Paediatrica Indonesiana

p-ISSN 0030-9311; e-ISSN 2338-476X; Vol.64, No.1(2024). p.92-8 ; DOI: https://doi.org/10.14238/pi64.1.2024.92-8

Case Report

Challenges in the management of pediatric ruptured brain arteriovenous malformation: a case report

Celia Celia[1,2], Susilawati Susilawati[3], Johanes Ari Cahyo[3], Robert Shen[1,2], Irene Fenia[4]

Current therapeutic approaches for ruptured bAVMs in children include open microsurgery, endovascular embolization, as well as stereotactic radiosurgery (SRS), be it isolated or as a multimodal treatment strategy. Herein, we present the case of a 6-year-old boy with a ruptured bAVM successively managed with hemicraniectomy decompression and intracranial bleeding evacuation, followed by stereotactic radiosurgery (SRS) using gamma knife for the small AVM which was inaccessible during open surgery. **[Paediatr Indones. 2024;64:92-8; DOI: 10.14238/pi64.1.2024.92-8**].

Keywords: *brain arteriovenous malformations (bAVMs); open microsurgery; stereotactic radiosurgery (SRS); pediatric intensive care*

Brain arteriovenous malformations (bAVMs) are intracranial vascular lesions characterized by abnormal connections between the arterial and venous systems without an interposed capillary bed. Pediatric bAVMs constitute merely 12-18% of all diagnosed bAVMs, but an initial finding of bAVM rupture occurs more frequently in the pediatric population than in adults, accounting for 58-77% of all pediatric bAVM admissions.[1,2] Although spontaneous pediatric intracerebral hemorrhage has an annual incidence of 1.4 per 100,000 people per year, it carries a risk of severe permanent neurological deficits, occurring in 20-40% of patients and significant mortality in up to 25% of affected individuals.[3-5] Ruptured bAVMs are the cause of 30-50% of intracranial hemorrhages in the pediatric population and the most common cause of hemorrhagic stroke in children.[1]

The case

A 6-year-old boy was brought by his parents to the emergency room with loss of consciousness approximately 30 minutes prior to admission. Before the loss of consciousness, he suddenly screamed loudly while playing with his caregiver, followed by a focal tonic seizure with a semiology of rigidly extended left arm accompanied by contortion of the face to the left. His parents denied any prior trauma, history of headache, seizure, nausea and vomiting, one-sided weakness, speech changes, or numbness or tingling of the arms or legs. Upon arrival, his mental state had deteriorated, with a *Glasgow Coma Scale* (GCS) of E1M4V1. His blood pressure was pre-hypertensive (111/59 mmHg); other vital signs were normal. Weakness in his left arm and leg was noted. He was given oxygen immediately and maintained on intravenous fluids while awaiting brain CT and further laboratory evaluations.

From the Department of Surgery[1], Atma Jaya Neuroscience Research (ANR), Master Study Program in Biomedical Sciences[2], School of Medicine and Health Sciences, Universitas Katolik Indonesia Atma Jaya, Department of Child Health, Atma Jaya Hospital[3], and Atma Jaya Hospital[4], Jakarta.

Corresponding author: Celia Celia. Department of Surgery, School of Medicine and Health Sciences, Universitas Katolik Indonesia Atma Jaya, Jl. Pluit Raya No. 2, North Jakarta, Jakarta 14440, Indonesia.

Submitted March 18, 2022. Accepted February 26, 2024.

The patient was the only child of non-consanguineous parents. His mother had preeclampsia in her third trimester. He was born full-term by cesarean section with an appropriate weight for gestational age. He had completed all immunizations recommended for his age. He had a history of delayed babbling during infancy, only started babbling at one year of age, but no developmental problems afterwards. His father had hypertension and his mother was obese. He had a weight of 29 kg, height of 118 cm, and BMI of 20.83 kg/m^2, which was consistent with obesity according to the CDC growth charts.[6]

Eye examination revealed anisocoric pupils (3 mm on the right and 5 mm on the left), with intact pupillary light reflex (PLR) in both eyes. There were no abnormalities of the lungs, heart, or abdomen. Neurological examination revealed no neck stiffness or pathological reflexes, but there was a left hemiparesis and lateralization of the third, fourth, fifth, and seventh cranial nerves. His pre- and post-surgical laboratory workup can be seen on **Table 1**). Brain CT showed an intraparenchymal hemorrhage of approximately 77 mL in volume with perifocal edema in the centrum semiovale, corona radiata, and lentiform nucleus up to the right temporal lobe, which resulted in an 8 mm subfalcine herniation to the left. There was a suspected infarction at the right caudate nucleus (**Figure 1**).

Mannitol and ceftriaxone were administered intravenously before surgery. Emergency hemicraniectomy decompression and evacuation of intracranial bleeding were performed immediately; a 60 mL hemorrhage was evacuated. A small bAVM was seen on the mediodorsal aspect of the right thalamus, measuring approximately 1-2 cm. AVM resection was not performed because of its location and size. The patient was transferred to the pediatric intensive care unit (PICU) right after surgery and was placed on mechanical ventilation for 5 days. On the third day, he had a five-minute generalized seizure. He was given IV phenytoin, after which no more seizures occurred.

The patient remained in the PICU for the

Table 1. Laboratory test results pre- and post-hemicraniectomy decompression and intracranial bleeding evacuation surgery

Laboratory parameter	Results		Reference values
	01/11/2021 ER (pre-surgery)	02/11/2021 PICU (post-surgery)	
Hemoglobin, g/dL	11.1	10.8	11.5-14.5
Hematocrit, %	32.2	31.2	33.0-43.0
Leukocyte, x10^3/mm^3	27.21	17.69	4.00-12.00
Erythrocyte, x10^6/uL	4.17	3.98	4.30-5.60
Thrombocyte, x10^3/uL	489	333	150-400
Prothrombin time, s	14.8 (control 12.6)	14.6 (control 12.6)	10.8-14.4
Partial prothrombin time, s	24.6 (control 33.5)	30.3 (control 26.5)	24.0-36.0
INR	1.2	1.2	0.8-1.1
Random glucose, mg/dL	187	89	60-140
SGOT/AST, U/L	34.8	-	12.0-38.0
SGPT/ALT, U/L	11.4	-	7.0-41.0
Urea, mg/dL	25.8	-	5.0-18.0
Creatinine, mg/dL	0.47	-	0.44-0.65
eGFR, mL/min/1.73m^2	176.55	-	≥60.00
Sodium, mmol/L	138.8	139.1	134.0-143.0
Potassium, mmol/L	2.91	4.02	3.30-4.60
Calcium, mmol/L	1.21	1.20	1.12-1.23

ER=emergency room; PICU=pediatric intensive care unit; INR=international normalized ratio; SGOT/AST=serum glutamic oxaloacetic transaminase/aspartate transaminase; SGPT/ALT=serum glutamic pyruvate transaminase/alanin aminotransferase; eGFR=estimated glomerural filtration rate

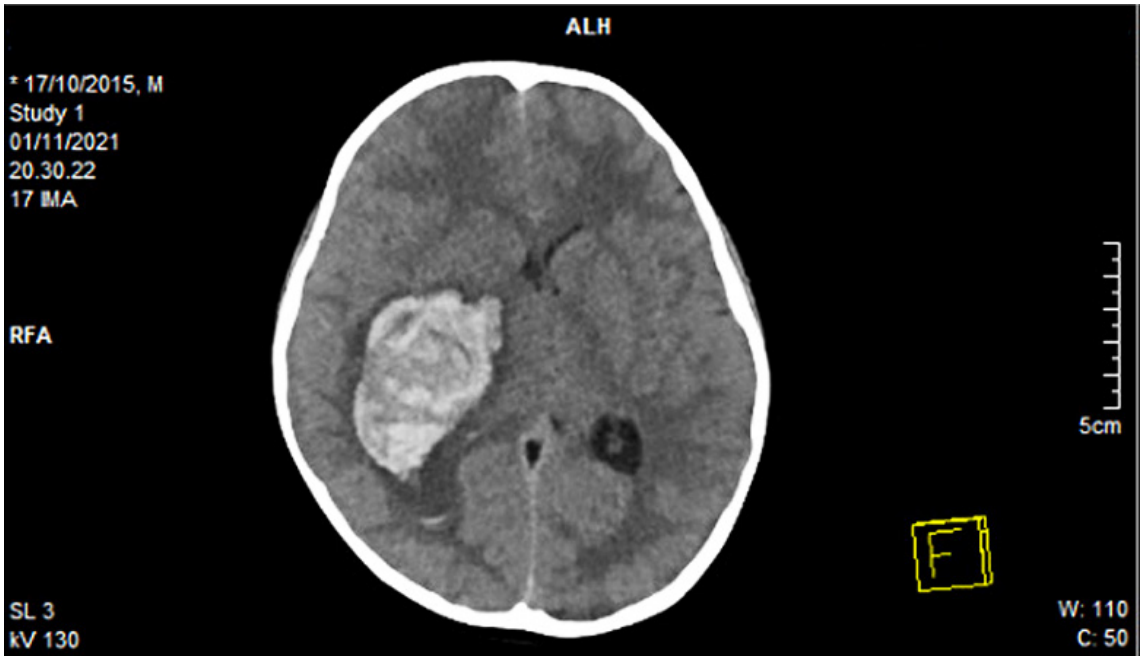

Figure 1. CT image of brain showing intraparenchymal hemorrhage prior to surgery

first seven post-operative days, afther which he was transferred to the general ward. Brain MRI was performed seven days post-operatively to evaluate residual hemorrhage due to recurrent rupture of the main bAVM and revealed acute and subacute hemorrhage with a volume of 10.8 mL, a near-total reduction, in the right basal ganglia with perifocal edema causing compression of the right lateral ventricle and right thalamus, as well as an improved midline shift of approximately 2.5 cm to the left (**Figure 2**).

After the surgery, the patient still had palsies of the left third, fourth, fifth, and seventh cranial nerves, as well as weakness of the left arm and left leg, which was managed by active physiotherapy. He was discharged after twelve days of hospitalization and remained stable thereafter. He was given oral citicoline and valproic acid up to 18 months after surgery.

Digital subtraction angiography (DSA) was performed one month after the surgery to further identify AVMs. DSA revealed that the AVM feeders were branches of the thalamostriatal artery, with drainage into the internal cerebral vein (ICV) (**Figure 3**). Two months after the initial surgery, an autologous cranioplasty was performed. One month after the cranioplasty, stereotactic radiosurgery (SRS) using gamma knife was performed considering the potential recurrent rupture of the main AVM and presence of a residual hemorrhage on the MRI. SRS using gamma knife was performed to totally eradicate the AVM, so that residual hemorrhage could be properly absorbed. The procedure was well tolerated by the patient. He received routine physical rehabilitation after the procedure. No further complications or recurrent rupture was observed during 2 years of follow-up.

Discussion

In our case, the bAVM originated from deep in the basal ganglia and thalamus. AVMs in the basal ganglia and mediodorsal thalamus account for 4.3-11% of all AVM cases.[7-9] A previous study observed an incidence rate of about 54.2%.[8] Pediatric bAVMs make up approximately 3% of total AVMs, indicating that the incidence in children is not as high as in adults.[10,11] The etiology of AVMs is still a matter of debate, although their angioarchitecture and occurrence in all age groups suggest that AVMs possibly have an embryonic origin. As in our case, intracranial hemorrhage caused by AVMs are more common in males. While genetic factors and family history of AVMs or other vascular malformations are risk factors for bAVM, we found none of these in our

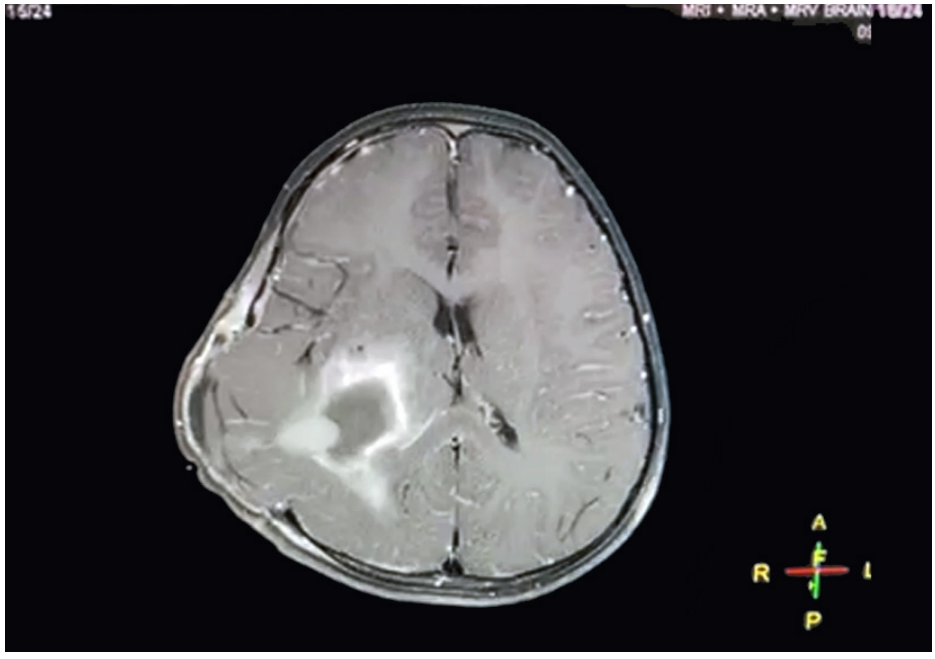

Figure 2. Brain MRI 7 days post-operatively

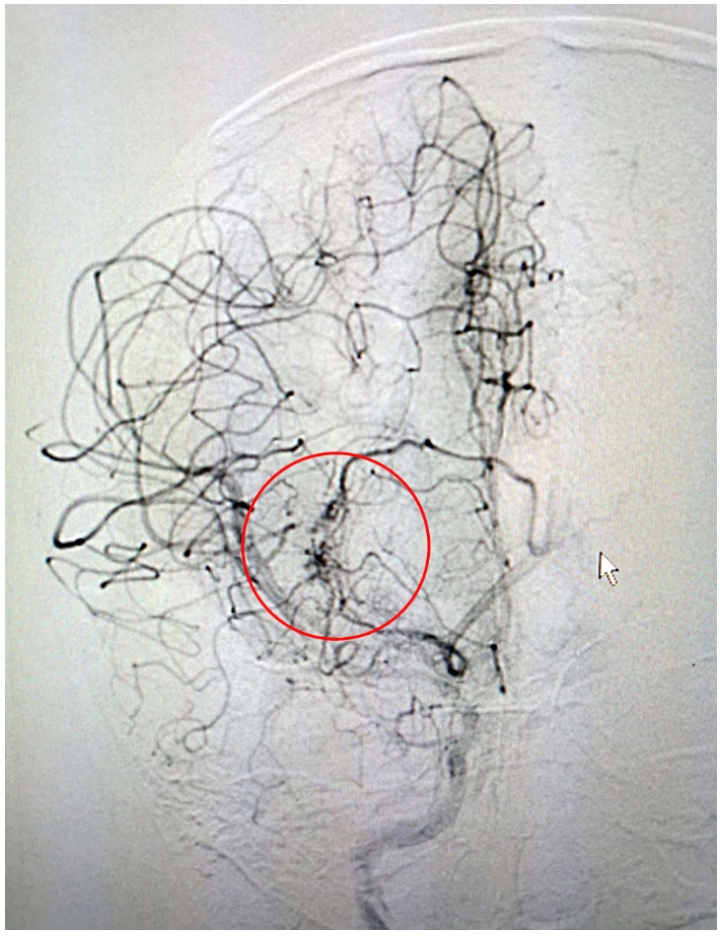

Figure 3. DSA confirmed the identification of arteriovenous malformation (red circle)

patient.[12,13]

Studies have shown that AVMs trigger about 2% of all strokes and 4% of hemorrhagic strokes. Ruptured AVMs are the cause of one-third of hemorrhagic strokes in children or young adults.[14,15] Hemorrhage arising from AVM is generally less life-threatening than the rupture of an intracranial aneurysm or spontaneous hypertensive intracranial hemorrhage. However, AVM rupture accompanied by intraparenchymal hemorrhage often leads to significant neurologic impairment.[14] Our patient suffered a hemorrhagic stroke caused by a rupture of the AVM, and presented with several neurological symptoms such as diminished mental status of GCS 6, anisocoric pupils, hemiparesis of the left extremities, and lateralization of the third, fourth, fifth, and seventh cranial nerves. The mortality rate and risk of lifetime morbidity resulting from AVM ruptures differ among studies, ranging from 5-25% to 10-40%.[14,16] In our patient, hemicraniectomy for decompression and evacuation of the intracranial hemorrhage was performed within six hours of symptom onset, in accordance with the golden time for surgical intervention of supratentorial ICH (STITCH). A randomized controlled trial found that early surgery at <12 hours was clinically beneficial as a lifesaving intervention and reduced clinical deterioration.[17]

Numerous anatomical factors have been identified as risk factors associated with the hemorrhagic manifestation of AVMs. These factors include small AVMs, deep venous drainage or a small number of draining veins, indefinite or borderless area (watershed), infratentorial locations, accompanying aneurysms, hypertension, venous ectasias, and high feeding artery pressure.[14,18] Our patient's brain CT scan showed small AVMs located on the right mediodorsal thalamus with a deep venous drainage site. Symptomatic seizure, which is seen in about 18-35% of cases, is the second most common manifestation of AVMs; such seizures in AVMs are related to anatomical features such as large size, the cortical location of the feeder, or the site of the AVM in reference to the middle cerebral artery (MCA).[14,19] In our case, AVM resection was not carried out due to the depth. Our patient underwent DSA one month after hemicraniectomy. The DSA showed that the AVM feed originated from the branches of the thalamostriatal artery, which is supplied by the MCA and anterior cerebral arteries (ACA), causing the seizure.

In addition to conservative treatment, there are three other treatment modalities for bAVMs: microsurgical resection, endovascular embolization, or radiosurgery. These options have advantages and disadvantages, so a multimodality treatment is most generally desirable. Furthermore, certain radiological and clinical qualities are essential determinants of the safest and most efficient management option. Although microsurgical resection provides a rapid remedy under appropriate circumstances, the rate of complications is primarily based on the Spetzler-Martin grade: the higher the grade, the higher the complication rate, and vice versa. Thus, microsurgical resection may be advantageous for cases with smaller and cortical-based bAVMs.[20,21] Our patient's Spetzler-Martin grade was 3, with a supplementary grading of 1. The total score of 4 indicated the patient was surgically acceptable with low risk (**Table 2**).

Endovascular embolization is a radiological treatment modality that can rapidly eradicate angiographic risk factors. Although there are no substantial contraindications for endovascular treatment, the success rate of this treatment modality is about 10-20%, which is comparatively very low except in high-flow pial arteriovenous fistulas or small lesions. Moreover, AVM embolization is not only limited to incomplete nidus embolization, although therapeutic embolization as an alternative to radiosurgery or surgical resection is feasible in particular cases. Thus, in our case, we preferred radiosurgery treatment, which has a higher potential for success. Furthermore, bAVMs with volumes greater than 12 mL have been linked to lower treatment rates and higher complication rates. Nevertheless, it is advisable to use radiosurgery treatment options in children with caution due to radiation consequences.[22] Conservative treatment is normally used when the risk posed by the three treatment modalities above is too high, such as in large and deep-seated AVMs or in asymptomatic cases in which imminent hemorrhage is very unlikely. The prognosis of pediatric AVM is usually good if well managed; however, re-rupture frequency is projected to be 2-4% with a death rate up to 25% for every re-rupture incident. The risk of re-rupture is greater within five years of the identification of an AVM.[10,11]

In conclusion, a deep bAVM rupture in children

Table 2. Spetzler-Martin grading and supplementary grading7,22

Assessments	Points	Patient
Spetzler-Martin Grading		
Size (maximum diameter)		1: Small size nidus, 2 cm
<3 cm (small)	1	
3-6 cm (medium)	2	
>6 cm (large)	3	
Venous drainage		1: AVM location on right mediodorsal thalamus accounted withis near a deep venous drainage location
Superficial (cortical veins)	0	
Deep (internal cerebral veins, basal Veins or pre-central cerebellar veins)	1	
Eloquence of adjacent brain parenchyma (cortex, thalamus, hypothalamus, internal capsule, brainstem, cerebellar peduncles, deep cerebellar nuclei; part of brain affecting sensory, motoric, language, visual function, etc.)		1: Eloquent with thalamus
Non-eloquent	0	
Eloquent	1	
Supplementary grading		
Age		1: 6 years
<20 years	1	
20-40 years	2	
>40 years	3	
Bleeding		0: Yes, ruptured brain AVM
Yes	0	
No	1	
Compactness		0: Yes, non-diffuse AVM
Yes	0	
No	1	
Total score		**4**

can be well managed with microsurgical resection followed by stereotactic radiosurgery, such as gamma knife surgery. Decision-making should consider the potential complication rate using Spetzler-Martin grading. Early surgery in the golden period of intracranial bleeding is also important as it is lifesaving and improves outcomes for clinical status and neurological function.

Conflict of interest

None declared.

Funding acknowledgment

The authors received no specific grants from any funding agency in the public, commercial, or not-for-profit sectors.

References

1. Smith ER, Butler WE, Ogilvy CS. Surgical approaches to vascular anomalies of the child's brain. Curr Opin Neurol. 2002;15:165-71. DOI: https://doi.org/10.1097/00019052-200204000-00007
2. Zheng T, Wang QJ, Liu YQ, Cui XB, Gao YY, Lai LF, *et al*. Clinical features and endovascular treatment of intracranial arteriovenous malformations in pediatric patients. Childs Nerv Syst. 2014;30:647-53. DOI: https://doi.org/10.1007/s00381-013-2277-3
3. Jordan LC, Johnston SC, Wu YW, Sidney S, Fullerton HJ. The importance of cerebral aneurysms in childhood hemorrhagic stroke: a population-based study. Stroke. 2009;40:400-5. DOI: https://doi.org/10.1161/STROKEAHA.108.518761
4. Buis DR, Dirven CMF, Lagerwaard FJ, Mandl ES, Nijeholt GJLÁ, Eshghi DS, et al. Radiosurgery of brain arteriovenous malformations in children. J Neurol. 2008;255:551-60. DOI: https://doi.org/10.1007/s00415-008-0739-4
5. Gross BA, Storey A, Orbach DB, Scott RM, Smith ER. Microsurgical treatment of arteriovenous malformations in

pediatric patients: the Boston Children's Hospital experience. J Neurosurg Pediatr. 2015;15:71-7. DOI: https://doi.org/10.3171/2014.9.PEDS146

6. CDC. Clinical growth charts - 2 to 20 years: Boys stature-for-age and weight-for-age percentiles. 2022. [cited 2022 Feb 15]. Available from: https://www.cdc.gov/growthcharts/clinical_charts.htm.
7. Spetzler RF, Martin NA. A proposed grading system for arteriovenous malformations. J Neurosurg. 1986;65:476-83. DOI: https://doi.org/10.3171/jns.1986.65.4.0476
8. Fleetwood IG, Marcellus ML, Levy RP, Marks MP, Steinberg GK. Deep arteriovenous malformations of the basal ganglia and thalamus: natural history. J Neurosurg. 2003;98:747-50. DOI: https://doi.org/10.3171/jns.2003.98.4.0747
9. Deruty R, Pelissou-Guyotat I, Mottolese C, Bascoulergue Y, Amat D. The combined management of cerebral arteriovenous malformations. Experience with 100 cases and review of the literature. Acta Neurochir (Wien). 1993;123:101-12. DOI: https://doi.org/10.1007/BF01401864
10. El-Ghanem M, Kass-Hout T, Kass-Hout O, Alderazi YJ, Amuluru K, Al-Mufti F, et al. Arteriovenous malformations in the pediatric population: review of the existing literature. Intervent Neurol. 2016;5:218-25. DOI: https://doi.org/10.1159/000447605
11. Di Rocco C, Tamburrini G, Rollo M. Cerebral arteriovenous malformations in children. Acta Neurochir (Wien). 2000;142:145-56. DOI: https://doi.org/10.1007/s007010050017
12. Ogilvy CS, Stieg PE, Awad I, Brown RD, Kondziolka D, Rosenwasser R, et al. AHA Scientific Statement: recommendations for the management of intracranial arteriovenous malformations: a statement for healthcare professionals from a special writing group of the Stroke Council, American Stroke Association. Stroke. 2001;32:1458-71. DOI: https://doi.org/10.1161/01.str.32.6.1458
13. Kim H, Marchuk DA, Pawlikowska L, Chen Y, Su H, Yang GY, et al. Genetic considerations relevant to intracranial hemorrhage and brain arteriovenous malformations. Acta Neurochir Suppl. 2008;105:199-206. DOI: https://doi.org/10.1007/978-3-211-09469-3_38
14. Laakso A, Hernesniemi J. Arteriovenous malformations: epidemiology and clinical presentation. Neurosurg Clin N Am. 2012;23:1-6. DOI: https://doi.org/10.1016/j.nec.2011.09.012
15. Al-Shahi R, Warlow C. A systematic review of the frequency and prognosis of arteriovenous malformations of the brain in adults. Brain. 2001;124:1900-26. DOI: https://doi.org/10.1093/brain/124.10.1900
16. Ondra SL, Troupp H, George ED, Schwab K. The natural history of symptomatic arteriovenous malformations of the brain: a 24-year follow-up assessment. J Neurosurg. 1990;73:387-91. DOI: https://doi.org/10.3171/jns.1990.73.3.0387
17. Hemphill JC, Greenberg SM, Anderson CS, Becker K, Bendok BR, Cushman M, et al. Guidelines for the management of spontaneous intracerebral hemorrhage: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2015;46:2032-60. DOI: https://doi.org/10.1161/STR.0000000000000069
18. Stapf C, Mast H, Sciacca R, Choi J, Khaw A, Connolly E, *et al*. Predictors of hemorrhage in patients with untreated brain arteriovenous malformation. Neurology. 2006;66:1350-5. DOI: https://doi.org/10.1212/01.wnl.0000210524.68507.87
19. Turjman F, Massoud TF, Sayre JW, Vinuela F, Guglielmi G, Duckwiler G. Epilepsy associated with cerebral arteriovenous malformations: a multivariate analysis of angioarchitectural characteristics. AJNR Am J Neuroradiol. 1995;16:345-50. PMID: 7726084.
20. Geibprasert S, Pongpech S, Jiarakongmun P, Shroff MM, Armstrong DC, Krings T. Radiologic assessment of brain arteriovenous malformations: what clinicians need to know. Radiographics. 2010;30:483-501. DOI: https://doi.org/10.1148/rg.302095728
21. Söderman M, Andersson T, Karlsson B, Wallace MC, Edner G. Management of patients with brain arteriovenous malformations. Eur J Radiol. 2003;46:195-205. DOI: https://doi.org/10.1016/s0720-048x(03)00091-3
22. Lawton MT, Kim H, McCulloch CE, Mikhak B, Young WL. A supplementary grading scale for selecting patients with brain arteriovenous malformations for surgery. Neurosurgery. 2010;66:702-13. DOI: https://doi.org/10.1227/01.NEU.0000367555.16733.E1