A proposal for a new pial arteriovenous fistulas grading scale for neuroendovascular procedures and literature review

Luis Rafael Moscote-Salazar[1], Hernando Raphael Alvis-Miranda[2]

[1]Department of Neurological Endovascular Therapy, Instituto Nacional de Neurología y Neurocirugía; México City, México, mineurocirujano@aol.com
[2]Universidad de Cartagena, Cartagena de Indias, Colombia

Abstract

Pial arteriovenous fistulas are an unusual type of cerebrovascular lesion. The vascular supply of this type of injury comes from cortical and pial vessels which are not located in the dura leaflets. With the aim to make a grading scale for this type of injury, we conducted a literature search using the keywords "pial arteriovenous fistulas", "embolization" associated with "outcome". Angiographic and imagenological characteristics typically found in pial arteriovenous fistulas were taken and was developed a preliminary classification system that must be validated in future studies. Pial arteriovenous fistulas are associated with a poor natural history and the establishment of an individualized therapeutic strategy can provide a good prognosis. The endovascular management of these lesions is safe and effective.

Key words: pial arteriovenous fistulas, embolization, outcome.

Introduction

Pial arteriovenous fistulas (PAVF) are a rare type of intracranial arteriovenous lesions, with clinical relevance, (1, 2) that recently have been recognized as different from arteriovenous malformations (AVM). (3) PAVF differ from dural arteriovenous fistulas in that their arterial supply derive from pial and cortical arteries and they are not involved by the leaflets of the dura-mater.

They can have one or multiple arterial conections with only one venous channel, without an intervening nidus or capillary. PAVF can be located in any cerebral region, but usually shown preference for supratentorial regions. (4)

PAVF can be acquired traumatically, iatrogenically or can be congenital lesions. Due to its unfavorable natural course, the conservatory management its associated with a mortality rate up to 63%. (5) Because of the nidus abscense the shunt closure by endovascular or surgical approaches represents a satisfactory therapeutical procedures. (6) At presentation, can be hemorrhages, seizures, focal déficits, and heart failure in neonates, headache and symptoms of raised intracranial pressure, mass effect, palpable masses, cranial erosions and macrocephaly.

This type of fistulas can receive diverse endovascular treatments, currently, due to the scarce cases reported, a classification pointing the type of endovascular approaches needed is absent. We propose a classification using factors already deemed as significant determinants of risk and outcome for endovascular PAVF patients. The classification scheme proposed is very practical in clinical use.

Methods

A literature search was performed in several medical databases including Medline, showing a total of 33 results using the keywords "pial arteriovenous fistulas", "embolization", associated with "outcome".

Emphasis was given to the angiographic, imaginologic and hemodynamic characteristics found usually in PAVF because these can be easily adapted to the management established for each particular patient; and was developed a preliminary grading scale that needs be applied in future studies to be validated. The resulting articles were assessed by considering factors such as: age, gender, clinical presentation, and aneurysm or varyx association.

Results

From the search of 33 articles, emphasis was given to the angiographic, imaginologic and hemodynamic characteristics found usually in PAVF because these can be easily adapted to the management established for each particular patient, as mentioned previously. 23 articles were found. In Table 1 are summarized the main factors associated with impact on the natural course of PAVF, that we consider determinant as variable for grading score.

Age

Hetts et al., (7) through a retrospective review of a neurointerventional database, identified 386 pediatric patients with intracranial AVFs and AVMs, from which 25 had PAVF. They found that PAVF constituted 7.3% of pediatric intracranial vascular lesions with a nondural arteriovenous shunt; single-hole fistulas predominate later in childhood and more frequently presented with seizures, hemorrhage, or focal neurologic deficits. In pediatrics patients, the age is a relevant factor, in these same review by Hetts et al.,(7) they found that patients ≤ 2 years of age compared with patients presenting at >2 years of age had more treatment procedures (P = .041), as in those harboring a multi-hole fistula versus those with a single-hole fistula (P = .003); patients ≤ 2 years of age were also more likely to have a multi-hole fistula (100% versus 25%, P = .0001) and to have a poor clinical outcome (54% versus 0%, P = .0052), defined as a pediatric mRS of ≥ 3.

Table 1. Proposal grading scale for PAVF

Variable	Characteristics	Value
• **Calcification**	Yes	1
	No	0
• **Aferences**	Unique	1
	Multiple	2
• **Location**	Eloquent área	1
	Non-eloquent área	0
• **Associated AVM**	Yes	1
	No	0
• **Varix**	>5cms	3
	3-5cms	2
	<3cms	1
	No	0

Interpretation: Type I: 2-3; Type II: 4-6; Type III: 7-8.
AVM: arteriovenous malformation
Eloquent area: visual cortex, motor-sensitive cortex, hypothalamus, thalamus, intern capsule, brainstem, crux cerebri, or cerebellar nucleus.

Varix

Varix formation is a special finding in patients with pial AVF. Some reports suggest that the high pressure blood flow from arterial feeder directly into the venous drainage may result in venous varix formation. (8–12) Yang et al., (13) determined that patients presented at younger age (≤15 years old) are more likely

to have varix in angiographic study ($p<0.05$) compared with the adult population, being the clinical presentation different in these two groups. Younger patients are more likely to have symptom related to shunting effect; however, haemorrhage is the major presentation in older patients. Furthermore, the absence of varix do have significant correlation with haemorrhage ($p=0.001$). However, it is necessarily to remember that patients with PAVF may manifest differently according to their age and the existence of varix. This later might exerts a buffer effect to tolerate the high arterial flow pressure and consequently decrease the risk of bleeding. Much less frequently, there is also an aneurysm of the feeding artery. (11)

Calcification

It is important to consider the presence of associated calcification, which is more probable in pial than dural arteriovenous lesions. The mechanism of calcification in these lesions is a dystrophic process due to hypoperfusion caused by steal phenomenon or venous congestion over a long time,(2) when mural calcification is thick, it implies a longstanding course of cerebral damage. In these circumstances, even when is feasible the obliteration trough endovascular methods, alleviating the mass effect could be impossible; furthermore, perform first an endovascular approach, and in a second stage surgical removal could be tricky when compared to a single operation for occluding the accessible feeder artery and removing the mass simultaneously. Another fact to consider is that the calcified shell would physically restrict approach and handling of endovascular devices.(2)

Arteriovenous malformation

PAVF inducing dural arteriovenous shunts (DAVS) have been proposed particularly in some high-flow PAVF associated with DAVS upstream from their drainage into the dural sinus. (14) This could be caused by a similar sump effect created by the high-flow venous drainage of the PAVF downstream. (15) The venous changes produced by high-flow pial AVS on the venous sinuses, such as increased venous pressure or venous outflow obstruction, can also be triggering factors. (15) But this is not the situation in our cases, because they were high-flow DAVSs anatomically closely related to the pial AVFs that were upstream from the DAVSs. The dominant shunts in our cases were high-flow DAVS rather than PAVF. (15)

Endovascular therapy of intracranial dural arteriovenous fistula may be curative but is often complex and carries definite risks. Neurosurgical ligation of pial draining veins, with pre-operative embolization when safe, may be a relatively more controlled method to achieve complete cure. (16)

Location

Lesions in deep and eloquent locations can be associated with a high surgical risk for neurologic morbidity. (17)

Outcome

Lv et al., (17) reviewed the clinical and radiologic data of 16 patients with PAVF who were treated endovascularly at the Beijing Tiantan Hospital between 1998 and 2008. At the time of the last follow-up evaluation (range, 3–12 months; median, 7 months), 15 patients (93.75%) had a Glasgow outcome score of V and 1 patient (6.25%) had a Glasgow outcome score of IV. Altogether, there were three perioperative complications (18.75%). During the follow-up period (range, 3–12 months; mean, 7.4 months), the overall morbidity rate was 6.25%.

Hydrocephalus caused by venous thrombosis is the main complication, thus heparin should be given routinely after endovascular embolization. (17,18)

Pathophysiology

Although they account for only 1.6% of all AVM are associated with a poor natural history. Patients with PAVF, and specially infants, are known to develop hydrovenous disorders that rapidly damage the surrounding brain, others alterations include subependymal or cortical atrophy, white matter calcification and delayed myelinization; thus early intervention is essential for optimal neurological and cognitive development. (4,19)

Intracranial PAVFs differ from AVM owing to the lack of nidus and from dural arteriovenous fistulas in that they derive their arterial supply from pial or cortical arterial vessels, and the lesion does not lie within the dural leaflets. (8) The abnormality from a PAVF arises from its high-flow nature. The origin of PAVFs can be traumatic, iatrogenic, or congenital. (4) Congenital pAVFs are usually present in childhood. PAVF are considered to be congenital in nature. (20) however, there is little evidence that the PAVF diagnosed in adults are present in the same form at birth. In addition, cases of de novo PAVF have been reported. (21–24)

Little is known about the pathophysiological development mechanism ofthese lesions, but probably are produced by a misstep in the embryological development of the cerebrovasculature, (4, 25), also, abnormal angiogenesis and associated vascular growth factors and cytokines may play a role. (4)

Lasjaunias (19) proposed that the congenital event is primarily involving the vascular modeling and remodeling process at the cellular and structural level, affecting the endothelial cells at the venous side of the capillaries, resulting in a progressive dysfunction, and its manifestations will be related with the triggers, such as mechanical, hormonal, pharmacologic, hemodynamic, thermal, radiation, viral, infective, and metabolic factors.

The frequency of venous varices and vessel ectasia, not to mention the association of syndromes that embrace angiodysplasia, (26) may reflect an inherent predilection of dysplastic elements toward the formation of such lesions. (4) The diverse nature and timing of the various triggers causes the different time and form of presentation of the abnormal arteriovenous shunts. The previous postulation can be applied to the acquired lesions, in which the trigger is applied for a certain length of time and had the same consequence on the target cells related to venous vascular remodeling.

The pathogenesis of PAVF also includes abnormal expression of various angiogenic factors such as vascular endothelial growth factor, basic fibroblast growth factor, and alpha transforming growth factor. (27–30) Suppression of vascular cell growth modulators, including endoglin1, has also been found. (31) As have been learned from cases of acquired PAVF following cerebral vein thrombosis (22), ischemia or hypoxia are important etiological factors. There is evidence that hypoxia is a powerful trigger for the up-regulation of angiogenic factors expression. (32)

Main clinical and angiographical characteristics

The majority of AVMs occurring in the neonatal and infant period are vein of Galen

malformations. Nongalenic cerebral AVM (or pial AVM) have been reported to account for roughly 22 % of AVMs found in neonates and 35% of AVMs in infants. (1) The common presentations in neonates are systemic cardiac manifestations (54%), seizures (31%), hemorrhage (15%). In infants, hemorrhage (38%), hydrodynamic disorders (38%), cardiac manifestations (16%) and seizures (8%) are known to occur. (1)

PAVF produced in the first years of life can be associated with syndromes such as Rendu-Osler - Weber and Klipel-Trenaunay-Weber síndromes. (33, 34) PAVF can cause headaches, hemorrhage, seizures, focal neurologic deficits, and raised intracranial pressure. (18)

Flow and perfusion pressure through a pial AV fistula is certainly high. Impaired venous drainage in AVMs has been implicated in the risk of hemorrhage, but whether venous varices accompanied by PAVF are associated with an increased risk of hemorrhage remains unclear. At present, four-vessel cerebral angiography is the gold standard diagnostic procedure which can distinguish nongalenic AVFs from AVMs. (35) Angiographic diagnostic criteria for AVFs consist of: (36)

1. Rapid circulation time because of high-velocity flow;
2. Enlarged feeding artery;
3. Direct filling of a large varix.

Therapeutical approaches

Therapeutic options of pial AVF include surgical excision of lesion, surgical ligation of feeder and endovascular obliteration of feeders. In addition to standard microsurgical technique, additional measures such as induced hypotension, temporary clipping and pharmacological neuroprotection may be helpful.

The anesthetic team should be ready in anticipation of severe blood loss and potential circulatory collapse, because preexisting venous hypertension may precipitate severe bleeding that does not respond to these and other standard hemostatic measures. The simple disconnection of the fistula should be the goal of therapy, (4) and attempts at excision of the varix may exacerbate parenchymal bleeding.

Hoh et al have summarized the literature from 1970 to 2000. There have been 79 patients reported to date. Venous varices were found in 48 of 54 cases (89%). However, at that individual centre, only three out of nine were associated with varices. In their series, the concept of 'flow-disconnection' either endovascularly or surgically was advocated. (4) Surgical disconnection involves either aneurysm clip application or cauterization of the feeding vessel. Though this has been proven effective, some lesions are deep or surgically inaccessible and the risk of surgery can be very significant. As in this case, severe bleeding can be expected due to:

(1) venous hypertension due to the high-flow system and,

(2) hyperaemia from normal perfusion pressure breakthrough.

Unlike the case of nidus-type AVM, the strategy of surgical disconnection without lesion resection was found to be sufficient for obliteration of the fistula. Hence, excision of the varix is probably not required. (4)

Endovascular approach

PAVF are rare vascular lesions that require prompt treatment. As symptomatic patients managed conservatively have a

poor prognosis, radical treatment should be undertaken as soon as possible. (37)

Obliteration of the fistula by an endovascular route, avoiding the risks associated with craniotomy, should always be considered especially when the lesion is deep seated or the risk of neurological deficit with surgery is high. (4, 19, 38, 39) Also should be considered the endoscopic intervention, that can be an effective and safe option for the treatment of this type of lesion.

Endovascular attempts are not always successful or safe. Several technical difficulties in obliteration of the fistula have been described. Endovascular embolization of the fistula may be complicated by migration of the embolization agent into a varix, to the lung or elsewhere in the cerebral vasculature. (4)

Newman et al., (40) described a novel endovascular treatment strategy that was used successfully to treat 2 pediatric patients with a PAVF, a single-channel high-flow PAVF was diagnosed in 2 male patients (6 and 17 years of age). Both patients were treated with endovascular flow arrest using a highly conformable balloon followed by Onyx infusion for definitive closure of the fistula. Neither patient suffered a complication as a result of the procedure. At the 6-month follow-up in both cases, the simple discontinuation of blood flow had resulted in durable obliteration of the fistula and stable or improved neurological function; thus, the authors conclude that Onyx can be delivered successfully into high-flow lesions after flow arrest to allow a minimally invasive and durable treatment for PAVF.

Paramasivam et al., (41) reported that development of de novo dural arteriovenous fistula(s) following endovascular embolization of a prior high-flow PAVF is not an uncommon development. They are mostly asymptomatic and develop anywhere along the drainage of the fistula, maturing over time and diagnosed during follow-up studies, emphasizing the need for follow-up angiography. They can be effectively treated by endovascular embolization. Localized refractory dural fistulas can be dealt with by radiosurgery.

Conclusions

Intracranial arteriovenous fistulas are vascular malformations in which clinical suspicion and prompt diagnosis, with a subsequent appropriate therapeutic approach, are crucial to avoid the development of irreversible neurological damage or even patient death because these lesions can be associated with heavy bleeding and high mortality rates. Depending on their location and high-flow dynamics, these lesions can present treatment challenges for both endovascular and open cerebrovascular surgeons. Disconnection of direct shunting, either by endovascular or surgically, is sufficient to achieve successful treatment; therefore, total resection of the lesion is unnecessary. We propose a PAVF grading score, however a retrospective study is necessary to validate it. To our knowledge this is the first proposal for classifying PAVF based on evidence.

Correspondence:

Dr. Luis Rafael Moscote-Salazar, Universidad de Cartagena, Cartagena de Indias, Colombia.
e-mail: mineurocirujano@aol.com

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