Evaluation of pediatric patients with vascular malformations managed with endovascular and radiosurgical techniques using a modified Rankin disability scale

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Backgroung: **Pre- and postoperative evaluation of the pediatric patient with a cerebrovascular malformation can be cumbersome. This may be due to several factors, including age and ability to verbalize. Functional evaluation scales have been devised, yet application to a retrospective study, where information can be limited, may not be possible. Simpler scales, serving the purpose of functional description and categorization would be beneficial in these cases.**

Methods: **Between December 1997 and December 2003, 24 patients between the ages of 4 months to 17 years old underwent endovascular treatment for cerebrovascular lesions at our institution. The majority of the arteriovenous malformation cases underwent further radiosurgical treatment. Mean follow-up period from the time of the last endovascular or radiosurgical intervention was 22 months. A pediatric modification of the Rankin Disability Scale was used for evaluation of pre-procedural and post-procedural functional status.**

Results: **Combined embolization/radiosurgical approach had 4% mortality and 4% morbidity rates. This combined technique achieved a 46% cure in a variety of pediatric vascular anomalies. Overall improvement in disability using the pediatric modification of the Rankin Scale was noted for all of the cases, and a tendency for improvement was noted in the arteriovenous malformation subgroup though not statistically significant, p = 0.0547.**

Conclusions: **These results indicate that a pediatric modification of the Rankin Disability Scale can be used for functional evaluation in this population. Although other functional evaluation scales are available and validated, using a Rankin Disability Scale modification is straightforward, and it can provide functional categorization in retrospective studies.**

Key words: Cerebrovascular disease, Rankin Disability Scale, Pediatric patient.

Cerebrovascular disease in children accounts for approximately 10% of pediatric neurosurgical practice (1). The most common vascular disorders are the vascular anomalies, including intraparenchymal and dural arteriovenous malformations (AVMs), arteriovenous fistulae (AVF), vein of Galen malformations, aneurysms, carotid-cavernous fistulae (CCF), angiomas, and Moya-Moya disease (2). In the pediatric population, most intraparenchymal hemorrhages are caused by AVMs.

Endovascular techniques are part of a multimodal approach in the management of vascular anomalies. These techniques involve occlusion of the lesion using liquid adhesives (n-butyl cyanoacrylate), particles and/or microcoils. AVMs are routinely embolized presurgically, making subsequent surgical or radiosurgical management easier and safer (3,4).

The evaluation of the endovascular and radiosurgical roles for the management of these vascular anomalies requires a way of clinically assessing the patients in a reproducible manner. Functional evaluation of the pediatric patient can be provided by scales such as the Functional Independence Measure for children (WeeFIM). Yet, this scale is validated for patients older than 6 months, and collected data needs to include information on a cognitive domain besides self-care and mobility (5). Among other functional grading scales, the Rankin Disability Scale assesses level of independence, yet is not sensitive to subtle neurologic deficits such as dysphasia and visual field defects (6). In this respect, we modified the Rankin Disability Scale, which is well established as a functional evaluation scale for stroke in adult patients, for application

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This investigation was supported, in part, by a 'RCMI clinical research infrastructure initiative' (RCRII) award, 1P20 RR 11126, from the National Center for Research Resources, National Institutes of Health.

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to a small series of pediatric patients with vascular malformation . It was used for establishment of pre-procedural and post-procedural functional status. This modified scale is not validated. Yet, to our best knowledge, no other similar cerebrovascular disorder disability scale that could be applied to our pediatric population exists in the literature

Materials and Methods

Between December 1997 and December 2003, 24 patients between the ages of 4 months and 17 years old underwent endovascular embolization treatment for various cerebrovascular lesions. A retrospective review of the hospitalization and outpatient medical records was made. There were 12 male and 12 female patients. The vascular lesions included 4 vein of Galen malformations, 2 cerebral aneurysms, 14 cerebral AVMs, 2 spinal AVMs, 1 posterior fossa dural AVF and 1 indirect acquired CCF. Institutional Review Board and Privacy Committee (HIPAA) approvals were obtained as required by our institution prior to the start of the study.

Endovascular procedures were carried out after thorough case evaluations, and using standardized institutional and OSHA approved occupational safety measures and aseptic materials and techniques. Digital substraction angiography (DSA) was made with monoplanar C-arm fluoroscopy (GE Medical Systems, Inc.) and biplane digital subtraction angiography unit with 3-D reconstruction (GE Medical Systems, Inc.). Catheterization and embolization materials used included flow-guided microcatheters (Spinnaker, Boston Scientific; Regatta, Cordis; Magic, Balt), steerable micro wires (0.035mm) (Trasend, Boston Scientific; Sorcerer, Balt; Agility, Cordis; Mirage, MTI), guide/envoy catheters (5Fr and 6Fr) (Envoy, Cordis), sheath introducers (5Fr) (Cordis), embolization particles (Trufill), coils (GDC and Berenstein liquid coils, Boston Scientific), histoacryl (Braun), NBCA (Cordis), Onyx (MTI) and Ethiodol (Cordis Neurovascular) adhesives. Brevital (Ranbaxy Pharmaceuticals, Inc.) was used uniformly for provocative testing. Conray and Optiray contrast media (Mallinckrodt) were used; the latter in the case of allergy history. A pressure bag with normal saline and heparin flush was used during the procedures for prevention of clot formation inside the arterial catheters and microcatheters. Follow-up was carried out at our endovascular neurosurgery clinics. Repeat embolization was carried out in intervals of 3 to 4 weeks in cases that required more than one endovascular procedure. In those cases where complete obliteration was obtained, a follow-up DSA was performed at 3 months and a magnetic resonance angiography (MRA) at 6 and 12 months. For those patients that required LINAC (X-knife, Radionics) or Gamma Knife (Leksell) radiosurgery, follow-up DSA is performed two years after the procedure. MRI/MRA is made between 3 months to 1 year after radiosurgery .

The Rankin Disability Scale (6) was modified by the authors for application to a pediatric population (RDSp) (Table 1). Care was taken to keep the same or similar functional stratification or grading by making a parallel adaptation of the Rankin Scale. This was done by taking into account developmental milestones, and establishing (from 0 to 5) similar stratification in level of independence and activities of daily living (locomotion, care for one-self) for ages 0 to 18. Pre-procedural and post-procedural functional status was graded accordingly.

Table 1. Modified Rankin Disability Scale for the pediatric patient (<18 years old).

Grade	Features
0	No symptoms
1	No significant disability, with symptoms
2	Slight disability, independent for age[a]
3	Moderate disability: requires assistance for age[b], purposeful movements and capable of displacement or locomotion
4	Moderately severe disability: requires assistance[b], not capable of purposeful movements, displacement or locomotion
5	Severe disability: Bedridden, incontinent, constant care[c]

a. Adequate feedings, spontaneous micturition and defecation, and purposeful movements, including locomotion, depending on age and associated milestones.
b. Requires assistance with feedings (nasoenteric, gastrostomy), yet spontaneous micturition and defecation.
c. Constant care requiring total assistance with feedings, micturition and defecation. Not capable of purposeful movements or locomotion.

Stata 8.0 was used for statistical analysis. A binomial distribution (Sign test) based on the amount of positive disability changes was used for p-value determination (7). Disability change (DC) was calculated using the formula: DC = RDSp score at diagnosis - RDSp score at long- term follow-up.

Results

During a period of 6 years, a series of 24 patients (1:1 male to female ratio) underwent endovascular embolization treatment for the following cerebrovascular lesions: 4 vein of Galen malformations (2 galenic aneurismal dilatations and 2 choroidal type AVMs), 2 cerebral aneurysms, 14 cerebral AVMs, 2 spinal AVMs, 1 posterior fossa dural arteriovenous fistula (AVF) and 1 indirect acquired carotid-cavernous fistula (CCF). All cerebral AVMs were grade 4 or 5 in the Spetzler-Martin classification (8). Table 2-4 summarizes demographic and clinical presentation data for each of the cerebrovascular conditions studied. Mean

Table 2. Demographics and clinical presentation data for patients with vein of Galen malformations, cerebral aneurysms, dural and carotid-cavernous fistulae, and spinal AVMs.

Pathology	Type	Age	Sex	Presentation
Vein of Galen malformations	Choroidal AVM	5 years	male	headache, macrocephaly
	Choroidal AVM	6 years	male	headache, nausea and vomits
	Venous aneurysm	4 months	male	macrocephaly, failure to thrive, seizures
	Venous aneurysm	6 months	male	macrocephaly, failure to thrive, high output CHF
Cerebral aneurysms	Cavernous carotid artery	16	male	headache, abducens palsy
	Internal carotid artery bifurcation	11	female	headache, nausea and vomits, photophobia
Cerebral fistulae	Dural AVF	1	male	headache, nausea and vomits, seizures, irritability
	CCF	8	female	proptosis, visual acuity loss
Spinal AVMs	Cervical (IV)	9	female	headache, neck pain, paresis, meningismus
	Medullary (I)	6	female	headache, neck pain

CHF = congestive heart failure
AVM = arteriovenous malformation
AVF = arteriovenous fistula
CCF = carotid-cavernous fistula

Table 3. Demographics for patients with superficial and deep cerebral arteriovenous malformations.

Type	Age (years)	Sex
superficial	8	female
superficial	9	male
superficial	11	female
superficial	13	female
superficial	14	male
superficial	14	male
superficial	14	female
superficial	14	female
superficial	16	female
superficial	17	male
deep	4	male
deep	6	female
deep	6	female
deep	14	male

Table 4. Clinical presentation for patients with superficial and deep cerebral arteriovenous malformations.

Signs and symptoms	Number of patients
headache	9
seizures	7
nausea and vomits	3
cranial nerve palsy	2
hemiparesis	2
incidental	2
developmental delay	1

follow-up period from the time of the last endovascular or radiosurgical intervention was 22 months. Early follow-up was considered before two years after the last intervention, while long term follow-up was after two years.

Four patients presented with vein of Galen malformations. One of these patients was lost to follow-up after receiving combined embolization and radiosurgical treatments. The other 3 patients, including 2 with a vein of Galen aneurysm and one with a choroidal type AVM have all undergone endovascular therapy with complete obliteration. In all of these cases, significant functional improvement was documented (Table 5).

We report only 2 cases of pediatric cerebral aneurysms, in accordance with the low prevalence of the condition in this age group. Table 5 shows the functional outcome of endovascular therapy, which included carotid balloon occlusion in the cavernous carotid artery aneurysm case and Guglielmi detachable coil embolization in the internal carotid artery bifurcation aneurysm case. They have showed no recanalization on follow-up DSA and MRA.

Patients with cerebral arteriovenous malformations represent the largest subgroup treated. AVM types were classified as superficial (pial and subcortical locations) and deep (periventricular location). Fifty percent of our patients presented with seizures (Table 4). Table 6 lists the functional outcomes after combined endovascular and radiosurgical interventions for these patients. Thirty-six percent of the patients (5/14) were reported as cured after complete obliteration (no recanalization on follow-up DSA and MRA). Patients reported as failure included those requiring either emergent surgical intervention due to hemorrhage, unresponsive radionecrosis with significant mass effect, and significant morbidity or mortality (negative disability changes). Table 7 lists the mean disability changes for patients with cerebral AVMs. One patient suffered a hemorrhagic stroke after combined embolization/ radiosurgical treatment, and persisted in a vegetative state. Only one patient died. She had a thalamic AVM (>30 cubic cms.) initially treated with embolization. A year after radiosurgery, she developed symptomatic radionecrosis

Table 5. Functional outcomes after endovascular intervention for patients presenting with vein of Galen malformations, cerebral aneurysms, dural and carotid-cavernous fistulae, and spinal AVMs.

Pathology:	Outcome:	Type:	Embolization sessions:	RDSp score at diagnosis:	RDSp score at early follow-up:	RDSp score at long term follow-up:	Disability change:
	obliterated	aneurysm	1	3	2	1	2
Vein of Galen	obliterated	choroidal AVM	3	1	0	0	1
malformations	obliterated	aneurysm	2	3	1	0	3
Cerebral aneurysms	obliterated	Cavernous carotid artery	1	2	0	0	2
	obliterated	Internal carotid artery bifurcation	1	1	0	0	1
Cerebral fistulae	obliterated	Dural AVF	1	1	0	0	1
	obliterated	CCF	1	2	1	0	2
Spinal AVMs	obliterated	cervical (IV)	2	3	2	1	2
	obliterated	medullary (I)	1	1	0	0	1

AVM = arteriovenous malformation
AVF = arteriovenous fistula
CCF = carotid-cavernous fistula
RDSp = pediatric Rankin Disability Score

Table 6. Functional outcomes after combined endovascular and radiosurgical interventions for patients presenting with cerebral arteriovenous malformations.

Outcome	Type	Embolization sessions	Radio-surgery	RDSp score at diagnosis	RDSp score at early follow-up	RDSp score at long term follow-up	Disability change
obliterated	superficial	1	no	1	1	0	1
obliterated	superficial	3	yes	3	2	0	3
obliterated	superficial	3	no	1	0	0	1
obliterated	superficial	9	yes	3	2	2	1
obliterated	deep	1	yes	3	2	1	2
failure	superficial	2	yes	3	1	2	1
failure	superficial	3	no	1	1	1	0
failure	superficial	5	yes	1	1	1	0
failure	superficial	21	yes	1	1	5	-4
failure	deep	32	yes	1	3	4	-3
on treatment	superficial	1	yes	1	1	-	-
on treatment	superficial	9	yes	1	1	0	1
on treatment	deep	1	yes	2	1	0	2
on treatment	deep	4	yes	2	2	2	0

Table 7. Mean disability changes for patients with cerebral arteriovenous malformations in terms of outcome.

Outcome:	Mean disability change
cure	1.6
failure	-1.2
on treatment	1

requiring surgery due to significant mass effect. Both patients had over 10 embolization sessions and adjuvant radiosurgery. Mean disability change for the whole subgroup of AVMs was 0.38. Using a binomial distribution, a p-value of 0.0547 for obtaining positive disability changes was calculated.

Table 5 summarizes the outcomes for the dural AVF and the indirect CCF. Both cases were cured, as documented

by showing no recanalization on follow-up DSA and MRA after a minimum of 6 months to one year. Positive disability changes were noted in these cases. Table 5 also summarizes the outcomes of the 2 cases of spinal AVMs. The cervical AVM was classified as a type IV cervical spinal AVM (intradural-perimedullary with medullary feeders), and the medullary AVM was classified as type I (spinal dural fistula) [9]. Both patients were cured and had positive disability changes.

Discussion

Vascular malformations represent the most common cause of spontaneous intracranial hemorrhage in children, with an incidence of hemorrhage of more than 1 per 100,000 children per year. Annual risks for hemorrhage has been estimated around 2-4% for unruptured AVMs and 6-7% for ruptured AVM's the first year and 2-3% per year thereafter (2,10). Similar estimates in children are lacking due to the paucity of large series and the small number of patients who do not undergo surgery after diagnosis. For adults, the annual mortality rate for AVMs is 1%, and there is a combined mortality and severe morbidity rate of 2.5% (10). In children, some series have reported mortalities as high as 21%, possibly due to more violent and massive bleeding (11). A possible causative role for Moya-Moya disease has been suggested in some AVMs (12). Spinal AVMs constitute around 3.3-11% of spinal cord lesions and account for only 1.9% of the lesions seen in patients under the age of 10 years (13). These lesions entertain their own classification scheme in view of their differing anatomical locations and pathophysiology of disease (9).

Dural AVF and indirect CCF are rare in the pediatric population. Only 2 cases were reported in our series. Vein of Galen malformations are most often due to congenital midline AVM draining into this vein. About 1% of central nervous system malformations involve the vein of Galen (14). Aneurysmal dilatation of the vein can be associated and these patients usually present with hydrocephalus due to obstruction of the aqueduct of Sylvius. Two patients of 5 and 6 years of age presented with symptoms and signs of increased intracranial pressure. These patients had choroidal type AVMs, and were treated similar to other intraparenchymal malformations. The 2 patients with vein of Galen aneurysms were younger than one year of age and presented with signs of heart failure and hydrocephaly. This different clinical presentation is evidence of the differing pathophysiology, prognosis and subsequent treatment implications (15).

Only 0.2% of patients had aneurysmal subarachnoid hemorrhage present in the first decade of life, more than two-thirds of cases were of obscure etiologies (2,16). Some authors have suggested birth trauma as a significant predisposing factor in pediatric posterior circulation aneurysms (17). Aneurysms in the pediatric population have a male predominance and a 50% rate of rebleeding most likely due to delay in the diagnosis (16). Overall frequency in the general population ranges from 0.2 to 9.9 percent (18), and around 0.5 to 4.6 percent in the pediatric population (11,16,19,20). Two cases were reported in our series. These were treated with balloon occlusion methods and detachable coil embolization. Radiological and clinical outcomes were both excellent, and these patients were considered cured.

The subgroup of AVMs represented a total of 14 patients without prior history of surgical resection. Thirty-six percent of the patients were cured (5/14) and they have showed no recanalization on follow-up DSA and MRA studies. Thirty-six percent (5/14) of the cases were reported as failures. Four cases were still under embolization treatment at the time of follow-up. Taking into account clinical outcomes, which were graded using a modified pediatric adaptation of the Rankin Disability Scale (evaluates self-care and mobility parameters), an improvement in disability was noted, yet not statistically significant ($p > 0.05$). Combined mortality and morbidity was 14% (2/14). This is lower than the mortality reported in the literature for this condition in children (11). Both patients with significant morbidity and mortality were treated with more than 10 sessions of embolization. The latter suggests that when more than 10 sessions of embolization are required, morbidity and mortality increases, and other alternatives like direct surgical treatment should be considered.

The majority of the patients with cerebral AVMs (11/14) in our series were given radiosurgery, precluding any inferences about endovascular treatment by itself. Further prospective and randomized studies, with larger series of pediatric patients and validated functional assessment measurements are needed. These may help to delineate the roles and the significance of each available therapeutic strategy in the multimodal approach to pediatric AVMs. Nevertheless, the use of a modified version of the Rankin Disability Scale in the setting of a retrospective study, occasionally limited by available clinical data, has been an invaluable tool for grading pre- and post-procedural functional outcomes in our series.

Conclusions

In the last decades, a tendency towards minimally invasive treatment modalities has emerged. They provide safer and less costly procedures for the patient and the health care system. Current technological advances are

facilitating the process. Endovascular and radiosurgical techniques are gaining more clinical significance in the management of neurosurgical patients. Yet, adequate functional outcome measures are needed to evaluate results. This is especially true for pediatric patients. Children are occasionally not capable of expressing themselves or what they are feeling. Several functional outcome scales have been devised and are validated for this purpose. These may require information from a cognitive standpoint, as well as neurological evaluations and independence measurements. While this is suitable for a prospective study, where prior design of the data gathering process is made, and usually not limited by the information in medical charts; this is not so for a retrospective study.

Our adaptation of the Rankin Disability Scale is straightforward to apply, reproducible and well suited for gross functional evaluation and categorization of the pediatric patient. This scale can be used for rapid assessment of pediatric patients stroke in situations where only information on gross neurological function, self care and mobility is available.

Resumen

Trasfondo: La evaluación pre- y postoperatoria del paciente pediátrico con una lesión cerebrovascular puede ser trabajosa debido a factores como la edad y la capacidad disminuida de verbalizar. Se han desarrollado escalas de evaluación funcional, pero la aplicación a estudios retrospectivos, donde la información puede ser limitada, puede no ser posible. Escalas más simples que puedan establecer una descripción y categorización funcional pueden ser de beneficio. ***Métodos:*** Entre diciembre de 1997 y diciembre de 2003, 24 pacientes entre las edades de 4 meses a 17 años fueron tratados de manera endovascular por lesiones cerebrovasculares en nuestra institución. La mayoría de los pacientes con malformaciones arteriovenosas se trataron además con radiocirugía. El tiempo de seguimiento promedio fue de 22 meses. Se utilizó una modificación pediátrica de la escala de función Rankin para la evaluación funcional. ***Resultados:*** El abordaje endovascular/radioquirúrgico resultó en una taza de morbilidad de 4% y mortalidad de 4%. Se logró una cura en el 46% de los casos. En todos se, registró una mejoría en la función usando la modificación de la escala de función Rankin. También se notó una tendencia hacia una mejoría en el grupo de pacientes con malformaciones arteriovenosas, aunque no estadísticamente significativa, p = 0.0547. ***Conclusión:*** Estos resultados indican que se puede usar una modificación pediátrica de la escala de función de Rankin para la evaluación funcional en la población estudiada. Otras escalas funcionales existen y están validadas, pero el uso de la modificación de la escala de Rankin es rápido, y puede proveer categorización funcional en estudios retrospectivos.

Acknowledgements

We would like to thank Drs. Nathan Rifkinson and Orlando de Jesús for reviewing the manuscript. In addition, we appreciate the assistance in data acquisition provided by Mrs. María Cruz, nurse assistant and coordinator of the Neuroendovascular Surgery Program at the Puerto Rico Medical Center.

References

1. Humphreys RP, Hoffman HJ, Drake JM, Rutka JT. Choices in the 1990s for the management of pediatric cerebral arteriovenous malformations. Pediatr Neurosurg 25:277-285,1996.
2. Mickle JP, Glasser RS: Cerebrovascular Diseases in Children. In: Youmans JR, ed. Neurological Surgery: A Comprehensive Reference Guide to the Diagnosis and Management of Neurosurgical Problems. Vol 2. Philadelphia: WB Saunders Company, 1996:1243-63.
3. Gobin YP, Laurent A, Merienne L, Schlienger M, Aymard A, Houdart E, Casasco A, Lefkopoulos D, George B, Merland JJ. Treatment of brain arteriovenous malformations by embolization and radiosurgery. J Neurosurg 85:19-28,1996.
4. Mizoi K, Takahashi A, Yoshimoto T, Sugawara T, Saito K. Surgical excision of giant cerebellar hemispheric arteriovenous malformations following preoperative embolization. J Neurosurg 76:1008-11,1992.
5. Wong V, Wong S, Chan K, Wong W. Functional Independence Measure (WeeFIM) for Chinese children: Hong Kong cohort. Pediatrics 109(2):E36,2002.
6. Rankin J. Cerebral vascular accidents in patients over the age of 60. II: Prognosis. Scott Med J 2:200-215,1957.
7. Moore D, McCabe G: From probability to inference. Inference for distributions. In: Moore D, ed. Introduction to the practice of statistics. New York: WH Freeman and Company, 1989:65-69,387-410,509-538.
8. Spetzler RF, Martin NA. A proposed grading system for arteriovenous malformations. J Neurosurg 65:476-483,1986.
9. Anson JA, Spetzler RF. Classification of spinal arteriovenous malformations and implications for treatment. BNIQ 8:2-8, 1992.
10. Paulsen RD, Steinberg GK, Norbash AM, Marcellus ML, Lopez JR, Marks MP. Embolization of rolandic cortex arteriovenous malformations. Neurosurgery 44:479-86,1999.
11. Humphreys R, Pirouzmand F: Arteriovenous Malformations and Intracranial Aneurysms in Children Malformations. In: Winn HR, ed. Youmans Neurological Surgery. 5th edition, vol 3. Philadelphia: WB Saunders Company, 2004:3447-59.
12. Schmit BP, Burrows PE, Kuban K, Goumnerova L, Scott RM. Acquired cerebral arteriovenous malformation in a child with moya-moya disease. Case report. J Neurosurg 84:677-80,1996.
13. Tillotson G, Guillermo Philipps S, Coker S, DiFazio M. Early

diagnosis of spinal cord arteriovenous malformation in a 7-yer-old child. Clin Pediatr 33:315-17,1994.

14. Drake CG. Cerebral arteriovenous malformations: Considerations for and experience with surgical treatment in 166 cases. Clin Neurosurg 26:145-208,1979.
15. Mickle JP, Mericle R, Burry M, Williams LS: Vein of Galen Malformations. In: Winn HR, ed. Youmans Neurological Surgery. 5th edition, vol 3. Philadelphia: WB Saunders Company, 2004:3433-45.
16. Meyer FB, Sundt TM Jr, Fode NC, Morgan MK, Forbes GS, Mellinger JF. Cerebral aneurysms in childhood and adolescence. J Neurosurg 70:420-25,1989.
17. Piatt JH Jr, Clunie DA. Intracranial arterial aneurysm due to birth trauma. Case report. J Neurosurg 77:799-803,1992.
18. Wiebers DO, et al.. Unruptured intracranial aneurysms - risk of rupture and risks of surgical intervention. N Engl J Med 339:1725-33,1998.
19. Almeida GM, Pindaro J, Plese P, et al.. Intracranial arterial aneurysms in infancy and childhood. Childs Brain 3:193-199,1977.
20. Proust F, Toussaint P, Garnieri J, Hannequin D, Legars D, Houtteville JP, Freger P. Pediatric cerebral aneurysms. J Neurosurg 94:733-39,2001.