Pediatric Intracranial Aneurysms: Endovascular Treatment

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ABSTRACT

Background: Intracranial aneurysms are rare in pediatric age group. Their clinicoradiological features may differ from those in adults. Objective: The aim of this study was to analyze clinical presentation, location and morphological characteristics of pediatric age aneurysm with assessment of feasibility, safety and efficacy of endovascular treatment. Patients and Methods: A retrospective study was conducted on patients with intracranial aneurysm aged 18 years or younger who underwent endovascular treatment in the period between July 2006 and July 2014 in the Departments of Neurosurgery in Ain Shams University and Souhag University. Data were collected and analyzed as regard: presenting symptom, aneurysm characteristics (site, size and subtype), endovascular management, and procedure clinic-radiological outcome and follow up were analyzed. There were twenty-two patients with twenty-two aneurysms, age range 1.5 to 17 years with a mean of 10.97±4.69, 13 males and 9 females. Results: Subarachnoid hemorrhage was the main presentation with a rate of 54.4%, and the rate of associated underlying diseases was 40.9%. Saccular aneurysms (without clinical association of infection or trauma) were found in ten patients (45.5%), dissecting fusiform (without clinical association of infection or trauma) in seven patients (31.8%), infectious in three patients (13.6%) and traumatic in two patients (9.1%). Five aneurysms (22.7%) were located in the posterior circulation, while six were located at internal carotid artery (ICA) termination (27.3%). Five aneurysms (22.7%) were giant aneurysms. Endovascular coiling was done in thirteen aneurysms (59.1%): ten were saccular, two traumatic, and one dissecting fusiform. Parent vessel occlusion was done in nine aneurysms (40.1%), three were infectious (glue was used), and six were fusiform aneurysms (four by detachable balloons and two by coils). Immediate angiographic cure was seen in twenty aneurysms (90.9%) and remaining two aneurysms had small neck residual. Recanalization at one year follow up occurred in three aneurysms (13.6%), two of which needed further endovascular treatment. There was no rebleeds during the follow up period. The rate of permanent procedure related complication and favorable outcome were 4.55% and 90.9% respectively. Conclusion: Pediatric intracranial aneurysms are a rare entity with different characteristics than adult aneurysms. In pediatric aneurysms association of an underlying disease should be considered. The rate of giant, dissecting fusiform and mycotic aneurysms is more common than in adults. In pediatric aneurysms association of an underlying disease should be considered. The rate of giant, dissecting fusiform and mycotic aneurysms is more common than in adults. ICA bifurcation and posterior circulation located aneurysms have higher incidence in pediatric patients than adults do. Endovascular treatment with different techniques is considered technically feasible, relatively safe and efficient with high favorable outcome and low rates of mortality and morbidity, yet longer period of follow up is needed to ensure long term safety.

INTRODUCTION

Pediatric Intracranial aneurysms are rare. Various studies have shown that the incidence of intracranial aneurysms in the pediatric age group ranges from 0.5% to 4.6%. Pediatric intracranial aneurysms differ in many ways from those in adults in terms of etiology, sexual prevalence, location, and morphology.

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There is male predominance and a higher proportion of aneurysms in the posterior circulation and also a higher frequency of giant aneurysms than in adults. For anterior circulation aneurysms, the most common location is the ICA bifurcation. Children with intracranial aneurysms often have various underlying diseases (eg, polycystic kidney disease, fibromuscular dysplasia, Ehlers Danlos syndrome and aortic coarctation) but have not been exposed to the environmental factors seen in adults. There has been a constant increase in the number of children with intracranial aneurysm being treated by means of endovascular techniques over the last two decades. This significant shift from...
microsurgical treatment towards endovascular management is due to the better outcomes and lower rates of procedural complications.  

The aim of this study is to analyze the etiology, clinical presentation, morphological characteristics of pediatric aneurysms in patients who underwent endovascular treatment at our institutions in the period between July 2006 and July 2014.

PATIENTS AND METHODS

A retrospective study was conducted on patients with intracranial aneurysm aged 18 years or younger who underwent endovascular treatment in the period between July 2006 and July 2014 in the Departments of Neurosurgery in Ain Shams University and Southag University. Twenty-two patients with 22 intracranial aneurysms were treated by endovascular techniques. Patients with vein of Galen aneurysms or aneurysms associated with arteriovenous malformations were excluded from this study. The results of radiological studies (ie, diagnosis of subarachnoid hemorrhage (SAH), location, angiographic morphological findings of the aneurysms, post-procedural and follow-up angiographic results), intraoperative reports and clinical records (ie, underlying disease, initial clinical presentation and outcome) are reviewed for each patient.

Clinical Presentation, Underling Disease

The underlying disease, clinical presentation and final outcome were reviewed using the medical records from each patient. All patients with SAH were graded according to the Hunt and Hess classification. Grades 0–3 were considered a good preoperative status and grades 4 and 5 were considered a poor status. Patients without a history of SAH were considered to have a grade 0 status.

Clinical outcome and follow up

The postoperative and follow-up outcomes were assessed according to the Glasgow outcome score (GOS). GOS 5 and 4 were taken as a favorable outcome whereas GOS 1–3 were taken as a poor outcome. Clinical follow-up was performed at 1 month, 3 months, 6 months, and 1 year post treatment; annually thereafter for a maximum of 5 years; and then every 5 years.

Radiological studies and Aneurysm Morphology

A diagnosis of SAH was confirmed with CT findings of subarachnoid blood in the basal cisterns. Preoperative Cerebral angiography was performed to confirm the diagnosis and plan treatment. Evaluation of the aneurysm size, location and the morphological findings of aneurysms, which were classified using the method described by Lasjaunias et al. into four groups on the basis of the angiographic morphology and clinical context: (1) fusiform dissecting aneurysms without clinical association of infection or trauma; (2) saccular aneurysms without clinical association of infection or trauma; (3) infectious aneurysms in cases of associated systemic infection or immunocompromise (patients with documented sepsis, meningitis, or infective endocarditis were considered to have infectious aneurysms.); and (4) traumatic aneurysms in patients with associated significant trauma. These morphological and etiological factors can have therapeutic implications.

Treatment

Following diagnostic angiograms, all patients were treated by endovascular intervention. Table 1 shows the distribution of aneurysms based on their morphology and the type of endovascular treatment performed. The aim of treatment was not only to alleviate acute symptoms but also, most importantly, to protect the patient from future bleeding.

The patients were divided into two groups based on the type of treatment they received: destructive techniques in the form of Parent vessel occlusion (PVO) either by detachable balloons (Balt, Extrusion, France) or by detachable coils (Stryker, Neurovascular, Fenton, California, USA; Codman Neurovascular, California, USA) was the treatment of choice for dissecting fusiform, giant partially thrombosed aneurysms and infectious aneurysms. It was preceded by balloon test occlusion for demonstration of adequate collateral circulation. A balloon occlusion test was performed in all patients scheduled for PVO, when possible by awake state. In three patients with infectious aneurysms we depended on the assessment of collateral circulation by leptomeningeal supply. If the patients were considered to be at risk of developing a critical cerebral ischemia as a result of the PVO (e.g. fusiform aneurysms located at M1, M2 or the bilateral internal carotid artery (ICA), patients were referred to surgery by the cerebrovascular surgeon. Reconstructive techniques was the preferred treatment for the saccular aneurysms, with selective coil embolization for obliteration of the aneurysms preserving the parent vessel patency (ie, conventional coiling, stent-assisted coiling done in thirteen aneurysms). The endovascular treatment was analyzed in terms of technique, patient-specific strategy, aneurysm location, and morphological characteristics of the aneurysm, angiographic results, and complications. Magnetic resonant angiography (MRA) phase of contrast was used for follow up at 6 month and one year. Follow-up Digital Subtraction Angiography (DSA) were performed in selected cases (three cases) when there is abnormality in the follow up MRA.

RESULTS

There were nine females and thirteen males (59.1%) included in the study, age ranged from 1.5 to 17 years (mean 10.97±4.69 years).
Clinical Presentation

Twelve patients presented with SAH as the result of a rupture of the aneurysm (54.4%). According to the Hunt–Hess scale, five patients were classified as grade 1, five were classified as grade 2, and two patients were grade 3. Eight patients (36.6%) presented with intracerebral hemorrhage (ICH). Total patients presented with hemorrhage were seventeen (77.3%) out of the twenty-two patients. Four patients presented with ophthalmoplegia due cranial nerve dysfunction and five patients exhibited focal neurological deficit. One patient presented with generalized epilepsy.

Underlying diseases

Associated underlying diseases were present in nine patients (40.9%) (Table 1 and 2); three patients had infective endocarditis on top of rheumatic valve disease or congenital heart disease (fallout tetralogy), one patient had coarctation of aorta, two patients had congenital polycystic kidney and three patients had vessel wall disease; Ehlers-Danlos syndrome, moyamoya and neurofibromatosis type one.

<p>| Table 1: Summary of patients’ age and sex distribution, clinical presentation, with aneurysm location, size, subtype and mode of treatment |
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<p>| Table 2: Clinical features of patients with associated underlying disease |
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Aneurysm Characteristics

Based on the subtypes defined by the angiographic morphology and clinical context, there were ten (45.5%) aneurysms were saccular, seven (31.8%) were fusiform, three (13.6%) were infectious and two (9.1%) were traumatic. Aneurysm size ranged from 3 mm to 29 mm with a mean of 12.86±9.1, five out of the twenty-two aneurysms (22.7%) were giant (≥ 25 mm).

Seventeen aneurysms (77.3%) were located in the anterior circulation; six (27.3%) at ICA bifurcation, four at cavernous carotid segment, three at middle cerebral artery (MCA), two Pericallosal, one anterior communicating (Acom) and one posterior communicating (Pcom). Five (22.7%) were located at the posterior circulation; two posterior cerebral artery (PCA), one Basilar tip, one posterior inferior cerebellar (PICA) and one vertebral artery (VA). (Table 1)

Treatment

All aneurysms were treated by endovascular approach. Ruptured aneurysms (seventeen aneurysms) were treated as early as possible after diagnosis, and unruptured aneurysms (five aneurysms) were managed electively. Thirteen patients (59.1%) had endovascular coil embolization (reconstructive treatment), while nine patients (40.9%) had PVO (deconstructive treatment). Selective obliteration of the aneurysm by coil embolization (Reconstructive treatment) was the preferred treatment for the saccular aneurysms (without clinical association of infection or trauma) (Fig. 1), and also was done in traumatic aneurysms (Fig. 2). PVO (Deconstructive treatment) was the treatment of choice for dissecting fusiform aneurysms (Fig. 3&4), and infectious aneurysms (Fig. 5). It was preceded by balloon occlusion test when feasible. A detailed description of the treatment for each aneurysm subtype is shown in table 1.

Nine of ten saccular aneurysms (without clinical association of infection or trauma) were treated with conventional endovascular coil embolization without any assistant device, and one Pcom saccular aneurysm was treated by balloon assisted coiling. Two traumatic aneurysms located at the pericallosal artery were treated by conventional coiling. Of the seven dissecting fusiform aneurysms (without clinical association of infection or trauma), one PCA aneurysm was treated by stent assisted coil embolization, and six were treated by PVO: four cavernous carotid segment aneurysms were treated by PVO by detachable balloons, one PCA and one VA aneurysms were treated by PVO using coils with obliteration of the parent vessel and the aneurysm. The three infectious aneurysms were located at MCA bifurcation (two) and distal MCA (one), all treated by using glue for both the PVO and the aneurysm.

Immediate and follow-up angiographic result

Angiograms performed at the end of the procedure showed angiographic cure of the nine aneurysms treated by PVO (three infectious and six fusiform), and angiographic total cure was established in eleven of the thirteen aneurysms (ten saccular without clinical association of infection or trauma, two traumatic and one dissecting) treated by coiling, the remaining two aneurysms (saccular) treated by coiling had a neck remnant. Total immediate angiographic cure was established in 90%, the remaining two case (10%) treated by endovascular coil embolization had a small neck remnant.

Follow-up Magnetic resonant angiography (MRA) phase of contrast was used for follow up at 6 month and one year. Follow-up Digital Subtraction Angiography (DSA) was performed in selected cases, when there is abnormality in the MRA. All aneurysms that was treated PVO (nine) showed no further recanalization, yet there were three aneurysms (13.6 %) of total aneurysms treated, and 23.1% of aneurysms treated by coil embolization showed recanalization at 12 month follow up, two of which had a residual neck at the primary treatment angiograms. Two of the three aneurysms with recanalization had further endovascular retreatment. There were no de novo aneurysms in our series. There were no rebleeds during the follow up period.
Fig. 1 a-f: Case 2, a 10-year-old girl presented with SAH. a, b & c: left ICA DSA lateral, AP and oblique injections respectively showing a saccular 6 mm diameter aneurysm at left ICA bifurcation. d, e & f: left ICA DSA lateral, AP and oblique injections respectively post-coiling of the aneurysm with total occlusion of the aneurysm.

Fig. 2 a-f: Case 10, a 10-year-old boy presented with deterioration of conscious level due to SAH and interhemispheric hemorrhage following a motorcar accident by a week. a,b&c: right ICA angiograms in AP, lateral and oblique views respectively showing traumatic saccular pericallosal aneurysm, measuring about 5mm. d,e&f: post-treatment angiograms same views of a,b&c: obtained immediately after coil embolization of the aneurysm showing total occlusion of the aneurysm.
**Fig. 3 a-f**: Case 11, a 1.5-year-old boy with seizures and neurological deficit. MRI showed a giant partially thrombosed aneurysm of the right PCA. a,b: Right VA DSA lateral and (AP) injection showing a fusiform dissecting giant aneurysm of right PCA. c,d: Right VA DSA lateral and (AP) injection post-coiling of the aneurysm with PVO by coils showing total occlusion of the aneurysm and the PCA distal to P1 segment. The procedure was well tolerated. e: 1 year follow up MRI showing disappearance of the giant aneurysm. f: 1 year follow up MRA showing stable radiological outcome with no recurrence.

**Fig. 4 a-i**: Case 18, a 15-year-old boy with left ophthalmoplegia. MRI showed a left giant partially thrombosed aneurysm of the left ICA cavernous segment. a,b: DSA lateral and AP injection showing a fusiform dissecting giant aneurysm of left ICA cavernous segment. Successful balloon occlusion test of the left ICA was done and was tolerable. c,d: Left common carotid artery lateral and AP injection after balloon occlusion of the left ICA showing filling of the left ECA with no filling of the left ICA. e,f: skull x-ray AP lateral and AP view showing the inflated balloons in the left ICA. g: post-procedural DSA AP injection of the right ICA showing filling of the left ACA and MCA through the ACOM artery. h,i: post-procedural DSA AP and lateral injection of the right VA showing filling of the left supraclinoidal ICA, left ACA and MCA through the PCOM artery. The procedure was well tolerated. There was no retrograde filling of the aneurysm after PVO of the left ICA.
Complication, Clinical outcome and follow up

Overall procedural complications occurred in two patients (9.1%). One patient had transient hemiparesis following PVO using detachable balloon of a dissecting fusiform aneurysm of cavernous carotid, which regressed completely by 3 weeks. Another patient with right PCA aneurysm had hemiparesis after selective stent assisted coiling, which recovered partially with a minimal deficit as permanent sequel, so only one patient (4.55%) was left with procedure related permanent complication in the form of left hemiparesis Grade 3.

The mean duration of follow-up was 2.5 years (range 6 month–4 years). Glasgow Outcome Scale scores were used to assess the outcome. The postoperative clinical follow-up was as follows: seventeen patients were classified as GOS 5, three were classified as GOS 4 and two were classified as GOS 3. The proportion of patients with a favorable outcome (ie, GOS 5 and 4) was 90.9%.

With respect to the patients with a poor outcome, two patients were classified as GOS grade 3 and their subtypes consisted of one fusiform dissecting aneurysm and one infectious aneurysm, (one case had stent assisted coiling of ruptured fusiform dissecting PCA aneurysm in the P1 segment and one had PVO with glue of MCA infectious aneurysm, respectively). The PCA aneurysm had a procedural complication implicated in the outcome as described above; the other patient with poor outcome was due to lack of improvement compared with the initial clinical condition. No patients died. Overall, good outcome was noted in 90.9% of the cases.

DISCUSSION

The first report of an aneurysmal SAH in a child was published in the German pathology literature in 1871 by Eppinger. In the late 19th and early 20th centuries, there were studies describing the incidence, etiology, and pathogenesis of cerebral aneurysms in the pediatric age group. Intracranial aneurysms in Pediatric age group are a rare entity, according to previous studies, they account for less than 5% of all intracranial aneurysms. In our current study, twenty-two intracranial aneurysms have been treated in the pediatric age group (18 years and below) over the last 8 years.

Intracranial aneurysms in pediatric patients differ from aneurysms in adults with respect to etiology and pathogenesis, demographic variables, aneurysm location, morphological characteristics, and clinical presentation. It has been observed that aneurysms in children tend to be larger, tend to have more complex shapes, and are more likely to be located in the posterior circulation than aneurysms in adults.

Etiology and Pathogenesis

Various studies have shown that the incidence of aneurysms is higher in boys than in girls in the pediatric age group where the proportion of males ranged from 48% to 65%.
current series, there were thirteen male patients (59.1%) and nine female patients (ratio 1.4:1).

Although it has been hypothesized that congenital factors causing aneurysms may be more expressed in males, because the pediatric aneurysms are more common in boys than in girls, the etiology and pathogenesis of pediatric intracranial aneurysms are still controversial.  

In spite pediatric intracranial aneurysms were considered by Allison et al 3 to be a congenital disease, yet Agid et al 2 believed that neither adult nor pediatric aneurysms were truly congenital in nature. Lasjaunias et al.18 in their report on pediatric aneurysms, suggested that aneurysms in children must be the expression of various vessel wall dysfunctions, producing transient or permanent failure to repair a partial insult. These included on one hand “recognized” mutations and “direct” primary trigger (for example humoral, immune, and infectious factors and trauma) and on the other hand “silent” genetic factors (for example, poly cyclic kidney disease, fibromuscular dysplasia, and Ehlers-Danlos syndrome). Given the fact that many pediatric intracranial aneurysms present with a larger size and more deformed shape than those in adults, we believe that such aneurysms probably arise due to baseline vasculopathy. Yet the etiology of aneurysms is mostly unknown.

In our series nine patients (40.9%) had associated underlying diseases. Focusing on this group with underlying diseases, three patients had a congenital medical condition related to vessel wall dysfunction (ie, Ehlers-Danlos syndrome, Neurofibromatosis type 1 and moyamoya disease). Two patients had congenital polycystic kidney disease, which is congenital yet with no vessel wall dysfunction. Although Patients with these medical conditions tend to have multiple large aneurysms4, we did not find any obvious characteristic in their size, number, location or morphological features. However, we also observed four patients with giant aneurysms in our series who did not have any particular underlying diseases. This fact could suggest an unknown medical condition related to vessel wall dysfunction is harboring in these patients as a silent congenital factor.

In one patient with aortic coarctation, the aneurysm may have developed due to arterial hypertension as a direct primary trigger. This aneurysm was small and saccular. In addition, three patients had infective endocarditis secondary to congenital heart disease (one) and rheumatic heart valve disease (two), those three patients had large MCA aneurysms. Ultimately, we did not find any obvious characteristic differences in the size, location or morphological features between the groups with and without underlying diseases. 

Clinical Presentation

In this study, 54.4% of the patients presented with SAH, 36% presented with intracerebral hemorrhage (total patients proportion with hemorrhage was 77.3%), 22.7% with focal neurological deficit, 18.1% presented with ophthalmoplegia, and 4.5% with seizures. The Hunt and Hess grade was good (Grades I–III) in all patients with SAH. These findings are similar to those of other studies, which suggest that the incidence of SAH ranges from 35% to 100%.13,20,31,37 (Table 3)

The rates of hemorrhagic presentation differ in aneurysm subtypes; it is more common in saccular aneurysms than in fusiform or infectious types.13 In our study, all saccular aneurysms presented with hemorrhage (nine of ten 90% with SAH and two of ten 20% presented with intracerebral hemorrhage). For fusiform dissecting aneurysms presented two of seven 28.6% (one SAH, and one ICH) presented with hemorrhage. All infectious and traumatic aneurysms presented with hemorrhage. All infectious and traumatic aneurysms presented with hemorrhage, ICH and SAH respectively.

Regarding hemorrhagic presentation, Hetts et al13 suggested that the rates appear to differ by aneurysm subtypes, being more common in saccular aneurysms than in fusiform or infectious types. Some authors have reported that the incidence of SAH appears to decrease with age.38 Sharma et al,47 whose proportion of saccular aneurysms was the highest (90%), showed the highest degree of hemorrhagic presentation (78%). In contrast, the study by Lasjaunias et al18 had an opposite character in the aneurysm subtype; the proportion of fusiform and infectious types amounted to 73% of their population and the proportion of saccular type aneurysms was only 27% (Table 3). However, their patients also presented with a relatively high frequency of SAH (54%).38 The factors affecting the hemorrhagic presentation are therefore still unclear.

Aneurysm Characteristics

As we previously described, aneurysms can be separated into four subtypes based on their morphology and etiology: infectious, traumatic, non-traumatic non-infectious fusiform, and non-traumatic non-infectious saccular. In our current study saccular (without clinical association of infection or trauma) (45.5%) and fusiform dissecting (without clinical association of infection or trauma) (31.8%) aneurysms were the main population of the patients (77.3%). Infectious (13.6%) and traumatic (9.1%) aneurysms were about (22.7%) of our series.

In many case series, both the infectious and the traumatic types comprised only around 10% of their proportions. The dissecting fusiform and saccular types were the main variety in their proportions ranging from 6% to 59% and from 27% to 90%, respectively (Table 3). Nevertheless, the proportion of the dissecting fusiform type was more than 30% in most of the studies, which is certainly higher than that in the adult population.2,6,13,18,31,37

Different case series the proportion of aneurysms in the posterior circulation ranged from 12% to 28.5% (our study 27.3%) and the frequency of giant aneurysms ranged from 11% to 31% (our study 22.7%). There was
relatively low variability between these reports (Table 3). On the other hand, the frequency of ICA terminus aneurysms had substantial variable incidence ranged from 2.6% to 31% (in our study it was six cases 27.3%) (Table 3). Many authors reported that the most common location of pediatric intracranial aneurysms is the ICA terminus.\(^1,4,9,29,32,33,37\) A few studies, however, have shown different results, and the ACA, MCA, ICA and BA also have been found to be common locations.\(^18,20,39\) This discrepancy may be caused by the occurrence of limited case number in small cohorts. Aryan et al\(^6\) reviewed previous reports with 236 aneurysms and the proportion of ICA terminus aneurysms was 15.8%, which is higher than the 4.4% observed in the adult population.\(^6,21,24,29,33,38\)

<table>
<thead>
<tr>
<th>Author year</th>
<th>Male %</th>
<th>Hge %</th>
<th>ICA Ter. %</th>
<th>Post %</th>
<th>Giant %</th>
<th>Sacc. %</th>
<th>Dis. %</th>
<th>Inf. %</th>
<th>Tr. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aryan(^6) 2005</td>
<td>------</td>
<td>68</td>
<td>------</td>
<td>24</td>
<td>------</td>
<td>-------</td>
<td>------</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Lasjaunias(^18) 2005</td>
<td>59</td>
<td>54</td>
<td>2.6</td>
<td>27</td>
<td>------</td>
<td>27</td>
<td>59</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Agid(^2) 2005</td>
<td>48</td>
<td>32</td>
<td>22</td>
<td>24</td>
<td>30</td>
<td>46</td>
<td>19</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Sharma(^37) 2007</td>
<td>57</td>
<td>78</td>
<td>31</td>
<td>12</td>
<td>19</td>
<td>90</td>
<td>6</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Hetts(^13) 2009</td>
<td>48</td>
<td>32</td>
<td>------</td>
<td>22</td>
<td>11</td>
<td>46</td>
<td>31</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Kakarla(^16) 2010</td>
<td>58</td>
<td>27</td>
<td>9.7</td>
<td>24</td>
<td>23</td>
<td>45</td>
<td>39</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Takemoto(^40) 2014</td>
<td>65</td>
<td>48</td>
<td>3</td>
<td>28.5</td>
<td>31</td>
<td>42.8</td>
<td>48.5</td>
<td>5.7</td>
<td>2.8</td>
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<td>Current</td>
<td>59.1</td>
<td>77.3</td>
<td>27.3</td>
<td>22.7</td>
<td>22.7</td>
<td>45.5</td>
<td>31.8</td>
<td>13.6</td>
<td>9.1</td>
</tr>
</tbody>
</table>


The frequency of patients who harbored multiple aneurysms had a certain level of variability ranging from 8% to 31% (in the present study we didn’t have any cases of multiple aneurysms).\(^2,6,13,14,20,23,25,34,35,37\) Although it has been reported to be considerably lower than that in adults,\(^19,25,28\) some authors recently indicated that multiple aneurysms are common in pediatric patients because they are linked to potential vessel wall dysfunction.\(^1,16\) This remains controversial and will need to be analyzed in more patients before any conclusions can be drawn.

**Endovascular Treatment**

Early attempts of surgical treatment of pediatric intracranial aneurysms resulted in high mortality rates, and it was not until the middle to latter part of the 20th century that meaningful therapeutic interventions were realized. With the improvement in microsurgical techniques, clips, illumination, and magnification of microscopes, surgical results in pediatric patients improved and appeared to be at least as good as results in adults.\(^7,24,41\) The advances in imaging techniques such as CT, MRA, and selective angiography permitted visualization of aneurysms with respect to parent vessels and surrounding structures.

With the recent development of devices and techniques for surgical and endovascular therapy, both therapeutic options should be effective for pediatric intracranial aneurysms.\(^30\) The past decade had witnessed a gradual shift from traditional surgical approaches towards endovascular treatment at some centers. One of the reasons for this shift is that these patients have a relatively large number of surgically intractable lesions such as giant, fusiform or posterior circulation aneurysms. Another reason is that, especially in patients with a subacute phase SAH or infection, it could be difficult to surgically expose the aneurysm due to the adhesion of arachnoid cisterns.\(^2,6,13,14,20,23,25,27,34,35,37,39\)

In this study, all patients were treated by endovascular techniques. The saccular (without clinical association of infection or trauma) aneurysms and traumatic aneurysms were managed by coil embolization to exclude the aneurysm from the circulation and preserve the parent artery. In fusiform dissecting and infectious types, the primary treatment choice was occlusion of parent vessel with or without the aneurysm.

Glue embolization was used for infectious aneurysms. In giant partial thrombosed aneurysms, the aim was to sacrifice the artery if possible, especially in locations like the cavernous ICA and non-dominant VA. Preservation of the parent artery was accomplished in a one case of dissecting fusiform aneurysm by the use of stent assisted coiling technique.

Although there have been limited studies for the pediatric age group, several recent endovascular techniques have been used since stents and flow...
diverters became available for this purpose.\textsuperscript{1,10,13,20,23,26,35}
The use of these techniques is expected to increase and will probably become an alternative therapeutic option to the classical PVO in the future.

**Clinical and Radiological outcome**

In our current study immediate angiographic cure was seen in twenty (90.9\%) of twenty-two patients. Immediate postoperative complications occurred in two patients (9.1\%) one was transient and one was permanent (4.55\%), on follow-up two patient had a poor outcome, one of them is due to persistence of the symptoms at time of presentation. Remaining patients had a good outcome. So overall, favorable outcome was observed in 90.9\% of the patients. There were no mortality, and the rate of significant morbidity was 4.5\% (1 patient). The mean duration of follow-up was 2.5 years. In total, nineteen (86.4\%) of twenty-two patients showed stable occlusion of the aneurysm on follow-up, as confirmed on MRA or DSA.

In the review of many case series (Table 4) the rate of permanent procedural complications and the favorable outcome rates ranged from 2.9\% to 6.7\% and from 77\% to 96\% respectively\textsuperscript{2,13,20,23,35,40}, while in our present study was 4.55\% and 90.9\% respectively.

In our series, six out of seven fusiform aneurysms were treated by curative PVO without bypass surgery. To avoid any infarction from the PVO, some authors advocate the use of complementally bypass surgery when needed.\textsuperscript{1,13,42} Other authors pointed out that the morbidity and mortality of bypass surgery is considerable in these aneurysms (36\%).\textsuperscript{5} In addition, the ischemic complications from the PVO are generally acceptable and are associated with neurologic recovery over time so that they are ultimately of limited clinical significance.\textsuperscript{21} The use of PVO for children seemed to be safer than for adults. When we reviewed the detailed locations and procedural results of PVOs without bypass surgery from the many therapeutic case series\textsuperscript{20,23,35} (Table 4) we found that they were located at the ICA in nine patients, the BA in two patients, the VA in two patients, the MCA in five patients (two in M2, three in M3) and the PCA in eight patients. Despite the lack of bypass surgery, a symptomatic infarction occurred in only one patient who had a BA trunk aneurysm. In our current study we had PVO in nine aneurysms, four located in the cavernous carotid segment, three in the MCA, one in VA and one in PCA, we have only one case of temporary neurological deficit following PVO that recovered within 3 weeks. Thus, PVO could be considered a relatively safe therapeutic option for distal cerebral aneurysms and unilateral ICA and VA aneurysms. However, we still believe that a complementary STA-MCA bypass should be performed in cases that inevitably sacrifice either the MCA trunk with no leptomeningeal collateral blood flow from other territories or bilateral ICA without sufficient flow from the Pcom arteries. Concerning the MCA trunk aneurysms, even with the bypass surgery it is thought to be difficult to preserve the critical perforators.\textsuperscript{43}

Some authors concluded that endovascular parent artery occlusion was simple, relatively safe and effective alternative treatment for giant aneurysms of the vertebrobasilar system untreatable by any other means, yet others noted worsening of symptoms, related to mass effect on the brainstem, may be observed after embolization.\textsuperscript{22}

Our results (favorable outcome and permanent procedural morbidity were respectively: 90.9 \% and 4.55 \%) are close to those of previous reports listed in table 4 that reported a good outcome ranging from 77\% to 96\%, and permanent procedural morbidity ranging from 2.9 \% to 6.7 \%.\textsuperscript{2,13,20,23,35,40} Parent vessel occlusion was found to be an effective and safe treatment for fusiform aneurysms.

<table>
<thead>
<tr>
<th>Author</th>
<th>Endovas. Therapy</th>
<th>PVO</th>
<th>Stent</th>
<th>Permanent Procedural Morbidity %</th>
<th>Favorable Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agid\textsuperscript{2} 2005</td>
<td>13</td>
<td>8</td>
<td>None</td>
<td>-----------------------------</td>
<td>77%</td>
</tr>
<tr>
<td>Lv\textsuperscript{23} 2009</td>
<td>25</td>
<td>16</td>
<td>3</td>
<td>4%</td>
<td>92%</td>
</tr>
<tr>
<td>Liang\textsuperscript{20} 2009</td>
<td>15</td>
<td>8</td>
<td>1</td>
<td>6.7%</td>
<td>87%</td>
</tr>
<tr>
<td>Hetts\textsuperscript{13} 2009</td>
<td>30</td>
<td>11</td>
<td>1</td>
<td>3.3%</td>
<td>----------------</td>
</tr>
<tr>
<td>Saraf\textsuperscript{35} 2012</td>
<td>23</td>
<td>10</td>
<td>1</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Takemoto\textsuperscript{14} 2014</td>
<td>34</td>
<td>16</td>
<td>3</td>
<td>2.9%</td>
<td>87%</td>
</tr>
<tr>
<td>Current</td>
<td>22</td>
<td>9</td>
<td>1</td>
<td>4.5%</td>
<td>90.9%</td>
</tr>
</tbody>
</table>

Both endovascular and microsurgical techniques can be used to effectively treat ruptured aneurysms in pediatric patients.\textsuperscript{39} Agid et al.\textsuperscript{2} compared surgical and endovascular treatment in children with cerebral aneurysms. In their case series, 13 aneurysms were managed endovascularly and 10 were managed surgically. Better outcomes and no deaths were observed in the endovascularly treated group; 1 patient died in the surgically treated group, and the authors concluded that endovascular treatment provides a better clinical outcome. Lasjaunias et al.\textsuperscript{14} reported a similar distribution among endovascular, surgical, and conservative approaches in their series of twenty cases. They treated eight (40\%) out of twenty patients by...
endovascular means and were successful in seven. In one case, endovascular treatment failed, and the patient received surgical treatment. All of the seven successful endovascular procedures resulted in complete regression of symptoms. In another study of one hundred and three aneurysms of which fifty were treated, Hettas et al. concluded that pediatric aneurysms can be treated in the present era with microsurgical techniques or an endovascular approach with good outcomes and low rates of mortality (1.3%) and morbidity. The authors noted that fusiform aneurysms may require a combined micro neurosurgical and endovascular approach more often and emphasized the need for long-term follow-up, as development of new aneurysms was observed in 6 patients.13

Follow up
Regardless of the type of aneurysm treatment (or observation alone), children with intracranial aneurysms require appropriate follow-up surveillance, given their long life expectancy during which additional aneurysms could arise or treated aneurysms could recur.4,13,16 In their angiographic follow-up of sixty seven aneurysms (mean 53 months), Kakarla et al. reported an annual recurrence rate of 2.6% and the annual rate of de novo formation or growth was 7.8% compared with 1.8% for adults.23

Pediatric intracranial aneurysms should be considered to be a potentially chronic progressive condition.13 The potential implications of connective tissue disorders in pediatric patients could be reflected by both the short time to recurrence and the size of the recurrent aneurysms.4 In our current study we had a recurrence of three (13.6%) cases at 12 month, two of which needed further treatment. However, our follow-up angiograms were performed for only when MRA showed abnormality and the radiological follow-up term after initial aneurysm treatment was for 12 months, thus limiting the ability to detect new or enlarging aneurysms. Considering the high incidence of underlying diseases associated with vascular fragility, further investigations and radiological follow up will be required to assure the long term safety.

CONCLUSION
In the current study we analyzed our data in order to clarify the characteristics of pediatric intracranial aneurysms and to establish appropriate management with regard to endovascular treatment. The pediatric intracranial aneurysms showed male predominance, a higher incidence of underlying diseases, a higher incidence in the posterior circulation, a higher incidence of giant aneurysms than in adults, and this was evident in both the available previous reports and our present results. The frequency of hemorrhagic presentation and the incidence of dissecting fusiform aneurysms and ICA terminus aneurysms had a relatively high variability between previous reports yet in our results we had a higher incidence of both dissecting fusiform aneurysms and ICA terminus. Concerning our treatment results, the rate of permanent procedural complications was low and of favorable outcome was high, which were comparable to other recent case series. Endovascular management is a feasible, relatively safe, durable, and effective treatment for pediatric intracranial aneurysms, yet longer periods of follow up is needed to assure long term safety.

REFERENCE

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