneurysms of the intradural artery of adamkiewicz: Angiographic features and treatment options. Clin Neurol Neurosurg. 2016;146:152–5.
38. Ikeda S, Takai K, Kikkawa Y, et al. Ruptured posterior spinal artery aneurysm: intraoperative and histologic findings with appreciable thrombosis. Spine J. 2016;16(3):e215–7.
39. Hill TC, Tanweer O, Thomas C, et al. Posterior Spinal Artery Aneurysm Presenting with Leukocytoclastic Vasculitis. J Cerebrovasc Endovasc Neurosurg. 2016;18(1):42–7.
40. Roka YB. Isolated cervical anterior spinal artery aneurysm: case report. Br J Neurosurg. 2017;1–2.
41. Kogan M, Morr S, Siddiqui AH. Serial magnetic resonance imaging findings in subarachnoid hemorrhage due to an initially angiographically occult type II spinal aneurysm: Case report. Acta Biomed. 2017;88(1):74–8.
42. Aljuboori Z, Sharma M, Simpson J, Altstadt T. Surgical Management of Ruptured Isolated Aneurysm of Artery of Adamkiewicz: Interesting Report and Overview of Literature. World Neurosurg. 2018;111:36–40.
43. Aguilar-Salinas P, Lima J, Brasiliense LBC. Hanel RA, Sauvageau E. Ruptured aneurysm of the artery of Adamkiewicz: is conservative management the standard of treatment in the current era? J Neurointerv Surg. 2018;10(8):e22.
44. Ren Y, He M, You C, Li J. Successful Surgical Resection of Spinal Artery Aneurysms: Report of 3 Cases. World Neurosurg. 2018;109:171–8.
45. Morozumi M, Imagama S, Ando K, et al. Surgical intervention for a pediatric isolated intramedullary spinal aneurysm. Eur Spine J. 2018;27(Suppl 3):342–6.
46. Simon-Gabriel CP, Ulltach H, Meckel S. Ruptured Fusiform Aneurysm of the Anterior Spinal Artery: Successful Treatment with Flow Diverter Stent Placed in the Feeding Vertebral Artery. Clin Neuroradiol. 2018;28(4):613–6.
47. Priola SM, Heyn C, Da costa L. Minimally invasive approach for removal of a ruptured radiculo-medullary artery aneurysm. Case report and literature review. World Neurosurg. 2019;126:605–10.

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