Endovascular treatment of a large ruptured middle cerebral artery bifurcation aneurysm in a 5-week-old infant: case report

Kristopher A. Lyon, MD; Eliel N. Arrey, MD; Ali S. Haider, BS; Dhruve S. Jeevan, MD; and Ethan A. Benardete, MD, PhD

Department of Neurosurgery, Scott and White Medical Center, Texas A&M University Health Science Center College of Medicine, Temple; and University of Texas Health Science Center, McGovern Medical School, Houston, Texas

Ruptured intracranial aneurysms are extremely rare in infants. The optimal treatment strategy is not well established. Both microsurgical and endovascular techniques and strategies have been tried, and in the literature there is a significant variability in outcome. The authors report the presentation and successful endovascular treatment of a large, ruptured, middle cerebral artery bifurcation aneurysm in a 5-week-old girl, one of only a few reported in the literature. Clinical and radiological findings at follow-up are also presented. The authors then review the literature on aneurysmal subarachnoid hemorrhage in infants, with particular regard to outcome after either endovascular or open surgical management. They also provide recommendations for follow-up in pediatric patients whose intracranial aneurysms have been treated with coil embolization.

https://thejns.org/doi/abs/10.3171/2017.5.PEDS17116

KEY WORDS neonate; intracranial aneurysm; endovascular; coil embolization; subarachnoid hemorrhage; vascular disorders

INTERRACRANIAL aneurysms in the pediatric population are rare, with an approximate incidence of 0.5%–4.6% of all cerebral aneurysms.1,2,4,6,12,20,28 Today, the number of reported cases of infantile intracranial aneurysms (ruptured and unruptured) numbers fewer than 150, with the number of intracranial aneurysms reported in neonates totaling fewer than 30.2,4 Until recently, the most common surgical treatment of these patients had been with open microsurgery, typically clipping.1,4,7,9,11–16,20,26–29,33,34,36,39,40

In the last few years, endovascular approaches to ruptured aneurysms in this age group have emerged as effective.5,7,12,26,28,29 This report illustrates successful endovascular treatment of a spontaneously ruptured intracranial saccular aneurysm in a 5-week-old infant. To our knowledge, this patient represents the eighth case of a ruptured saccular aneurysm in a child less than 3 months old treated with coil embolization. A literature review is provided to compare the treatment and outcomes of ruptured intracranial saccular aneurysms in infants less than 3 months old, in terms of endovascular and microsurgical techniques.
Insula. Diffusion-weighted imaging confirmed these findings (not shown). A diffusion coefficient map with evidence of ischemia in opercular cortex and right MCA bifurcation measuring 13 mm in maximum dimension.

**FIG. 1.** Neuroimaging studies obtained at initial evaluation. **A** and **B**: Noncontrast axial CT scans showing blood within the right sylvian fissure and a “halo” around the large MCA aneurysm. **C**: Coronal CT angiogram of the head showing a large saccular aneurysm (arrow) at the right MCA bifurcation measuring 13 mm in maximum dimension. **D**: Axial MRI study obtained on the day of admission showing apparent diffusion coefficient map with evidence of ischemia in opercular cortex and insula. Diffusion-weighted imaging confirmed these findings (not shown).

The patient was observed in the ICU for 10 days. Normotension and normovolemia were maintained. Daily transcranial Doppler ultrasound and MRA sequences of the brain were used to monitor for vasospasm. This testing indicated only mild vasospasm in the right MCA, which resolved during her hospitalization. While in the hospital, the patient had intermittent left upper-extremity shaking. An electroencephalogram performed at the time demonstrated spikes and waves in the right central region, consistent with the area of restricted diffusion seen in the right MCA distribution on MRI obtained prior to intervention (Fig. 1D). Fourteen days after the procedure, she was discharged home with equal strength, tone, and movement in bilateral upper and lower extremities. Antiepileptic medications were continued for her occasional seizure activity. In her 6-month follow-up visit, she was making appropriate developmental milestones but still had rare flexion and extension spasms while on anticonvulsant medication. Repeat MRA and catheter angiography at her 7-month follow-up showed complete occlusion of a previously embolized large right MCA aneurysm (Raymond-Roy Class 1) with preservation of the parent vessels (Fig. 3A and B). An MRI study of the brain showed volume loss in the right hemisphere, probably secondary to the prior injury from the SAH (Fig. 3C and D). At the 10-month follow-up visit, she continued to do well and had met all developmental milestones. Although she was still receiving antiepileptic drugs, her seizure activity had ceased.

**Postoperative Course**

The patient was observed in the ICU for 10 days. Normotension and normovolemia were maintained. Daily transcranial Doppler ultrasound and MRA sequences of the brain were used to monitor for vasospasm. This testing indicated only mild vasospasm in the right MCA, which resolved during her hospitalization. While in the hospital, the patient had intermittent left upper-extremity shaking. An electroencephalogram performed at the time demonstrated spikes and waves in the right central region, consistent with the area of restricted diffusion seen in the right MCA distribution on MRI obtained prior to intervention (Fig. 1D). Fourteen days after the procedure, she was discharged home with equal strength, tone, and movement in bilateral upper and lower extremities. Antiepileptic medications were continued for her occasional seizure activity. In her 6-month follow-up visit, she was making appropriate developmental milestones but still had rare flexion and extension spasms while on anticonvulsant medication. Repeat MRA and catheter angiography at her 7-month follow-up showed complete occlusion of a previously embolized large right MCA aneurysm (Raymond-Roy Class 1) with preservation of the parent vessels (Fig. 3A and B). An MRI study of the brain showed volume loss in the right hemisphere, probably secondary to the prior injury from the SAH (Fig. 3C and D). At the 10-month follow-up visit, she continued to do well and had met all developmental milestones. Although she was still receiving antiepileptic drugs, her seizure activity had ceased.
Discussion

Etiology of Lesions

Saccular aneurysms in infants are extremely rare, so much so that Stehbens in the classic work published in 1972, *Pathology of the Cerebral Blood Vessels*, doubted their existence. Large autopsy studies done at that time had failed to find a single one, leading the author to suggest that intracranial aneurysms must be an acquired abnormality. Nevertheless, over the ensuing years, case reports such as ours have demonstrated unquestionably the existence of saccular aneurysms in the neonate and young infant. Nevertheless, the problem of their etiology remains unanswered because the literature remains heterogeneous with respect to aneurysm type, predisposing factors, and extent of follow-up.

We focused our review on ruptured saccular aneurysms in infants less than 3 months old. We found 26 surgically treated cases clearly documented in the literature, 8 of which (including ours) were treated endovascularly (Table 1). In this group, the MCA (18 of 26) is the most common location, although not all of these aneurysms occurred at the bifurcation. For example, the report by Rana et al. from 2007 describes 2 cases of distal saccular MCA aneurysms treated endovascularly. The other aneurysm locations found in our review, such as cavernous ICA, anterior cerebral artery (ACA), or posterior inferior cerebellar artery (PICA) are minimally represented. The embryological development of intracranial vessels may explain why the majority of infants with aneurysms have them near the MCA, because it and the ICA develop earlier and receive more blood flow than other vessels in the cerebrum. In 1978, Grode et al. performed pathological examinations on the walls of 2 neonatal aneurysms; both showed findings similar to adult aneurysms, with disruption of the arterial layers and thinning of the wall.

Although connective tissue disorders (such as Ehlers-Danlos syndrome or Marfan syndrome) and other hereditary factors (sickle cell anemia, polycystic kidney disease, neurofibromatosis Type 1) are frequently mentioned as predisposing causes in the pediatric aneurysm population, none of the patients in the literature on treated neonatal aneurysmal SAH had one of these conditions. Many authors have speculated that birth-related or perinatal trauma (accidental or deliberate) may also cause aneurysms or precipitate a rupture. However, in most cases in our review, no clear traumatic event had occurred.

Patient Presentation

Infants with aneurysmal SAH present in different ways, but abrupt neurological decline and seizures are common. The most common presentation of SAH is acute loss of consciousness, as seen in our patient. Subarachnoid hemorrhage is easily detected with CT imaging of the head. Because this directs a high level of radiation to the developing brain, Tekkök and Ventureyra (1997) argue that transfontanelle cranial ultrasonography should be the
first investigation in neonates; it demonstrates the location and size of the hemorrhage, the degree of hydrocephalus, and may show the aneurysm itself. To confirm the findings on ultrasound or CT, an MR image or MR angiogram of the head should be ordered before a CT angiogram, to limit radiation exposure. Catheter angiography, typically via the transfemoral route, poses higher than average risks in the neonate and infant, and is probably best done as a confirmatory study or with an intent to treat endovascularly. Keeping the volume of contrast and the dose of iodine to a minimum is reasonable, given the risk of kidney injury.

Treatment: Microsurgical Versus Endovascular

Early series and case reports demonstrated that the mortality was high in cases of ruptured aneurysm occurring in infants in which patients were only supported medically. Both open surgical and endovascular treatment options have resulted in favorable outcomes. Van Raay et al. (2009) and Song et al. (2005) have even argued that surgery is better tolerated in infants than in adults. Table 1 summarizes the results of our review of infants less than 3 months old who were treated either by microsurgical clipping or endovascular intervention for a ruptured saccular intracranial aneurysm. The degree of impairment and the length of follow-up are variable. In both the clip ligation group and the endovascular group, some degree of neurological impairment is common during the follow-up period, when it is reported.

In most centers, endovascular approaches with detachable platinum coils are now viewed as a first-line treatment for adults with ruptured intracranial aneurysms, although aneurysms of the MCA are still often treated with open surgical clip ligation. In one review, the authors suggested that open surgical clipping may be favorable for children because of better durability; however, from our review it is not clear that either superior benefit or durability can be argued for one treatment modality or the other. Certainly, endovascular treatment has the advantage of less blood loss and less surgical trauma.

From the 8 cases in the literature (including this patient) illustrating coil embolization of ruptured aneurysms

![Image](image_url)
# TABLE 1. Previous reports of aneurysmal rupture in the first 3 months of life from saccular aneurysms, with aneurysm location, treatment, and outcome

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Age, Sex</th>
<th>Presentation</th>
<th>Aneurysm Location</th>
<th>Imaging Findings</th>
<th>Treatment</th>
<th>Outcome After Intervention</th>
<th>Outpatient Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones &amp; Shearburn, 1961</td>
<td>28 days, F</td>
<td>Crying, seizures, eye deviation</td>
<td>Rt MCA</td>
<td>SAH</td>
<td>Clipped</td>
<td>Good condition</td>
<td>Unknown</td>
</tr>
<tr>
<td>Vapalahti et al., 1969</td>
<td>90 days, F*</td>
<td>Vomiting, seizures, hemiparesis</td>
<td>Rt MCA</td>
<td>SAH</td>
<td>Clipped</td>
<td>Good condition; resolved hemiparesis</td>
<td>Developmentally normal at 6 wks</td>
</tr>
<tr>
<td>Grode et al., 1978</td>
<td>8 days, F</td>
<td>Lethargy, vomiting, seizures</td>
<td>Lt MCA</td>
<td>SAH</td>
<td>Clipped</td>
<td>Intact neurologically</td>
<td>Slight psychomotor delay at 3 yrs</td>
</tr>
<tr>
<td>Hungerford et al., 1981</td>
<td>28 days, F</td>
<td>Crying, vomiting</td>
<td>Rt MCA</td>
<td>SAH, IPH</td>
<td>Clipped</td>
<td>Full recovery after surgery</td>
<td>Unknown</td>
</tr>
<tr>
<td>Russegger &amp; Grunert, 1987</td>
<td>70 days, F*</td>
<td>Crying, vomiting, seizures</td>
<td>Lt MCA</td>
<td>SAH, IPH</td>
<td>Clipped</td>
<td>Slight clumsiness of rt arm</td>
<td>Persistent rt arm clumsiness at 3 mos</td>
</tr>
<tr>
<td>Thrush &amp; Marrano, 1988</td>
<td>28 days, F</td>
<td>Irritability, lethargy, respiratory issues</td>
<td>Lt MCA</td>
<td>IPH</td>
<td>Clipped</td>
<td>No neurological deficits</td>
<td>Unknown</td>
</tr>
<tr>
<td>Hosotani et al., 1995</td>
<td>24 days, F</td>
<td>Hydrocephalus, enlarging head</td>
<td>Lt PICA</td>
<td>SAH</td>
<td>Clipped</td>
<td>No neurological deficits</td>
<td>Alive at 7 mos</td>
</tr>
<tr>
<td>Allison et al., 1998</td>
<td>30 days, M*</td>
<td>Hydrocephalus</td>
<td>Lt MCA</td>
<td>SAH, IPH</td>
<td>Open surgery, unknown</td>
<td>Alive, unknown condition</td>
<td>Unknown</td>
</tr>
<tr>
<td>Jansen et al., 2000</td>
<td>30 days, F*</td>
<td>Irritability, vomiting, eye deviation</td>
<td>Lt PICA</td>
<td>SAH, IPH</td>
<td>Clipped</td>
<td>No neurological deficits</td>
<td>Alive at 18 mos</td>
</tr>
<tr>
<td>Kourtopoulous et al., 2000</td>
<td>13 days, F</td>
<td>Failure to thrive</td>
<td>Lt MCA</td>
<td>IPH, IVH</td>
<td>Clipped</td>
<td>No neurological deficits</td>
<td>Alive at 1 yr</td>
</tr>
<tr>
<td>Young &amp; Patitsapu, 2000</td>
<td>39 days, M</td>
<td>Somnolence, bulging fontanelle</td>
<td>Lt MCA</td>
<td>SAH, IPH</td>
<td>Bipolar coagulation</td>
<td>Rt hemiparesis, dev delays, seizures</td>
<td>Alive at 2 yrs</td>
</tr>
<tr>
<td>Maroun et al., 2003</td>
<td>3 days, M</td>
<td>Irritability, seizures, hypertonia, dilated lt pupil</td>
<td>Lt MCA</td>
<td>SAH</td>
<td>Clipped</td>
<td>Bilat CN III paresis, spastic tetraparesis</td>
<td>Dead at 4 yrs old</td>
</tr>
<tr>
<td>Song et al., 2005</td>
<td>11 days, F</td>
<td>Irritability, seizures, neglect, choreoid movements, disconjugate gaze</td>
<td>ACoA, bilat ACA, lt ICA</td>
<td>IPH, IVH</td>
<td>Coiled</td>
<td>Significant recovery from prep presentation</td>
<td>Continued neurological improvement at 3 mos</td>
</tr>
<tr>
<td>Gallia et al., 2005</td>
<td>21 days, F</td>
<td>Vomiting, irritability, cranial nerve palsies</td>
<td>Lt cavernous ICA</td>
<td>Lt middle fossa mass</td>
<td>Coiled</td>
<td>Unilat CN III, VI palsies</td>
<td>Resolving CN palsies at 5 mos</td>
</tr>
<tr>
<td>Huang et al., 2005</td>
<td>30 days, F*</td>
<td>Cranial nerve palsies</td>
<td>Lt cavernous ICA</td>
<td>Lt middle fossa mass</td>
<td>Coiled</td>
<td>GOS Score 5</td>
<td>Alive at 1 yr</td>
</tr>
<tr>
<td>Wong &amp; Fong, 2007</td>
<td>30 days, M*</td>
<td>Seizures</td>
<td>Rt MCA</td>
<td>SAH, IPH</td>
<td>Surgical excision</td>
<td>No neurological deficits</td>
<td>15 mos</td>
</tr>
<tr>
<td>Sanai et al., 2006</td>
<td>58 days, U*</td>
<td>Hunt &amp; Hess 2</td>
<td>Unspecified</td>
<td>SAH</td>
<td>Coiled</td>
<td>Good outcome</td>
<td>Alive at 1 yr</td>
</tr>
<tr>
<td>Rana et al., 2007</td>
<td>31 days, M</td>
<td>Seizures, respiratory depression</td>
<td>Rt MCA</td>
<td>SDH, IPH</td>
<td>Coiled</td>
<td>No neurological deficits</td>
<td>Developmentally normal at 15 mos</td>
</tr>
<tr>
<td>Van Raay et al., 2009</td>
<td>54 days, F</td>
<td>Seizures, irritability, rt hemiparesis</td>
<td>Lt MCA</td>
<td>IPH</td>
<td>Coiled</td>
<td>Rt hemiparesis</td>
<td>Dev delay, rt hemiparesis at 3 yrs</td>
</tr>
<tr>
<td>González-Bonet et al., 2010</td>
<td>7 days, F</td>
<td>Fever, irritability, bulging fontanelle</td>
<td>Rt PICA</td>
<td>IVH</td>
<td>Clipped &amp; resected</td>
<td>Swallowing difficulties</td>
<td>Resolved swallowing difficulties at a few mos</td>
</tr>
<tr>
<td>Choi &amp; Lee, 2013</td>
<td>7 days, F</td>
<td>Hypotonia, decreased level of consciousness</td>
<td>Lt MCA</td>
<td>IPH</td>
<td>Clipped</td>
<td>Rt arm paresis</td>
<td>Rt hand paresis, normal cognition at 3 yrs</td>
</tr>
<tr>
<td>Fathi et al., 2015</td>
<td>60 days, F*</td>
<td>Seizures</td>
<td>Lt ACA</td>
<td>SAH, IVH</td>
<td>Clipped</td>
<td>No neurological deficits</td>
<td>Delay in motor milestones at 2 yrs</td>
</tr>
<tr>
<td>Del Santo &amp; Cordina, 2016</td>
<td>90 days, F*</td>
<td>Limp, vomiting, downward gaze</td>
<td>Rt SCA</td>
<td>SAH</td>
<td>Coiled</td>
<td>Good outcome</td>
<td>Met all dev milestones at 7 mos</td>
</tr>
</tbody>
</table>

*Continued on page 362*
Sequelae of Rupture

Regardless of whether microsurgical clipping or endovascular coiling is used to treat a ruptured aneurysm in an infant, Proust et al. (2001) have suggested that the main determinant of outcome is the initial SAH itself.\textsuperscript{35} All patients with SAH are susceptible to delayed cerebral ischemia from vasospasm. In addition, the pediatric brain in particular is susceptible to developing other complications such as seizures if an area of the brain becomes injured.\textsuperscript{24,30} Our patient developed focal epilepsy, and the MRI study of the brain before treatment revealed a small right MCA distribution infarct (Fig. 1D). Subsequent electroencephalography confirmed the presence of epileptic activity arising from the right hemisphere.

Conclusions

Neonatal ruptured aneurysms are rare, and the exact cause is unknown. Currently, both endovascular and microsurgical treatments are valid options, each with special challenges. Until recently, microsurgical clipping was favored in the pediatric population of patients with aneurysms because of the technical challenges of angiography and embolization in neonates and a perceived reduced risk of recurrence compared with coil embolization. However, with at least in adults, stable or improved angiographic results at the 6-month follow-up tend to predict an excellent long-term result.\textsuperscript{35}

Table 1: Previous reports of aneurysmal rupture in the first 3 months of life from saccular aneurysms, with aneurysm location, treatment, and outcome

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Age, Sex</th>
<th>Presentation</th>
<th>Aneurysm Location</th>
<th>Imaging Findings</th>
<th>Treatment</th>
<th>Outcome After Intervention</th>
<th>Outpatient Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hidalgo et al., 2017</td>
<td>26 days, F</td>
<td>Seizures, lethargy</td>
<td>Lt MCA</td>
<td>SAH, IPH, SDH</td>
<td>Clipped</td>
<td>Good outcome</td>
<td>Normal development at 25 mos</td>
</tr>
<tr>
<td>Present case</td>
<td>40 days, F</td>
<td>Limp, unresponsive</td>
<td>Rt MCA</td>
<td>SAH</td>
<td>Coiled</td>
<td>Seizures</td>
<td>Met all dev milestones at 10 mos</td>
</tr>
</tbody>
</table>

ACA = anterior cerebral artery; ACoA = anterior communicating artery; CN = cranial nerve; dev = developmental; GOS = Glasgow Outcome Scale; ICA = internal carotid artery; IPH = intraparenchymal hemorrhage; IVH = intraventricular hemorrhage; PICA = posterior inferior cerebellar artery; SCA = superior cerebellar artery; SDH = subdural hematoma; U = unknown sex.

* Approximate age.

In infants less than 3 months old, we see an average follow-up of 12.5 months.\textsuperscript{5,7,12,26,28,29} Although each case report has shown stable or improved patient outcomes at follow-up, the durability of a coil construct in an infant for more than 36 months is unknown.\textsuperscript{26} However, at least in adults, stable patient outcomes at follow-up, chances of future recurrence are low.\textsuperscript{35} Nevertheless, in the neonatal age group it is hard to predict what might develop in the future, given the effects of maturation and a possible underlying genetic predisposition to aneurysm formation. Therefore, we recommend that MRA of the brain be performed every 6 months for the first 2 years after treatment, followed by yearly MRA of the brain. If an abnormal MR angiogram of the brain is obtained at any of these intervals, follow-up catheter angiography and possible retreatment should be performed. The durability of endovascular treatment will become clear as more centers report the long-term follow-up of these unusual patients.

Acknowledgments

We thank Dr. Patrick T. Noonan Jr. for helpful suggestions during the procedure.

References

Endovascular treatment of ruptured aneurysm in infant


Disclosures
The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions
Conception and design: Lyon, Benardete. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: Lyon, Arrey, Haider, Benardete. Correspondence: Lyon, Jeevan, Benardete. Study supervision: Benardete.

Correspondence
Kristopher A. Lyon, Department of Neurosurgery, Scott and White Medical Center, 2401 S 31st St., Temple, TX 76508. email: kristopher.lyon@bswhealth.org.