Intracranial aneurysms are not common in the pediatric age group, with pediatric cases accounting for only 0.5% to 4.5% of all aneurysms encountered.28,29 These cases may be further divided into 3 periods: neonatal (involving patients younger than 4 weeks), infancy (involving patients 4 weeks–2 years of age), and childhood (involving patients 2–18 years of age). Neonatal intracranial aneurysms are exceedingly uncommon, and to date, only 36 cases have been reported. They represent a unique subset of intracranial aneurysms that differ from those encountered in the adult population.

Hypertension, atherosclerosis, and smoking are risk factors for the development of aneurysms in adults. The etiology of intracranial aneurysms in neonates is less clear, although trauma, infection, connective tissue disorders, and congenital vessel abnormalities have been suggested as potential contributors.36 In the current study, we present the case of a 28-day-old neonate admitted with seizures from a ruptured left middle cerebral artery (MCA) aneurysm.

Initial noninvasive imaging with transfontanelle ultrasound and CT confirmed intraparenchymal and subarachnoid hemorrhage. Contrast-enhanced MRI revealed a 14-mm ruptured fusiform MCA aneurysm that was not identified on time-of-flight magnetic resonance angiography (MRA). Microsurgical treatment was performed with partial neurological recovery. A comprehensive review of the literature from 1949 to 2017 revealed a total of 40 aneurysms in 37 neonates, including the present case. The most common presenting symptom was seizure. Although subarachnoid hemorrhage was the most common form of hemorrhage, 40% had intraparenchymal hemorrhage. The median aneurysm size was 10 mm (range 2–30 mm) and the most common location was the MCA, with two-thirds of cases involving the distal intracranial vasculature. Over the last 10 years, there has been a trend of increasing noninvasive diagnosis of ruptured cerebral aneurysms in neonates, with CT angiography and contrast-enhanced MRI being the most useful diagnostic modalities. The use of contrast-enhanced MRI may improve sensitivity over time-of-flight MRA. Microsurgical treatment was the most common treatment modality overall, with increased use of endovascular treatment in the last decade. Most patients underwent microsurgical vessel ligation or endovascular parent vessel occlusion. There were high rates of neurological recovery after microsurgical or endovascular treatment, particularly for patients with distal aneurysms.

Intracranial aneurysms in the neonate, presenting in the first 4 weeks of life, are exceedingly rare. They appear to have characteristics, including presentation and location, that vary from those found in adults. The authors present a case of a 28-day-old neonate with a ruptured distal middle cerebral artery (MCA) aneurysm.

**KEY WORDS** intracranial aneurysms; neonate; clipping; endovascular embolization; coiling; vascular disorders
Case Report

History

A 28-day-old female neonate was admitted to our institution with irritability, decreased oral intake, and recurrent right-sided upper and lower limb focal seizures over 2 days. There was no history of trauma or recent infection. The patient was born at 38 weeks’ gestation through an emergency caesarean section in the setting of poor progression of labor, which had been induced due to mild maternal preeclampsia. The perinatal period was normal and the Apgar score was 9 at 1 and 5 minutes. During the early neonatal period, the patient suffered mild jaundice that required phototherapy, but she was discharged clinically well 5 days after birth.

Initial Examination

On initial examination, the patient was drowsy and lethargic with a tense anterior fontanelle. Her vital signs were within the normal ranges, and her breathing was spontaneous. She opened her eyes in response to pain and moved all 4 limbs spontaneously with moderate strength. Her pupils measured 2 mm bilaterally and were reactive to light. There were no clinical findings suggestive of infection.

Investigations

No evidence of infection was revealed on full blood examination, inflammatory markers, chest radiograph, or urine or blood cultures. Initial cranial investigation was with transfontanelle ultrasound (Fig. 1 left) followed by CT (Fig. 1 right). These revealed extensive left-sided parenchymal hemorrhage. MRI confirmed considerable associated vasogenic edema and mass effect, characterized by midline shift and subfalcine and uncal herniation (Fig. 2A and B). Time-of-flight (TOF) magnetic resonance angiography (MRA) did not reveal a structural cause to the hemorrhage (Fig. 2C). However, the contrast-enhanced MRI revealed a vividly enhancing oval mass (14 × 8 mm) located directly adjacent to the parenchymal hemorrhage with distal MCA branches leading up to it, compatible with a ruptured distal MCA aneurysm (Fig. 2D). All radiological investigations were performed within 10 hours of initial after-hours hospital presentation.

While under assessment, the patient was noticed to stop moving her right upper and lower limbs. Her left pupil became progressively dilated and fixed at 4 mm. Intravenous mannitol was administered immediately, and she was taken to the operating theater for urgent craniotomy.

Operation

Before anesthesia, the patient’s heart rate was 157 beats/minute, her blood pressure was 81/37 mm Hg, and her hemoglobin level was 79 g/L. During the 4 hours of anesthetic time, fluid balance and hemoglobin levels were monitored by a pediatric anesthesiologist, with administration of 100 ml total of normal saline and 75 ml of red blood cells in 25-ml aliquots during surgery. Intraoperatively, the aneurysm arose from the trunk of an M3 branch, and not from a bifurcation. There was a vessel exiting the aneurysm in continuity and a daughter sac that pointed medially into the hematoma, which was the rupture point. Clipping of the daughter sac alone was not feasible, and thus the branch proximal to the aneurysm was secured with a 7-mm Sugita aneurysm clip and the vessel distal to the aneurysm was fulgurated with bipolar diathermy and divided. The feeding vessel was divided immediately dis-
tal to the clip, and the aneurysm was removed and sent for analysis. The hematoma was evacuated, and hemostasis was achieved. There were no intraoperative complications.

Postoperative Course

Postoperative radiological assessment demonstrated satisfactory evacuation of the intraparenchymal hematoma and no residual aneurysm. Microscopy and culture of the aneurysm dome did not reveal evidence of infection. The etiology remained unknown, with no history of trauma or collagen vascular disease or other congenital syndrome associated with cerebral aneurysms. In the postoperative period, the patient suffered ongoing right hemiparesis and seizures. She required long-term levetiracetam and was eventually discharged to pediatric rehabilitation. At 15 months’ follow-up, the patient had persistent right hemiparesis and delays in reaching gross and fine motor movement milestones. Despite high-dose levetiracetam, she continued to experience recurrent seizures. Follow-up MRI of the brain showed left MCA territory cystic encephalomalacia and gliosis.

Literature Review

Search Strategy

A comprehensive literature search was performed to identify reports of neonatal aneurysms. We searched PubMed, Ovid MEDLINE, and Embase databases from database inception until December 2016 to identify relevant articles. Appropriate key words and MeSH terms were used to identify all studies: “neonate”, “newborn”, “aneurysm”, “cerebral”, and “intracranial.” The reference lists of the final included articles were also searched to identify additional data sources.

Selection Criteria and Data Extraction

Studies eligible for inclusion were those that reported intracranial arterial aneurysms in children aged 1 month or younger. All studies selected are in English. Proximal aneurysms were defined as those arising from arteries of the circle of Willis (including the M1, A1, and P1 segments of the middle, anterior, and posterior cerebral arteries), the cavernous internal carotid artery (ICA), or the tip of the basilar artery. Intracranial aneurysms arising outside of these arteries were considered distal. Aneurysm location was, as per these definitions, dichotomized as proximal or distal. Clinical outcomes were classified into 3 groups: death, partial recovery, and full recovery. Patients with no residual neurological deficit were considered to have reached full recovery, while partial recovery was considered to denote survival with some neurological deficit. Two reviewers (J.E.M. and N.S.C.) independently appraised studies and extracted relevant clinical, imaging, and treatment characteristics. Discrepancies between reviewers were resolved by discussion, and consensus was reached; the pooled cohort was analyzed descriptively.

Study Selection

A total of 510 studies were identified through database searches and underwent title, abstract, and/or full-text review. Four hundred seventy-six studies were excluded. Reasons for exclusion included duplication and/or irrelevance to the present study. After comprehensive review, 34 studies were included in the analysis.

Study Characteristics and Outcomes

Our literature review yielded an additional 36 reported cases of neonates presenting with symptoms that resulted in the diagnosis of an intracranial aneurysm. The patients’ demographic characteristics and the clinical features, diagnostic modality, treatment, and outcomes of each case, including our present case, are given in Table 1.

Including the present case, our literature analysis yielded a total of 40 aneurysms in 37 neonatal patients reported between June 1949 and December 2016. The patients’ median age at diagnosis was 20 days, and 58% were female. Almost all (95%) of the neonates were diagnosed with a ruptured aneurysm; the most common clinical symptoms were seizures (19 cases) and irritability (16 cases). Other presenting features included cyanosis, apnea, tachypnea, vomiting, decreased state of consciousness, and fever. The median aneurysm size was 10 mm (range 2–30 mm). Two-thirds of aneurysms arose in the distal intracranial vessels; almost half were in the MCA branches (Fig. 3).

Treatment decisions and outcomes are summarized in Table 2. Of the 37 patients, 8 died prior to treatment. Of the remaining 29 patients, 20 underwent surgical treatment with clipping, excision, or ligation of their aneurysms; 6 underwent endovascular treatment; and a further 3 cases were managed conservatively. Most (89%) of the patients treated surgically had a full or partial recovery; there were 2 deaths. The use of endovascular coiling was first reported in 2005,4 and all patients treated with that technique had full or partial recovery.

Discussion

Neonatal intracranial aneurysms are a rare pathology and are infrequently reported. In this paper, we analyzed data from 37 cases involving neonates with intracranial aneurysms (including our own case as well as those identified in our literature search). Although the literature is limited to case reports, we can draw some conclusions from this comprehensive pooled series regarding clinical presentation, imaging, and treatment. In contrast to adult cases, the most common symptom in neonatal cases of intracranial aneurysms is seizure. Given the relatively common occurrence of seizures in the neonatal period, cranial imaging is critical to identify intracranial hemorrhage. Since 1980, noninvasive imaging with transfontanelle ultrasound and CT have been increasingly used to diagnose intracranial hemorrhage. Although subarachnoid hemorrhage was the most common form of hemorrhage identified, almost 40% of patients had intraparenchymal hemorrhage, and 20% had no subarachnoid hemorrhage. Intraventricular hemorrhage and/or hydrocephalus was present in 30% of patients. While transfontanelle ultrasound offers an attractive first-line imaging option for identification of large hematomas or hydrocephalus, in the last 10 years, most patients received MRI to diagnose intracranial hemorrhage.
## TABLE 1. Overview of neonatal intracranial aneurysm cases reported in the literature

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Age, Sex</th>
<th>Hemorrhage Type</th>
<th>Modality of Dx*</th>
<th>Side</th>
<th>Site</th>
<th>Distal or Prox</th>
<th>Max Size (mm)</th>
<th>Tx</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newcomb et al., 1949</td>
<td>23 days, M</td>
<td>SAH, SDH</td>
<td>Autopsy</td>
<td>—</td>
<td>CoW</td>
<td>Prox</td>
<td>NR</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 days, M</td>
<td>SAH</td>
<td>Autopsy</td>
<td>Rt</td>
<td>PCA/PCoA junction</td>
<td>Prox</td>
<td>2</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td>Jones et al., 1961</td>
<td>20 days, F</td>
<td>SAH, IVH</td>
<td>Angio</td>
<td>Rt</td>
<td>MCA</td>
<td>Prox</td>
<td>NR</td>
<td>MS clip</td>
<td>Full recov</td>
</tr>
<tr>
<td>Wierdus et al., 1965</td>
<td>0 days, NR</td>
<td>SAH</td>
<td>Autopsy</td>
<td>Rt</td>
<td>MCA</td>
<td>Distal</td>
<td>NR</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td>Pickering et al., 1970</td>
<td>1 mo, M</td>
<td>SAH</td>
<td>Autopsy</td>
<td>Rt</td>
<td>PICA</td>
<td>Distal</td>
<td>25</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td>Lee et al., 1978</td>
<td>0 days, F</td>
<td>SAH, IVH</td>
<td>Angio</td>
<td>—</td>
<td>Basilar bifurc</td>
<td>Prox</td>
<td>30</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td>Lipper et al., 1978</td>
<td>19 days, F</td>
<td>SAH, IVH</td>
<td>Autopsy</td>
<td>Lt</td>
<td>ICA/PCoA</td>
<td>Prox</td>
<td>21</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td>Grode et al., 1978</td>
<td>8 days, F</td>
<td>SAH</td>
<td>Angio</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>NR</td>
<td>MS lig</td>
<td>Partial recov</td>
</tr>
<tr>
<td>Hungerford et al., 1981</td>
<td>22 days, F</td>
<td>ICH</td>
<td>Angio</td>
<td>Rt</td>
<td>MCA</td>
<td>Distal</td>
<td>15</td>
<td>MS lig</td>
<td>Full recov</td>
</tr>
<tr>
<td>Thrus &amp; Marano, 1988</td>
<td>1 mo, F</td>
<td>ICH</td>
<td>Angio</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>6</td>
<td>MS clip</td>
<td>Full recov</td>
</tr>
<tr>
<td>Shimauchi et al., 1989</td>
<td>19 days, F</td>
<td>SAH, ICH</td>
<td>Angio</td>
<td>Rt</td>
<td>MCA</td>
<td>Distal</td>
<td>10</td>
<td>MS failed</td>
<td>Death</td>
</tr>
<tr>
<td>Boop et al., 1991–1992</td>
<td>23 days, M</td>
<td>ICH, IVH</td>
<td>Intraop</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>20</td>
<td>MS lig</td>
<td>Partial recov</td>
</tr>
<tr>
<td>Piatt &amp; Clunie, 1992</td>
<td>1 day, M</td>
<td>SAH, ICH</td>
<td>Angio</td>
<td>Lt</td>
<td>SCA</td>
<td>Distal</td>
<td>15</td>
<td>Conserv</td>
<td>Full recov</td>
</tr>
<tr>
<td>Kuchelmeister et al., 1993</td>
<td>4 days, M</td>
<td>SAH, IVH</td>
<td>Autopsy</td>
<td>—</td>
<td>ACoA</td>
<td>Prox</td>
<td>10</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td>Hosotani et al., 1995</td>
<td>24 days, M</td>
<td>SAH</td>
<td>Angio</td>
<td>Lt</td>
<td>PICA</td>
<td>Distal</td>
<td>15</td>
<td>MS lig</td>
<td>Full recov</td>
</tr>
<tr>
<td>Ozek et al., 1996</td>
<td>17 days, F</td>
<td>ICH</td>
<td>MRA</td>
<td>Rt</td>
<td>MCA</td>
<td>Distal</td>
<td>NR</td>
<td>MS lig</td>
<td>Full recov</td>
</tr>
<tr>
<td>Allison et al., 1998</td>
<td>1 mo, M</td>
<td>SAH, ICH</td>
<td>Intraop</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>20</td>
<td>MS†</td>
<td>NR</td>
</tr>
<tr>
<td>Tan et al., 1998</td>
<td>9 days, M</td>
<td>SAH, IVH</td>
<td>MRA</td>
<td>Lt</td>
<td>ACA</td>
<td>Prox</td>
<td>10</td>
<td>MS failed</td>
<td>Death</td>
</tr>
<tr>
<td>Jansen et al., 2000</td>
<td>1 mo, F</td>
<td>SAH, ICH</td>
<td>CTA</td>
<td>Lt</td>
<td>PICA</td>
<td>Distal</td>
<td>8</td>
<td>MS†</td>
<td>Full recov</td>
</tr>
<tr>
<td>Kourtopoulos et al., 2000</td>
<td>13 days, F</td>
<td>SAH, ICH</td>
<td>Angio</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>3</td>
<td>MS ligation</td>
<td>Full recov</td>
</tr>
<tr>
<td>Maroun et al., 2003</td>
<td>2 days, M</td>
<td>SAH</td>
<td>Angio</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>10</td>
<td>MS ligation</td>
<td>Death</td>
</tr>
<tr>
<td>Motohashi et al., 2004</td>
<td>1 mo, F</td>
<td>SAH</td>
<td>CTA</td>
<td>Rt</td>
<td>ACA</td>
<td>Distal</td>
<td>7</td>
<td>MS ligation</td>
<td>Full recov</td>
</tr>
<tr>
<td>Gallia et al., 2005</td>
<td>21 days, F</td>
<td>—</td>
<td>Angio</td>
<td>Lt</td>
<td>Cav ICA</td>
<td>Prox</td>
<td>20</td>
<td>EV occl</td>
<td>Partial recov</td>
</tr>
<tr>
<td>Lasjaunias et al., 2005</td>
<td>28 days, F</td>
<td>—</td>
<td>Angio</td>
<td>—</td>
<td>MCA</td>
<td>Distal</td>
<td>NR</td>
<td>Conserv</td>
<td>Full recov</td>
</tr>
<tr>
<td></td>
<td>8 days, F</td>
<td>SAH</td>
<td>Angio</td>
<td>—</td>
<td>ACoA</td>
<td>Prox</td>
<td>NR</td>
<td>MS†</td>
<td>Partial recov</td>
</tr>
<tr>
<td>Song et al., 2005</td>
<td>11 days, F</td>
<td>SAH, ICH</td>
<td>Angio</td>
<td>—</td>
<td>ACoA, RAH, Lt ICA</td>
<td>2 prox, 1 distal</td>
<td>NR</td>
<td>EV occl</td>
<td>Partial recov</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rana et al., 2007</td>
<td>21 days, M</td>
<td>SDH</td>
<td>MRA</td>
<td>Rt</td>
<td>MCA</td>
<td>Distal</td>
<td>5</td>
<td>EV occl</td>
<td>Full recov</td>
</tr>
<tr>
<td>Wong &amp; Fong, 2007</td>
<td>1 mo, M</td>
<td>SAH, ICH</td>
<td>Intraop</td>
<td>Rt</td>
<td>MCA</td>
<td>Distal</td>
<td>10</td>
<td>MS excision w/ anastomosis</td>
<td>Full recov</td>
</tr>
<tr>
<td>Kasliwal et al., 2008</td>
<td>14 days, M</td>
<td>SAH</td>
<td>MRA</td>
<td>Rt</td>
<td>Cav ICA</td>
<td>Prox</td>
<td>26</td>
<td>Conserv</td>
<td>Full recov</td>
</tr>
<tr>
<td>Van Raay et al., 2009</td>
<td>7 days, F</td>
<td>SAH, IVH</td>
<td>MRI</td>
<td>Rt</td>
<td>PICA</td>
<td>Distal</td>
<td>5</td>
<td>MS lig</td>
<td>Full recov</td>
</tr>
<tr>
<td>Vizcaíno-Díaz et al., 2009</td>
<td>26 days, M</td>
<td>ICH, IVH</td>
<td>MRI</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>20</td>
<td>—</td>
<td>Death</td>
</tr>
<tr>
<td>Tai et al., 2010</td>
<td>7 days, M</td>
<td>SAH, IVH</td>
<td>CTA</td>
<td>Both rt</td>
<td>Both PICA</td>
<td>2 distal</td>
<td>Both 3</td>
<td>EV occl</td>
<td>Full recov</td>
</tr>
<tr>
<td>Choi &amp; Lee, 2013</td>
<td>26 days, F</td>
<td>SAH, ICH, IVH</td>
<td>CTA</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>7</td>
<td>MS clip</td>
<td>Partial recov</td>
</tr>
<tr>
<td>Rao et al., 2013</td>
<td>21 days, F</td>
<td>SAH, SDH</td>
<td>CTA</td>
<td>Rt</td>
<td>MCA</td>
<td>Distal</td>
<td>15</td>
<td>EV occl</td>
<td>Partial recov</td>
</tr>
<tr>
<td>Kim et al., 2014</td>
<td>11 days, F</td>
<td>ICH</td>
<td>CTA</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>8</td>
<td>MS†</td>
<td>Full recov</td>
</tr>
<tr>
<td>Yatomi et al., 2014</td>
<td>1 mo, F</td>
<td>SAH</td>
<td>MRI</td>
<td>—</td>
<td>ACoA</td>
<td>Prox</td>
<td>NR</td>
<td>EV occl</td>
<td>Full recov</td>
</tr>
<tr>
<td>Present case</td>
<td>26 days, F</td>
<td>ICH, SAH</td>
<td>MRI</td>
<td>Lt</td>
<td>MCA</td>
<td>Distal</td>
<td>14</td>
<td>MS lig</td>
<td>Partial recov</td>
</tr>
</tbody>
</table>

ACA = anterior cerebral artery; ACoA = anterior communicating artery; angio = angiography; bifurc = bifurcation; cav = cavernous; conserv = conservative; CoW = circle of Willis; CTA = computed tomography angiography; Dx = diagnosis; EV = endovascular; ICA = internal carotid artery; ICH = intracerebral hemorrhage; IVH = intraventricular hemorrhage; lig = ligation; MCA = middle cerebral artery; MRA = magnetic resonance angiography; MRI = magnetic resonance imaging (protocol not stated); MS = microsurgical; mul = multiple; NR = not reported; occl = occlusion; PCA = posterior cerebral artery; PCoA = posterior communicating artery; PICA = posterior inferior cerebellar artery; prox = proximal; RAH = recurrent artery of Heubner; recov = recovery; SAH = subarachnoid hemorrhage; SCA = superior cerebellar artery; SDH = subdural hemorrhage; Tx = treatment.  
* Modality used to diagnose aneurysm.  
† Microsurgical technique not reported.
Between 1980 and 2005, the noninvasive diagnosis of a ruptured aneurysm as the cause of intracranial hemorrhage was uncommon (22%); the diagnosis was generally made with invasive preoperative cerebral angiography or intraoperatively. However, this has changed significantly in the last 10 years, with 90% of neonatal patients diagnosed with a ruptured aneurysm with computed tomography angiography (CTA), MRI, and/or MRA. There was 1 patient with an intraoperative diagnosis of a ruptured distal MCA aneurysm; however, in retrospect the aneurysm was evident on MRI as a 5-mm contrast-enhancing mass along the lateral margin of the hematoma. In our patient, and in other patients reported in the literature, the diagnosis could be made on contrast-enhanced MRI, a contrast-enhancing mass on the margin of the hematoma. In our patient, and in other patients reported in the literature, the diagnosis could be made on contrast-enhanced MRI, a contrast-enhancing mass on the margin of the hematoma. In our patient, and in other patients reported in the literature, the diagnosis could be made on contrast-enhanced MRI, a contrast-enhancing mass on the margin of the hematoma. Notably in 2 of the 3 cases in which both MRA and contrast-enhanced MRI were performed, TOF MRA was negative, while contrast-enhanced MRI revealed the aneurysm. This may be related to lack of sensitivity of the TOF MRA technique with slow or reduced intracranial vascular flow, which is not uncommon in cases of severe subarachnoid hemorrhage. CTA is less sensitive to alterations in vascular flow and was the diagnostic modality for 4 of the 11 neonatal cases reported in the last decade. However, MRI with contrast and MRA offer advantages over CTA with the lack of ionizing radiation, an important consideration in this patient cohort.

Most neonatal aneurysms arose in the distal circulation, mainly in the MCA territory. This contrasts with cerebral aneurysm occurrence in adults and can explain the high (40%) rate of intraparenchymal hemorrhage. Maintaining a high index of suspicion for a ruptured aneurysm is important, since 1 in 5 patients did not have any subarachnoid hemorrhage. The etiology of the aneurysm was unknown in most cases (70%); it was considered congeni-

**TABLE 2. Management of neonatal cerebral aneurysms and patient outcomes**

<table>
<thead>
<tr>
<th>Management</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microsurgical</td>
<td>Full Recov 5</td>
</tr>
<tr>
<td>Endovascular</td>
<td>3</td>
</tr>
<tr>
<td>Conservative</td>
<td>3</td>
</tr>
<tr>
<td>Died prior to Tx</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
</tr>
</tbody>
</table>

**FIG. 3.** Distribution of diagnosed neonatal aneurysms from 1949 to 2017. ACoA = anterior communicating artery; CoW = circle of Willis; ICA = internal carotid artery; PCA = posterior cerebral artery; PCoA = posterior communicating artery; PICA = posterior inferior cerebellar artery; RAH = recurrent artery of Heubner; SCA = superior cerebellar artery.
tal in 4 cases, traumatic in one, mycotic in one, associated with an AVM in one, and not reported in the remainder. In our case, the etiology remained unknown. There was no history of trauma, collagen vascular disease, or congenital syndrome. In addition, culture of the aneurysm did not reveal evidence of infection.

Once the diagnosis is made, treatment can be offered. Spontaneous occlusion of the aneurysm is rare but was reported in a patient with a ruptured superior cerebellar artery aneurysm, and in another patient with a giant ICA aneurysm. Both neonates made a full recovery despite asymptomatic complete right ICA occlusion in the second patient. Treatment was carried out in 26 neonates, with approximately one-quarter receiving endovascular treatment. Our review of all the available published cases demonstrates an increasing rate of active treatment—with almost 90% of patients in last the 2 decades receiving active treatment compared with only 50% prior to 1997. The mainstay of treatment in the cases identified by our literature review (85%) was microsurgical vessel ligation or endovascular parent vessel occlusion. The rate of full neurological recovery was higher in neonates who were treated with distal aneurysms (67%) compared with those with proximal aneurysms (33%), with an overall posttreatment mortality rate of 8%. Despite the high rate of initial seizure presentation, only 1 patient experienced recurrent seizures requiring ongoing anticonvulsants.

The major limitation of our article is that the literature is limited to published case reports, which introduces selection bias. Moreover, previous publications have varied in the level of detail included regarding clinical presentation, treatment, and follow-up. Nonetheless, due to the rarity of the condition, large series are unlikely to be published. Thus, this pooled case series provides unique clinical insights from a large pooled analysis of reports of neonatal aneurysms.

Conclusions

Neonatal intracranial aneurysms are exceedingly rare. The most common presenting symptom was seizure. Although subarachnoid hemorrhage was most common, some neonates had intraparenchymal hemorrhage without subarachnoid hemorrhage, indicating a need to maintain a high index of clinical suspicion for a ruptured aneurysm in any neonate with intracranial hemorrhage. Over the last 10 years, there has been increasing noninvasive diagnosis of ruptured neonatal cerebral aneurysms, with most found in the distal intracranial vasculature, particularly in the MCA territory. Microsurgical and endovascular treatment both represent reasonable therapeutic strategies with high rates of neurological recovery, particularly for patients with distal aneurysms.

References

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

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