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Research article

The features of computed tomography and digital subtraction angiography images of ruptured cerebral arteriovenous malformation

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Abstract: Objectives: This study aims to analyze lesions on computed tomography (CT) images and digital subtraction angiography (DSA) of ruptured cerebral arteriovenous malformation (AVM). **Methods:** Cross-sectional description of 82 patients' cerebral bleeding due to rupture of AVM, determined by multislice computed tomography or cerebral DSA at Bach Mai Hospital. **Results:** Patients with ruptured AVM are commonly under 40 years old (62.2%), average age: 35.1 ± 11.2. On CT or DSA images, it is common to see AVM rupture causing cerebral bleeding in the supratentorial region (91.5%), with 83% cerebral lobe bleeding, mainly small and moderate hematoma volume (<60 cm^3) (74.4%), and a low rate of consciousness disorders ($p < 0.05$). AVM is usually found in the supratentorial region (91.5%), and the size is small (74.4%) ($p < 0.05$). The feeding arteries are mainly derived from the middle (53.7%) and posterior (42.7%) cerebral arteries; 70.7% is drained by superficial veins. According to the Spetzler–Martin classification, degrees I and II account for the highest percentage (73.2%), in which the majority of patients are selected for surgery; grades IV and V have a low rate (8.5%), often a combination of vascular and surgical nodes. **Conclusions:** On MSCT and DSA images, ruptured AVMs often cause lobar hemorrhage in young people. AVMs are usually small to moderate in size. The feeding arteries are mainly derived from middle and posterior cerebral arteries, and drained mainly by superficial veins. The Spetzler–Martin classification and the

supplementary grading scales are used for ranking the severity of the lesion, as well as for choosing AVM treatment options and assessing the prognosis.

Keywords: rupture; arteriovenous malformation; computed tomography; digital subtraction angiography; Spetzler–Martin classification

1. Introduction

A brain arteriovenous malformation (AVM) is an innate blood vessel abnormality in the brain that is caused by the abnormal development of the cerebral vascular system, in which the cerebral artery and veins bypass the capillary system [1]. The structure of cerebral arteriovenous malformation includes the feeding artery, the malformation drive, and the drainage vein [2]. The vascular malformation drive consists of deformed, dilated, zigzag arteries instead of a network of capillaries located between the feeding artery and the drainage vein. The arteriovenous malformation is a congenital abnormality and tends to progress to complications. One of the most common and dangerous complications is brain bleeding [3,4].

Cerebral bleeding due to rupture of AVM accounts for a small percentage of general brain bleeding but has a high mortality rate and can lead to many long-term neurological defects, so assessing the clinical symptoms and characteristics via imaging is an important step in disease prognosis and treatment choice [5]. The definitive diagnosis of a malformation requires diagnostic tools such as computed tomography (CT) and background digital subtraction angiography (DSA) [6]. CT scans of the brain vessels are performed by injecting an intravenous contrast agent, allowing the majority of cases to be diagnosed. The DSA film selectively shows cerebral vessels by injecting a contrast agent directly into the artery, picturing in more detail the structure of the AVM [7–9]. In Vietnam, there is not much research in this area, so we conducted this study with the aim of evaluating the imaging characteristics of CT and DSA of the ruptured cerebral AVM.

2. Materials and methods

2.1. Study selection

This prospective, cross-sectional study was carried out with 82 patients diagnosed with cerebral hemorrhage due to ruptured AVM and treated at Bach Mai hospital from April 2019 to April 2020.

Inclusion criteria were patients with cerebral hemorrhage due to ruptured brain AVM, as determined by MSCT or DSA images. Exclusion criteria were CT and DSA images that determined that the feeding arteries come from an external carotid source or there were one or more other AVM masses outside the skull. Pure subarachnoid hemorrhage or intraventricular hemorrhage due to ruptured aneurysms on the feeding arteries was also excluded.

2.2. Data collection

Our research included gathering medical history, examinations, subclinical tests, and assessment of patient progress and management. We explored the cerebrovascular images by CT and DSA, classifying the grades based on the Spetzler–Martin scale (Table 1) and evaluating the AVM size, pattern of venous drainage, and eloquence of brain location scoring from 1 to 5 (corresponding to grades I to V) [10]. Lawton's supplementary grading scale also included the rupture status, age of the patient, and nidal architecture (diffuse versus focal) [11].

Table 1. Spetzler–Martin grading.

Spetzler–Martin grading	Points	Supplementary grading
Size		Age
< 3 cm	1	< 20
3–6 cm	2	20–40
> 6 cm	3	> 40
Eloquence (*)		Bleeding
No	0	Yes
Yes	1	No
Venous drainage		Compactness
Superficial	0	Yes
Deep	1	No

Note: * Sensory motor, language, visual cortex, hypothalamus, thalamus, internal capsule, brainstem, cerebellar peduncles, or cerebellar nuclei.

2.3. Data analysis

We entered and processed the data using SPSS Statistics 20.0 software.

2.4. Ethical approval and declaration of patient consent

This study was approved by the Research Ethics Committee of Bach Mai Hospital under the reference number 16/BMH. Written informed consent was obtained from all patients.

3. Results

3.1. General features

The proportion of patients under 40 years old was 62.2%. The average age of patients in the study was 35.1 ± 15.3 years, with the youngest patient being 8 years old and the oldest being 67 (Table 2).

3.2. Imaging characteristics of ruptured AVM

Intraparenchymal hemorrhages accounted for a high proportion (61%); most were lobar hemorrhages (83%) ($p < 0.05$). Deep bleeding in the thalamus and basal ganglia accounted for a low percentage. Most hematomas are small to medium in volume (74.4%) ($p < 0.05$). The mean volume of the hematomas was 42.2 ± 34.5 cm^3 (Table 3). The majority of cases (91.5%) were in the supratentorial region, in which the temporal and frontal lobes are more common (32% and 29.3%, respectively). Most cases (74.4%) of AVM are small in size, less than 3 cm (Table 4). The feeding arteries mainly originate from the branches of the middle cerebral arteries (53.7%) and posterior cerebral arteries (42.7%) (Table 5).

Table 2. General features of patients.

General features	Total (*n* = 82)	%	*p*
Age			
< 40	51	62.2	0.027
≥ 40	31	37.8	
Sex			
Male	48	58.5	0.122
Female	34	41.5	
Clinical symptoms			
Sudden headache	72	89.0	
Nausea/vomiting	44	53.7	
Level of consciousness			
Alert	56	68.3	0.001
Conscious	26	31.7	
Numbness, Hemiplegia	26	31.7	
Seizure	8	9.8	

Table 3. Cerebral hemorrhage features on CT scans.

Cerebral hemorrhage features	Total (*n* = 82)	(%)	*p*
Types of presenting hemorrhage			
Intraparenchymal hemorrhage	50	61.0	0.185
Parenchymal hemorrhage with subarachnoid/intraventricular hemorrhage	32	21.0	
Locations			
Supratentorial	75	91.5	0.001
Lobar hemorrhage	68	83.0	
Thalamus–basal ganglia hemorrhage	7	8.5	
Infratentorial	7	8.5	
Volume of hematoma			
< 30 cm^3	36	43.9	0.001
30–60 cm^3	25	30.5	
> 60 cm^3	21	25.6	

Table 4. AVM nidus features on CT and DSA.

Nidus	Total (n = 82)	(%)	p
Location			
Supratentorial	75	91.5	0.001
Temporal lobe	24	29.3	
Frontal lobe	22	26.8	
Occipital lobe	14	17.1	
Parietal lobe	8	9.8	
Thalamus	6	7.3	
Basal ganglia	1	1.2	
Infratentorial	7	8.5	
Brainstem	3	3.7	
Cerebellum	4	4.9	
Size			
< 3 cm	61	74.4	0.001
3–6 cm	18	21.9	
> 6 cm	3	3.7	

Table 5. Feeding arteries and venous drainage pattern.

Variables	Total (n = 82)	(%)	p
Feeding arteries			
Anterior cerebral arteries	19	23.2	0.001
Middle cerebral arteries	44	53.7	
Posterior cerebral arteries	35	42.7	
Basilar and vertebral arteries	5	6.1	
Venous drainage pattern			
Superficial	58	70.7	0.001
Deep	24	29.3	

Spetzler–Martin grades I and II accounted for 73.2% of cases, and grades IV and V for 8.5% (Table 6). Table 7 shows the Spetzler–Martin grading scale and chosen treatment therapies. After intervention, the average volume of the AVM was reduced by about 50%. There were no complications recorded.

Table 6. Spetzler–Martin grading and Lawton's supplemental grading scales.

Spetzler–Martin grading scale		*n* (%)	Points	Supplemental grading		*n* (%)
Size	< 3 cm	61 (74.4)	1	Age	< 20	14 (17.1)
	3–6 cm	18 (22.0)	2		20–40	37 (45.1)
	> 6 cm	3 (3.7)	3		> 40	31 (37.2)
Eloquence	No	52 (63.4)	0	Bleeding	Yes	82 (100)
	Yes	30 (36.6)	1		No	0
Draining veins	Superficial	59 (72.0)	0	Compactness	Yes	80 (97.5)
	Deep	23 (28.0)	1		No	2 (2.4)
Grade I		35 (42.7)		Grade I		14 (17.1)
Grade II		25 (30.5)		Grade II		35 (42.7)
Grade III		15 (18.3)		Grade III		33 (40.2)
Grade IV		6 (7.3)		Grade IV		0
Grade V		1 (1.2)		Grade V		0

Table 7. Spetzler–Martin grading scale and chosen treatment therapies.

Spetzler–Martin	Treatment therapies						Total
	Surgery (*n* = 61), %		Embolization (*n* = 8), %		Embolization + surgery (*n* = 13), %		
Grade I	33	**94.3**	0	0	2	5.7	35
Grade II	22	**88.0**	2	8.0	1	4.0	25
Grade III	5	33.3	4	26.7	6	40.0	15
Grade IV	1	16.7	2	**33.3**	3	**50.0**	6
Grade V	0	0	0	0	1	**100**	1

4. Discussion

In the present study, within a year, we assessed 82 patients diagnosed with cerebral hemorrhage due to ruptured AVM and treated at our hospital. The hospital where we collected the data has many departments such as internal medicine, surgery, and neurology interventional radiology. Our study is prospective research and so the results are limited to the above sample and time period.

Regarding the inclusion criteria for patients, this study refers to ruptured AVM cases, so cases with rupturing aneurysms on the arterial feedings were not included in our study. A ruptured AVM with only subarachnoid hemorrhage was not seen during our research. Also, the dural feeders were not seen well in the MSCT images compared to intracranial feeders. Therefore, we excluded from the sample those patients with dural feeders to ensure homogeneity. We excluded patients with extracranial AVM because they were in small in number at our hospital. If we accepted one or two such patients into the study, the homogeneity of the sample would have been lost. All cases in the study were pure AVM, including the eight-year-old patient. Pial AVF cases are not common, so we did not assess them in the study.

The proportion of patients under 40 years old in the present study was 62.2%. The average age of patients in the study was 35.1 ± 15.3 years, with the youngest being 8 years old and the oldest being 67. This age distribution is similar to that of other authors, seeing as the rupture of venous artery malformation is a common cause of brain bleeding in younger people. For these patients, brain bleeding greatly affects their quality of life and emotional wellbeing, having many consequences for the family and society.

Sudden headache (nearly 90%) and vomiting/nausea (more than 50%) are the most common symptoms of a ruptured cerebral AVM, with one-third of patients experiencing hemiplegia. According to Steiger, the percentage of patients with focal neurologic deficits is variable, from 1% to 40%, depending on the location of the AVM [12]. This is explained by the fact that the rupture of a vascular malformation has less of an effect on motor skills and tends to lead to fewer disturbances of consciousness (31.7%) ($p < 0.05$), but more frequently involves cerebral lobe bleeding as opposed to deep internal bleeding, aneurysm rupture, or increased blood pressure. This result is similar to what was found by some other authors: according to Phan (graduate thesis from resident doctor, Hanoi Medical University), the rate of patients with consciousness disorders is 22.8%, while, according to Murthy et al., the rate of patients with a Glasgow score below 9 is 17.6% [13].

Intraparenchymal hemorrhages accounted for a high proportion (61%), but most were lobar hemorrhages (83%) ($p < 0.05$). Deep bleeding in the thalamus and basal ganglia accounted for a low percentage. Most hematomas were small to medium in volume (74.4%) ($p < 0.05$). The mean volume of the hematomas was 42.2 ± 34.5 cm^3.

According to Phan, the rate of parenchymal bleeding is 78%, of which lobe bleeding accounts for 84.4%. According to Murthy et al., the rate of lobar bleeding is 70%, while that of deep site bleeding is 14.7% [13]. According to Spetzler, the rate of hematomas in the general brain parenchyma is about 65.2% [10]. Most rain lobe bleeding has little effect on movement and the rate of consciousness disorders is also less ($p < 0.05$); in any case, the bleeding is not heavy.

Hematomas were present in both the supratentorial (91.5%) and infratentorial (8.5%) regions with $p < 0.05$. According to Murthy et al, the rate of infratentorial hematomas is 14.7%. Our rate was lower due to our data selection excluding cases of pure subarachnoid/intraventricular hemorrhage. Spetzler commented that a ruptured AVM in the brainstem or cerebellum often causes a pure subarachnoid hemorrhage. The average volume of the hematoma is 42.2 ± 34.5 cm^3. Nearly 75% of hematomas are small to medium (<60 cm^3), and the rest are large. Of large hematomas (volume > 60 cm^3), 75% were in the frontal and temporal lobes. According to Spetzler, hematomas > 4 cm diameter are common in the temporal, frontal, and occipital lobes [10].

The majority of cases (91.5%) were in the supratentorial region, in which the temporal and frontal lobes are more common (32% and 29.3%, respectively). Most cases (74.4%) of AVM are small in size, less than 3 cm.

Among the supratentorial AVM, 83% of those in the nidus are superficial. This result is similar to what was found by the authors of [14], in which the rate of superficial nidus was 79% and they most commonly presented in the temporal lobe (25.2%). Three-quarters of all malformations are <3 cm. Due to the small size of the AVM drive, most of the time when the AVM drive ruptures it does not alter the patient's consciousness. The cause of the rupture is the high pressure in the feeding arteries and usually only a single draining vein. Studies of circulation in the malformed mass have also shown that bleeding malformations have low circulating volume. The malformation drive size is the most important criterion among the many prognostic scales in order to choose the right treatment for each patient [12,14].

The feeding arteries mainly originate from the branches of the middle cerebral arteries (53.7%) and posterior cerebral arteries (42.7%). The draining veins are mainly superficial return to cortical veins and/or superficial sinuses (70.7%) ($p < 0.05$), similar to the results of Iosif (70%) [5].

Spetzler–Martin grades I and II accounted for 73.2% of cases, and grades IV and V for 8.5%. Our results are similar to those of some other authors, with grades I–III accounting for 89.1%, grade IV for 9.9%, and grade V for 0.99% [12].

Despite its simplicity and ease of use, the Spetzler–Martin grading scale does not take into account other important factors for evaluating surgical prognosis such as bleeding in malformations, the age of the patient, and the nidal architecture (diffuse versus focal). Lawton et al. provided a supplemental grading scale for the evaluation of AVM based on these characteristics. In our study, 17.1% of patients were in supplemental grade I, 42.7% in grade II, and 40.2% in grade III. According to Lawton, the rate of severe complications and mortality increased as scores in the supplemental grading scales increased; the rate was only 3.7% in grade I and up to 50% in grade V [11,15].

The Spetzler–Martin scale is the most commonly used rating table to evaluate the surgical prognosis of malformations. The authors commented that surgery on grade I malformations involved no complications, while grade II involved mild complications and no serious complications. Grades IV and V involved mild post-operative complications in 20% and 19% of patients, respectively, and severe complications in 7% or 12% [11,16,17].

Therefore, surgeons often choose patients with grade I and II to minimize complications and consider a combination of therapies (embolization and surgery) or conservative treatment with grades IV and V. In our study, grade I (94.3%) and grade II (88%) patients who received surgical treatment showed good outcomes. The treatment therapy for grade IV and V patients is a combination of embolization and surgery. In this study, a case with complex AVM grade V was diagnosed and treated with embolization and radiosurgery eight years ago. In this case, the size was large (72 mm) and the deep venous drainage in the great cerebral vein of Galen ruptured into the thalamus. We chose intervention and embolization of the three branches of arterial supply. After four weeks of intervention, the patient stabilized.

These patients had ruptured AVMs and it was necessary to deal with the AVMs early. Therefore, we did not choose radiosurgery in this study. We have not decided on treatment therapies for each patient. However, in almost cases, we suggested surgery for patients with SM 1–2 points and embolism or a combination treatment for the other patients. We did not choose radiosurgery in case of hemorrhage in acute period.

We found that the ranking on the Spetzler–Martin scale is often low in patients with a small nidus or intraparenchymal hemorrhage, with little change in the level of consciousness ($p < 0.05$), so these patients have fewer complications after an operation. In contrast, patients with parenchymal and intraventricular/subarachnoid hemorrhages often suffer from severe consciousness disorders. Large hematomas can have a major effect on healthy brain parenchymal tissue, increasing the intracranial pressure and herniation and thus worsening consciousness very quickly. Choosing proper treatment therapies for each case will help to minimize complications and mortality. This is a challenge for physicians and requires careful image analysis and clinical evaluation (Figures 1 and 2).

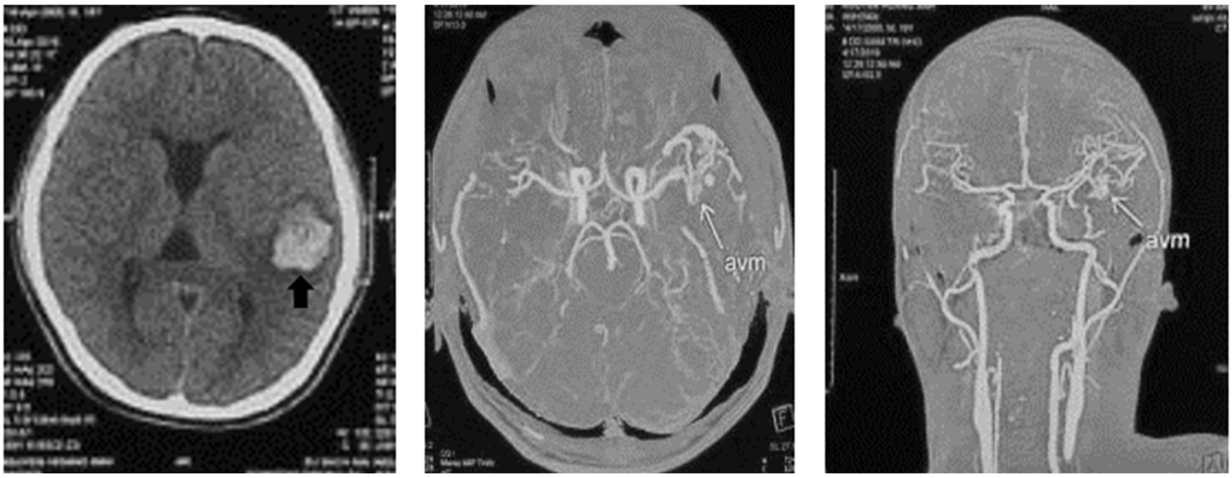

Figure 1. A 19-year-old patient was hospitalized with a sudden headache. Cerebral MSCT: left temporal lobe AVM, size 23 × 10 mm, fed by branch of the left middle cerebral artery, drained by the cortical vein to the left transverse sinus; Spetzler–Martin: 2 points. After surgery without complications, the patient had no headache, and postoperative MSCT no longer found a malformation.

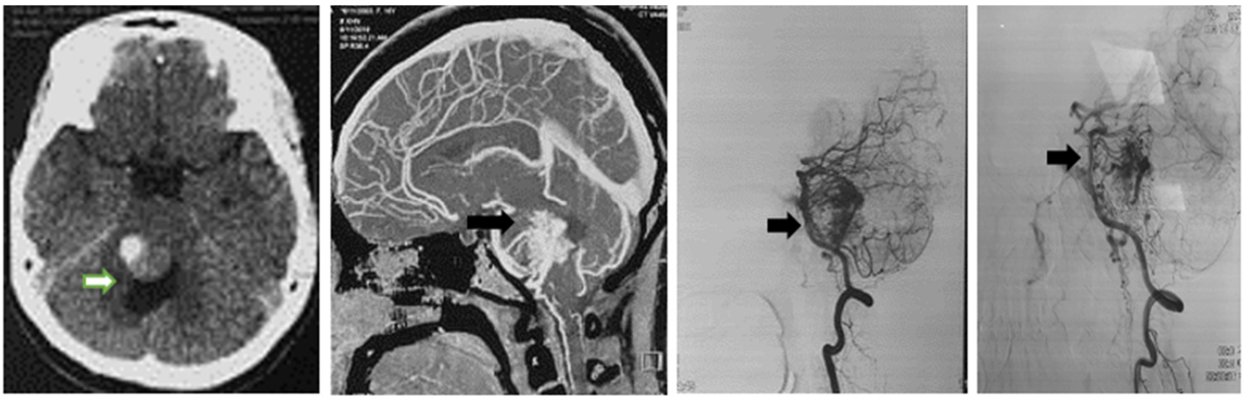

Figure 2. A 16-year-old patient complained of a sudden headache and left side hemiparesis. MSCT imaging: The ruptured 25 × 30 mm AVM in the posterior fossa of the right cerebellum and cerebellum caused bleeding of the right cerebellum with IV ventricular dilatation. The feeding arteries were from the oblique branch of the basal artery; the deep draining vein poured into the straight sinus; Spetzler–Martin: 3 points. The patient had indications of preoperative vascular intervention, causing obstruction to the AICA artery feeding about 50% of the malformation. Microsurgery removed the remaining deformity one week later.

Our study has some limitations. The study focused on describing the symptoms and characteristic imaging of brain AVM, comparing the images on MSCT and DSA, so we did not mention the treatment results. We will research the above topic in another noncontrolled intervention study. We also did not see any patients with capillary malformation–arteriovenous malformation (CM-AVM), cerebrofacial arteriovenous metameric syndrome (CAMS), or hereditary hemorrhagic telangiectasia (HHT).

5. Conclusions

Patients with ruptured AVM are commonly under 40 years old (62.2%); average age: 35.1 ± 15.3. On CT and DSA images, 91.5% of cases were supratentorial hemorrhages and 83% were lobar hemorrhages; 74.4% of hematomas were small to medium in volume (<60 cm^3) ($p < 0.05$), with fewer disturbances of consciousness (31.7%) ($p < 0.05$).

AVMs were mainly in the supratentorial region (91.5%), and the size was usually <3 cm^3 (74.4%). Feeding arteries mainly came from the middle (53.7%) and posterior (42.7%) cerebral arteries. The majority of AVMs were drained by superficial veins (70.7%) ($p < 0.05$).

In the classification of malformations according to Spetzler–Martin, grades I and II accounted for the highest percentage (73.2%), and most of these patients had surgery. The Spetzler–Martin score, with the complementary scale, not only serves to classify the severity of the lesion, but also serves as the basis for treatment selection in AVMs as well as the prognosis of treatment outcomes.

Conflicts of interest

The authors declare no conflict of interest.

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