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Characteristics and Surgical Outcomes of Pediatric Intracranial Aneurysms in Romania

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ABSTRACT

AIM: To analyze the demographic characteristics and surgical outcomes of the largest series of patients with pediatric aneurysms reported in Romania, in consideration of the primary factors that lead to good long-term outcomes. Given that all cases involved ruptured aneurysms, we also investigated the ability of microsurgical clipping to prevent massive hemorrhage andaggravation of neurological deficits.

MATERIAL and METHODS: This multicenter retrospective study included 47 pediatric patients (<16 years old) who underwent operation over the 20-year period between January 1999 and January 2019. We analyzed medical records and imaging findings in each patient. Treatment consisted of open microsurgical dissection (clipping) and endovascular embolization (coiling).

RESULTS: Mean patient age was 14.3 years, ranging from 5 months to 16 years, with 28 boys (59.5%) and 19 girls (40.4%). In our series, pediatric aneurysms represented 6.1% of all intracranial aneurysms (771 cases). Clinical features were dominated by headache (45 cases, 95.7%), neck stiffness (43 cases, 91.4%) and vomiting (42 cases, 89.3%). The most frequently involved locations were the anterior communicating artery (17 cases, 36.1%), middle cerebral artery (12 cases, 25.5%), and internal carotid artery bifurcation (9 cases, 19.1%). Glasgow Outcome Scale scores at 6 months indicated good recovery in 36 patients (76.5%), moderate disability in ninepatients (19.1%), severe disability in one patient (2.1%), and (preoperative) death in one patient (2.1%).

CONCLUSION: Intracranial aneurysms in children are very rare. Early diagnosis based on brain imaging and microsurgical treatment is essential for attaining excellent results.Primary factors such as preoperative status, child profile, aneurysm size, treatment choice, and timing of the operation influence both short and long-term outcomes.

KEYWORDS: Aneurysms, Hemorrhage, Clipping, Microsurgical removal

ABBREVIATIONS: IA: Intracranial aneurysm, **H&H:** Hunt & Hess Scale, **ICA:** Internal carotid artery, **MCA:** Middle cerebral artery, **ACoA:** Anterior communicating artery, **PCoA:** Posterior communicating artery, **VA:** Vertebral artery, **PKD:** Polycystic kidney disease, **SAH:** Subarachnoid hemorrhage, **GCS:** Glasgow Coma Scale, **GOS:** Glasgow Outcome Scale, **DSA:** Digital subtraction angiography, **CT:** Computed tomography, **CTA:** Computed tomography angiography

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INTRODUCTION

Intracranial aneurysms (IAs) usually form at the bifurcation of an artery, wherehemodynamic stress is high. Aneurysms may develop due to trauma or infection, although they can also be associated with vasculopathy or alterations in vessel wall structure (7). Pediatric aneurysms are rare, occurring in under 5% of cases, and the clinical presentation, rupture probability, location, and outcome of pediatric aneurysms differ from those in adults (23). In older pediatric patients, symptoms are more similar to those observed in adults. However, in neonates or younger children, symptoms are non-specific or even absent. Furthermore, children tend to exhibit better clinical outcomes than adults after IA rupture. In contrast to the female predominance observed for adult IAs, pediatric aneurysms occur at a male-to-female ratio of 2:1 (21).

In the present clinical retrospective study, we aimed to analyze the etiology, clinical features, and surgical outcomes of the first series of patients with pediatric IAs reported in Romania. Given that aneurysm rupture occurred in all cases, our main surgical approach was microsurgical clipping.

MATERIAL and METHODS

This retrospective study was approved by the institutional ethics councils of our hospitals, and informed consent was obtained from all patients included in the study. Inclusion criteria were as follows: age <16 years, presence of IAs that were not associated with other tumors or arteriovenous malformations. Patients presenting with neurological deficits or hemorrhage caused by any condition other than IA were excluded.

We analyzed data for 47 consecutive cases of pediatric (≤16 years old) aneurysms operated upon at three medical centers in Romania during the 20-year period from 1999 to 2019. Most of the included patients underwent surgery at a single teaching hospital [BagdasarArseni – Pediatric Neurosurgical Department (n=40)].

Pediatric images and medical histories were provided by the Departments of Neurosurgery and Radiology at three hospitals in Romania. Demographic characteristics, genetic conditions, clinical status at admission, aneurysm locations and status, and postoperative follow-up data were included for analysis (Table I).

Subarachnoid hemorrhage (SAH) status on admission was assessed using the Hunt & Hess Scale (H&H). Digital subtraction angiography (DSA) followed by computed tomography (CT) andCT angiography (CTA) was used to diagnose SAH, determine aneurysm location, and assess postoperative control.

Treatment consisted of open microsurgical dissection (clipping) and endovascular embolization (coiling). Our policy for patient management includes follow-up every 6 months, at which time patients undergo neurological and ophthalmological examination and follow-up CT. Good recovery was defined as full recovery without any symptoms, moderate recovery was defined as the inability to perform some previous work activities, and severe disability was defined as the inability to resume previous activities.

Table I: Demographics, Clinical Status, Aneurysm Location and Type, Evolution

Demographics	**No. Cases (%)**
Mean age	14.3 years
Males	28 (58.7)
Females	19 (41.2)
Hereditary conditions	
PKD	5 (10.6)
Aortic Coarctation	2 (4.2)
Symptoms	
Headaches	45 (96)
Neck Stiffness	43 (91)
Vomiting	42 (89)
Neurological deficits	21 (45)
Impaired consciousness	17 (36)
Coma	9 (23)
Seizures	21 (45)
Fever	16 (34)
SAH	37 (78)
Hunt & Hess Scale	
Grade 1 (GCS = 15)	10 (22)
Grade 2 (GCS = 13-14 w/o focal deficit)	25 (53)
Grade 3 (GCS = 13-14 with focal deficit)	9 (17)
Grade 4 (GCS = 7-12)	3 (8)
Grade 5 (GCS=3-6)	0 (0)
Aneurysm Location	
Internal Carotid Artery (ICA)	9 (19.5)
Middle Carotid Artery (MCA)	12 (25)
Anterior Communicating Artery (ACoA)	17 (36)
Posterior Communicating Artery (PCoA)	6 (17.5)
Basilary Top	1 (2.5)
Vertebral Artery (VA)	1 (2.5)
Multiple locations	1 (2.5)
Aneurysm type	
Ruptured Aneurysms	47 (100)
Small-Medium	33 (70.3)
Large	14 (29.7)
Postoperative GOS 6 months	
Good recovery	37 (78.5)
Moderate disability	8 (17.2)
Severe disability	1 (2.1)
Vegetative state	0 (0)
Death	1 (2.1)

RESULTS

We analyzed data for 47 cases of pediatric IAs, with patients ranging in age from 5 months to 16 years (mean age: 14.3 years). There were 28 boys (58.7%) and 19 girls (41.2%). Hereditary conditions associated with aneurysm development included polycystic kidney disease (PKD) in five (10.6%) patients and aortic coarctation in two (4.2%) patients. Thirty-seven (78%) patients presented with SAH. Common symptoms included headache (45 cases, 96%), neck stiffness (43 cases, 91%) and vomiting (42 cases, 89%). The most common neurological deficits were hemiparesis and speech disorders, hemianopia with oculomotor paresis (21 cases, 45%), and seizures (21 cases, 45%). At admission, 10 patients (22%) exhibited H&H scores of 1, indicating the presence of mild headaches but normal mental status. Twenty-five patients (53%) exhibited H&H scores of 2, indicating the presence of severe headaches with mild cranial nerve deficits. Nine patients (17%) presented with H&H scores of 3, indicative of confusion and moderate nerve lesions. Three patients (8%) presented with H&H scores of 4, signifying stupor and severe motor deficits (Table I).

The most common locations for IAs were the anterior communicating artery (ACoA; 17 cases, 36%), followed by the middle cerebral artery (MCA; 12 cases, 25%) and internal carotid artery (ICA; 9 cases, 19.5%). Large IAs (neck >4 mm) were observed in 14 cases (29.7%), while small-to-medium IAs were observed in 33 cases (70.3%).

Considering that all patients experienced aneurysm rupture, our main treatment was clipping. Thus, open microsurgical dissection under intraoperative monitoring was performed in 46 cases (97%), while endovascular embolization was performed in one case (3%). All patients were treated between day 0 and day 4 after the onset of rupture. Glasgow Outcome Scale scores at the 6-month follow-up indicated good recovery in 37 patients (78.5%), moderate disability in eight patients (17.2%), severe disability in one patient (2.1%), and death in one patient (2.1%). No cases of vegetative state were observed. Microsurgical clipping was the treatment of choice for ruptured aneurysms due to its ability to prevent vascular instability and aggravation of neurological deficits.

DISCUSSION

In the present study, we investigated the etiology, clinical features, and surgical outcomes of patients with pediatric IAs in Romania. The main clinical features of IA included headache, neck stiffness, and vomiting. IAs occurred most frequently in the ACoA, followed by the MCA and ICA bifurcation, respectively. Glasgow Outcome Scale scores at 6 months indicated good recovery in76.5% of patients.

Pediatric aneurysms differ from those encountered in adults in that they exhibit a male predominance (9,29). The female predominance in adults may be associated with low levels of estrogens, which in turn lead to low vessel resistance and subsequent aneurysm formation.

Common risk factors for IA in adults include systemic hypertension, smoking, hypercholesterolemia, diabetes mellitus, and cardiopathy (28). However, in children, aneurysm etiology is more often associated with congenital malformations of the blood vessel walls (if the aneurysms appear in the first 2 years of life), vascular syndromes, and malformations in the heart or aorta (if they appear after the first 2 years of life) (28). Thus, hereditary diseases (Ehlers–Danlos Type IV, Marfan syndrome, Osler–Weber–Rendu syndrome, fibromuscular dysplasia, and PKD) play an important role in the development of aneurysms or congenital malformations (19, 26). In this series, we observed five cases of PKD and two cases of aortic coarctation. Systemic arterial malformations of the aorta can lead to high cerebral pressure, which results in focal degeneration of the internal lamina of the cerebral vessels. In such situations, open clipping should be performed to prevent endovascular manipulation of the systemic malformation and to remove the possible hemorrhage (8).

Pediatric IA is most often associated with SAH on imaging, especially in younger patients (5). SAH is better tolerated in children than in adults, and the rate of vasospasm is low in pediatric patients (14). Children also exhibitbetter preoperative grades, fewer comorbidities, higher brain plasticity, and lower levels of atherosclerosis (18). High-potential leptomeningeal circulation also plays an important role in decreasing the effect of vasospasm (15). Aneurysm rebleeding after SAH appears in 52–60% cases, and reports regarding its outcomes have conflicted among studies (3,20). While one study identified aneurysm rebleeding as the primary cause of mortality (76% of total deaths), another case series reported that approximatively 80% of rebleeding cases were associated with good postoperative outcomes (3,17). Table II includes the study names, years of publication, cohort ages, numbers of patients, and SAH rates for literature regarding pediatric aneurysms, including the most relevant case series (Table II). The rate of SAH observed in our study falls within the range reported across previous studies (58%–100%), and total recovery occurred in 37 patients (78.5%). These good outcomes are likely the result of children's better capacity to tolerate SAH, the surgical clipping approach chosen by thetreating neurosurgeons, and the clinical grade at admission, which was generally good to mild. Other factors such as mild SAH, absence of vasospasms, and complete obliteration of aneurysms play an important role in patient recovery (13). Patients admitted with good H&H scores exhibited better recovery, and no perioperative mortality was observed.

Previous studies have reported that the incidence of IAs in the posterior circulation is higher in children than in adults (6). In our series, most aneurysms were located in the anterior circulation, in accordance with the previous finding that the ACoA is the most common aneurysm site in adults (22). Studies have reported a direct relationship between patient age and aneurysm location, demonstrating that aneurysms are more likely to arise from the MCA in young patients. Early embryological development and associated vascular pathologies may also play an important role in aneurysm development after birth (4).

Surgical approaches to IA vary and include clipping, proximal vessel occlusion, wrapping, trapping, bypass alone, and

Table II: Pediatric Patients Series Published Starting From Year 2000

Author	Year	No.	Age (yrs)	SAH (%)
Proust et al. (21)	2001	22	≤16	95
Lasjaunias et al. (15)	2005	59	≤15	51
Agid et al. (1)	2005	33	≤17	36
Krishna et al. (14)	2005	22	≤18	91
Huang et al. (9)	2005	19	≤18	58
Stiefel et al. (27)	2008	12	≤16	100
Vaid et al. (28)	2008	27	≤18	100
Liang et al. (16)	2009	24	≤14	46
Jordan et al. (10)	2009	15	≤19	100
Songsaeng et al. (25)	2009	8	<16	25
Sanai et al. (24)	2010	32	≤17	44
Kakarla et al. (11)	2010	48	≤18	17
Koroknay et al. (13)	2012	114	≤18	78
Garg et al. (5)	2014	62	≤18	58
Current Study		47	≤16	78

endovascular treatment. However, the selected treatment depends on the size and location of the aneurysm as well as the patient's preoperative status. Previous studies have reported that clipping and coiling are associated with good outcomes in 69–91% of cases (1,13,16,25,29). We consider clipping to be preferable when dealing with ruptured aneurysms or when the vascular system does not allow access to the aneurysm site. Of note, vertebral tip aneurysms are more often treated via coiling, while MCA aneurysms are more often treated via clipping due to the arterial branches that may arise directly from the MCA aneurysm (27).

Research regarding the rate of IA recurrence remains conflicting, with reports ranging from 12–36% depending on the approach, aneurysm size, and anatomy (22). Some studies have reported high recurrence rates when IAs were treated with coiling, while some reported that endovascular treatment alone was associated with good long-term outcomes (24). Higher immediate postoperative mortality and longer hospital stays are more frequently associated with clipping than embolization (2). In our case series, 70.3% of aneurysms were small-to-medium in size (neck <4 mm), and none were associated with bleeding or new aneurysm formation after surgery over a period of 5 years. Thus, the authors advocate for use of clipping to decrease the recurrence rate, although we admit that future studies should assess recurrence rates over a longer follow-up period. Despite the scarcity of relevant studies, recurrence rates are high for complex or giant aneurysms. In one previous study, the authors aimed to reduce recurrence rates by performing bypass surgery combined with artery clipping, reporting good outcomes following the procedure (12). No cases of giant aneurysm were observed in our study. Other studies have indicated that aneurysms associated with arterial aplasia or asymmetric vessel organization tend to recur more often (25).

Another factor influencing outcomes is the timing of surgery. Aneurysm rupture is a critical event that should be treated as quickly as possible to prevent complications. Thus, patients in our study were treated between 0 and 4 days after rupture.

Clinicians face many challenges when treating pediatric patients with IAs. Thus, we recommend that each patient's treatment be chosen separately according to the complexity of the case and the experience of the neurosurgeon. Although previous studies have reported new aneurysm formation following surgery in children, no such cases were observed in the current study (11). Nonetheless, careful postoperative surveillance involving both clinical and imaging examinations is necessary for early identification of recurrence in pediatric patients with IAs.

CONCLUSION

IAs are rare in pediatric neurosurgery. Our series of 47 consecutive patients who underwent surgery for aneurysm rupture provides insight into the clinical features and surgical outcomes of IAs in children. Primary factors such as preoperative status, child profile, aneurysm size, treatment choice, and timing of the operation influence both short and long-term outcomes. Given their emergent nature, the authors recommend clipping over coiling for the treatment of ruptured aneurysms.

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