Endovascular treatment of proximal and distal posterior inferior cerebellar artery aneurysms

Clinical article

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Object. Surgical clipping of posterior inferior cerebellar artery (PICA) aneurysms can be challenging and carries a potentially significant risk of morbidity and mortality. Experience with endovascular therapy has been limited to a few studies. The authors assess the feasibility, safety, and efficacy of endovascular therapy in the largest series of proximal and distal PICA aneurysms to date.

Methods. A total of 76 patients, 54 with proximal and 22 with distal PICA aneurysms, underwent endovascular treatment at Jefferson Hospital for Neuroscience between 2001 and 2011.

Results. Endovascular treatment was successful in 52 patients (96.3%) with proximal aneurysms and 19 patients (86.4%) with distal aneurysms. Treatment consisted of selective aneurysm coiling in 60 patients (84.5%) (including 4 with stent assistance and 4 with balloon assistance) and parent vessel trapping in 11 patients (15.5%). Specifically, a deconstructive procedure was necessary in 9.6% of proximal aneurysms (5 of 52) and 31.6% of distal aneurysms (6 of 19). There were 9 overall procedural complications (12.7%), 6 infarcts (8.5%; 4 occurring after deliberate occlusion of the PICA), and 3 intraprocedural ruptures (4.2%). The rate of procedure-related permanent morbidity was 2.8%. Complete aneurysm occlusion was achieved in 63.4% of patients (45 of 71). One patient (1.4%) treated with selective aneurysm coiling suffered a rehemorrhage on postoperative Day 15. The mean angiographic follow-up time was 17.2 months. Recurrence and re-treatment rates were, respectively, 20% and 17.1% for proximal aneurysms compared with 30.8% and 23.1% for distal aneurysms. Favorable outcomes (moderate, mild, or no disability) at follow-up were seen in 93% of patients with unruptured aneurysms and in 78.7% of those with ruptured aneurysms.

Conclusions. Endovascular therapy is a feasible, safe, and effective treatment in patients with proximal and distal PICA aneurysms, providing excellent patient outcomes and adequate protection against rehemorrhage. The long-term incidence of aneurysm recanalization appears to be high, especially in distal aneurysms, and requires careful angiographic follow-up.

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Key Words • distal aneurysm • endovascular therapy • proximal aneurysm • posterior inferior cerebellar artery • interventional neurosurgery

Posterior inferior cerebellar artery aneurysms are rare and account for only 0.5%–3% of all intracranial aneurysms. 3 Most arise from the PICA–vertebral artery junction or the first anteromedullary segment of the vessel. 10,26 Early aneurysm treatment is necessary in patients presenting with SAH as rebleeding rates may be as high as 78%. 11 Despite high technical success rates, surgical treatment of these aneurysms is often challenging; may require manipulation of the brainstem and cranial nerves IX, X, and XI; and carries a significant risk of morbidity. 19 In a study that included 34 patients undergoing surgical treatment for PICA aneurysms, up to 68% of patients developed new postoperative neurological deficits. 9

Endovascular therapy is a useful and minimally invasive alternative that allows for treatment of PICA aneurysms without the inherent risks associated with micro-
surgical procedures, especially lower cranial neuropathy. Several recently published reports describe successful endovascular treatment of PICA aneurysms. However, most of these studies had small sample sizes with limited angiographic follow-up, which makes it difficult to draw definitive conclusions regarding the feasibility, safety, and durability of endovascular therapy.

Given the challenges posed by open surgery, we have offered endovascular therapy as the primary treatment option for most patients presenting to our institution with PICA aneurysms. We assess the feasibility, safety, and efficacy of endovascular therapy in the largest series of proximal and distal PICA aneurysms to date.

Methods

The study protocol was approved by the Thomas Jefferson University Institutional Review Board. We searched our prospectively maintained database for all patients with PICA aneurysms who were treated by endovascular means at our institution between 2001 and 2011. A total of 76 patients with 76 PICA aneurysms were identified and constituted our study population. Medical charts, imaging studies, and initial and follow-up angiograms were reviewed to determine the patient age, sex, size of the aneurysm, proximal/distal aneurysm location, Hunt and Hess grades, associated aneurysms, type of endovascular technique, procedure-related morbidity and mortality, incidence of hydrocephalus and vasospasm, immediate and follow-up angiographic results, clinical outcome, and rate of hemorrhage/rehemorrhage.

Proximal PICA aneurysms were defined as aneurysms arising from the PICA–vertebral artery junction or the anteromedullary segment of the vessel. Those arising beyond the anteromedullary segment were classified as distal. All procedure-related complications were reported regardless of their clinical significance. Intraoperative rupture was diagnosed by the exit of the microcatheter or coil tip outside the limit of the aneurysm sac and/or extravasation of contrast. Thromboembolic and ischemic events were diagnosed intraoperatively by angiography, clinically (new deficits), or postoperatively on CT/MRI (new infarcts). In patients who sustained an SAH, the presence of vasospasm was assessed clinically and confirmed by transcranial Doppler ultrasonography, CT angiography, or DSA. Angiographic vasospasm and delayed cerebral ischemia were defined based on the criteria of Vergouwen et al. Clinical outcome was determined at follow-up using the GOS and classified as follows: 1, dead; 2, vegetative state; 3, severely disabled; 4, moderately disabled; and 5, mildly or not disabled. Initial and follow-up DSA images were compared to determine the initial and follow-up percentages of aneurysm occlusion. Aneurysm recurrence was defined as any decrease in the percentage of occlusion at follow-up.

We preferentially offer endovascular therapy to patients with posterior circulation aneurysms, including those with PICA aneurysms, whenever this approach is deemed feasible. In aneurysms with a favorable geometry, the aim of treatment was selective and complete coiling of the aneurysm with preservation of the patency of the PICA (Fig. 1). In wide-necked aneurysms or when the PICA originated from the aneurysm sac, selective endo-saccular coiling was attempted before resorting to parent vessel occlusion. In certain proximal wide-necked aneurysms, coiling was performed using Hyperglide balloon (eV3) or Neuroform stent (Stryker Neurovascular) assistance (Fig. 2). A patient’s tolerance to PICA occlusion was assessed based on the presence and extent of collaterals from the ipsilateral anterior inferior cerebellar artery, superior cerebellar artery, or contralateral PICA. When collateral circulation was deemed insufficient, microsurgical treatment with bypass surgery was generally undertaken (occipital artery–PICA or PICA-PICA bypass). Dissecting aneurysms of the PICA, defined as lesions with irregular fusiform dilations and/or irregularity/stenosis proximal or distal to the aneurysm with or without an intimal flap, were usually managed with parent artery occlusion (Fig. 3). One patient with a distal dissecting aneurysm of the PICA was treated with a liquid embolic agent (Onyx, ev3). After selective microcatheterization of the PICA, Onyx was injected just proximal to the aneurysm, limiting distal migration to just past the aneurysm neck (Fig. 4).

All procedures were performed under general anesthesia and continuous electrophysiological monitoring including somatosensory evoked potentials, brainstem auditory evoked responses, and electroencephalography. Patients who sustained an SAH with a Hunt and Hess grade of III or higher underwent placement of ventriculostomy catheters, central venous catheters, and radial arterial lines. Patients with unruptured aneurysms received an initial 100-U/kg bolus of heparin, and activated clotting time was maintained at 2–3 times the baseline intraoperatively and for 24 hours following the procedure. When the use of a stent was anticipated, patients were pretreated with aspirin (81 mg) and clopidogrel (75 mg) 10 days prior to the procedure. For aneurysms treated with coiling in the setting of SAH, a bolus of 50 U/kg of heparin was given after deployment of the first coil. Patients also received a loading dose of 600 mg of clopidogrel intraprocedurally if a stent was used and were maintained on daily doses of 75 mg of clopidogrel and 81 mg of aspirin in the postoperative period. Angiographic follow-up (DSA or MRA) was scheduled at 6 months, 1 year, 2 years, and 5 years after treatment.

Results

Demographics and Aneurysm Characteristics

Of the 76 patients, 58 (76.3%) were women and 18 (23.7%) were men. The mean age in the series was 55.6 years, with a range of 28–83 years and a median of 57 years. Aneurysm size was 6.1 mm on average, with a range of 2–25 mm and a median of 6 mm. Of the 76 aneurysms, 54 (71.1%) were proximal and 22 (28.9%) were distal. Dissecting aneurysms accounted for 7.4% of proximal aneurysms (4 of 54) and 22.7% of distal aneurysms (5 of 22). Nineteen patients (25.0%) had at least 1 aneurysm at another location, and 4 patients (5.3%) had at least 2 aneurysms at other locations (Table 1). Most associated aneurysms were located in the anterior circulation (74%).
Sixty-one patients (80.3%) had sustained an SAH, and almost half of them (29 of 61) had poor Hunt and Hess grades (IV and V) at initial presentation. Hunt and Hess grades are summarized in Table 2.

**Endovascular Treatment**

Endovascular treatment failed in 3.7% of patients with proximal aneurysms (2 of 54) and 13.6% of those with distal aneurysms (3 of 22). The overall technical failure rate was 6.6%. The reasons for treatment failure were the following: failure to microcatheterize the aneurysm (2 distal aneurysms), failure to retain the coil within the aneurysm sac (1 distal aneurysm), failure to stabilize the microcatheter within the aneurysm (1 proximal aneurysm), and failure to deploy a stent due to tortuosity of the PICA (1 proximal aneurysm). All 5 patients were later successfully treated with microsurgical aneurysm clipping. In the remaining 71 patients, endovascular treatment consisted of selective aneurysm coiling in 60 patients (84.5%; including 4 with stent assistance and 4 with balloon assistance) and PICA sacrifice in 11 patients (15.5%). Specifically, a deconstructive procedure was necessary in 9.6% of proximal aneurysms (5 of 52) and 31.6% of distal aneurysms (6 of 19).

There were 9 (12.7%) overall procedure-related complications in the series: 6 (8.5%) new infarcts in PICA territory and 3 (4.2%) intraprocedural aneurysm ruptures (Table 3). Of these 6 infarcts, 2 were clinically silent, 3 caused only transient or mild morbidity (minor unilateral cerebellar infarcts), and 1 caused permanent morbidity due to bilateral involvement of the brainstem and cerebellum. Four (66.7%) of the 6 infarcts were anticipated due to deliberate occlusion of the PICA. The remaining 2 infarcts developed despite adequate flow in the PICA following selective aneurysm coiling. Of the 11 patients in whom the PICA was sacrificed, only 4 (36.4%) developed postoperative infarcts. The specific rates of procedure-related complications were 13.5% and 10.5% for proximal and distal aneurysms, respectively. Overall, the rate of procedure-related permanent morbidity was 2.8% (1 intraprocedural rupture and 1 infarct in the PICA territory). The rate of overall in-hospital mortality was 7.0% (4 of 57) among patients with SAH (Table 4).

**Clinical and Angiographic Outcome**

Of 57 patients presenting with SAH (excluding 4 patients with a failed procedure), hydrocephalus developed in 40 (70.2%) and required placement of a ventriculoperitoneal shunt in 26 (65%). Clinical deterioration caused by delayed cerebral ischemia was seen in 9 patients (15.8%). Seven patients had moderate to severe angiographic vasospasm and 2 patients had mild vasospasm. Four patients in this group developed cerebral infarction and 7 patients had a poor outcome (severe disability in 5 and death in 2).

Excluding 5 patients who had unsuccessful procedures and 4 patients who died in the hospital, clinical follow-up was available for 61 (91%) of 67 patients at a mean of 21 months (range 1–96 months). Of these 61 patients, 50 (82%) achieved a favorable outcome (moderate, mild, or no disability). Specifically, favorable outcomes were noted in 13 (93%) of 14 elective cases and 37 (78.7%) of 47 SAH cases (Table 5). Twelve (63.2%) of 19 patients

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**Fig. 1.** A and B: Digital subtraction angiograms (frontal [A] and lateral [B] views) showing a left-sided dysplastic 5-mm aneurysm arising from the distal PICA. C–F: The aneurysm was selectively treated with coiling with preservation of the patency of the distal PICA (frontal [C] and lateral [D] views) and remained occluded on the angiogram obtained at the 9-month follow-up (frontal [E] and lateral [F] views).
who presented with a poor clinical grade (Hunt and Hess grade IV or V) attained a good outcome (moderate, mild, or no disability) at follow-up.

At completion of the endovascular procedure, complete aneurysm occlusion (100%) was achieved in 63.4% of patients (45 of 71), near-complete occlusion (95%–100%) in 25.3% (18 of 71), and incomplete occlusion (<95%) in 11.3% (8 of 71). Excluding the 5 patients who had unsuccessful procedures and the 7 patients who died in the hospital or prior to their scheduled follow-up, angiographic follow-up (MRA or DSA) was available in 75% of patients (48 of 64). The reasons for missing angiographic follow-up in 16 patients were the following: patient severely disabled (n = 8), patient refused angiographic follow-up (n = 2), and patient lost to follow-up (n = 6). The mean follow-up time was 17.2 months, with a range of 6–60 months and a median of 11.5 months. At the last available angiographic follow-up, 11 patients (22.9%) had evidence of recurrence and 9 (18.8%) required further intervention (Table 6). Of these 9 patients, 7 underwent additional coiling and 2 underwent microsurgical clipping. Among the 7 patients who were re-treated with coils, 5 (71.4%) had a stable occlusion at follow-up (mean 15.2 months) while 2 (28.6%) developed a recurrence that required additional coiling. Re-treatment was uneventful in these patients, and no rebleeding or new neurological symptoms were noted during the follow-up period in this group. Recurrence and re-treatment rates were, respectively, 20% (7 of 35) and 17.1% (6 of 35) for proximal aneurysms compared with 30.8% (4 of 13) and 23.1% (3 of 13) for distal aneurysms. Of note, all 11 patients who had a recurrence at follow-up had been initially treated with selective aneurysm coiling. Accordingly, the rates of recurrence and re-treatment were, respectively, 26.8% (11 of 41) and 22% (9 of 41) for those aneurysms that were initially selectively coiled (Table 6). The highest recurrence rates were noted in selectively coiled distal PICA aneurysms (50%).

Only 1 patient in the series (1.4%) experienced re-bleeding after initial endovascular treatment. This was a 54-year-old man who initially presented with a Hunt and Hess Grade III SAH from a proximal PICA aneurysm that was selectively coiled (90% aneurysm occlusion). He experienced a rehemorrhage on postoperative Day 15, which left him severely disabled.

**Discussion**

Posterior inferior cerebellar artery aneurysms are uncommon. There is a paucity of data pertaining to the feasibility, safety, and efficacy of endovascular therapy in this aneurysm population. The long-term treatment durability in terms of recurrence, re-treatment, and rehemorrhage rates also remains unknown. We reviewed our experience with endovascular therapy in a large series of proximal and distal PICA aneurysms.

Most patients (80.3%) in the present series were
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with endovascular therapy, the authors noted that up to 50% of patients with poor clinical condition on admission made an excellent clinical recovery, a finding they attributed to their aggressive management of hydrocephalus as well as the minimally invasive nature of the endovascular approach. Similarly, in our study, 63.2% of patients who presented with a poor clinical grade (Hunt and Hess Grade IV or V) had a good outcome at the time of discharge. Thus, neurosurgeons should not refrain from offering treatment to those patients with PICA aneurysms presenting with poor clinical condition. Early endovascular aneurysm treatment and aggressive management of hydrocephalus and vasospasm appear to be key factors in promoting good patient outcomes.

Our results show that endovascular treatment of PICA aneurysms can be undertaken with a fairly high success rate, with the possibility of preserving parent artery patency in most patients. As such, we were able to successfully embolize PICA aneurysms in 93.4% of cases, with parent artery preservation in 90.4% of proximal lesions and 68.4% of distal lesions. These rates compare favorably with previously reported series. Peluso et al.24 treated 47 proximal PICA aneurysms and were able to achieve selective aneurysm occlusion in almost 76% of cases. Isokangas et al.12 reported their experience with endovascular treatment of 12 distal PICA aneurysms, achieving parent artery preservation in 4 patients with a technical failure rate of 16.7%. However, our study also highlights significant technical problems associated with endovascular treatment of PICA aneurysms, especially in those that arise distally on the vessel. This is largely due to the challenging anatomy of the PICA, namely its small caliber, tortuosity, and angulations, which precluded selective aneurysm catheterization in several cases. In some instances, even the PICA itself can be difficult to catheterize, especially when it courses inferiorly at an acute angle, and may require technically demanding procedures such as transcirculation approaches. Our study also shows that stenting and balloon remodeling can provide valuable assistance in complex and wide-necked proximal PICA aneurysms (8 cases in the present series). In fact, without these adjunctive techniques many patients would have undergone deconstructive procedures or would have probably been referred for open surgical treatment. Unfortunately, these techniques are currently inapplicable in distal aneurysms given the small caliber of the PICA and the mechanical limitations of available stents and balloons. Thus, in many patients with distal aneurysms,
the only available endovascular option is to occlude the aneurysm along with the PICA. This was the case for as many as 31.6% of distal aneurysms in the present series, which reflects the challenges associated with selective endovascular embolization of distal PICA lesions. The fact that many aneurysms arising from the distal PICA are dissecting in nature also explains the frequent need for deconstructive procedures. While selective coiling of dissecting aneurysms of the PICA may be feasible in some cases, we generally prefer parent artery trapping to avoid leaving the point of initial intimal tear untreated and minimize the subsequent risk of recanalization and rehemorrhage. Recently, we have used Onyx liquid embolic agent as a rapid and effective means of achieving obliteration of dissecting and/or pseudoaneurysms (Fig. 4). A key is to inject the liquid embolic agent just proximal to the aneurysm, allow filling of the aneurysm, and limit distal migration to just past the aneurysm neck.

Despite some technical challenges, our study shows that endovascular treatment of both proximal and distal PICA aneurysms has a favorable safety profile. Procedural complications occurred in 12.7% of cases, with most complications producing only transient or mild problems (and in some cases the complications were clinically silent). As such, the rate of permanent morbidity was as low as 2.8%. In contrast to previous series, the rate of intraprocedural aneurysm rupture was low in our hands (4.2%). Peluso et al. reported a strikingly high rate of intraprocedural rupture (19%) during embolization of proximal PICA aneurysms. Likewise, in a study by Bradac and Bergui that included 18 PICA aneurysms (12 proximal and 6 distal) treated by endovascular means, intraprocedural aneurysm ruptures occurred in up to 11% of cases. We believe that recent refinements to microcatheters and detachable coils as well as our institutional experience with aneurysm treatment were key factors in reducing the incidence of intraprocedural ruptures. Our study also confirms previous reports that proximal and distal trapping of the PICA causes only minimal morbidity. As such, PICA occlusion led to infarctions in only 36.4% of cases, none of which resulted in permanent morbidity. In fact, all infarctions were remarkably well tolerated (or even clinically silent) and involved only the cerebellum (sparring the brainstem). The anatomy of the PICA has been well described and accounts for these observations. The PICA supplies the posterolateral portion of the medulla oblongata through perforating arteries arising from its proximal segments, along with the cerebellar tonsils, vermis, and cerebellar hemispheres through terminal branches. Because perforating arteries form an anastomotic plexiform network at the surface of the medulla, the risk of brainstem ischemia with proximal PICA occlusion is thought to be low in appropriately selected patients, as corroborated by our study. Moreover, in some cases, the medulla is exclusively supplied by the anterior spinal artery and direct branches of the vertebral arteries (other than the PICA). On the other hand, collateral supply from the ipsilateral anterior inferior cerebellar

### Table 3: Procedure-related complications

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Aneurysm Size (mm)</th>
<th>Aneurysm Location</th>
<th>H &amp; H Grade</th>
<th>Procedure</th>
<th>Complication</th>
<th>Permanent Morbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>42, F</td>
<td>6</td>
<td>proximal</td>
<td>III</td>
<td>selective coiling</td>
<td>IOR</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>49, F</td>
<td>6.5</td>
<td>proximal</td>
<td>IV</td>
<td>selective coiling</td>
<td>bilat cerebellar &amp; brain-stem infarcts</td>
<td>yes (lat medullary syndrome)</td>
</tr>
<tr>
<td>3</td>
<td>63, M</td>
<td>8</td>
<td>proximal (dissecting)</td>
<td>IV</td>
<td>vessel occlusion</td>
<td>unilat cerebellar infarcts</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>42, F</td>
<td>3</td>
<td>proximal (dissecting)</td>
<td>I</td>
<td>vessel occlusion</td>
<td>unilat cerebellar infarcts</td>
<td>no</td>
</tr>
<tr>
<td>5</td>
<td>60, M</td>
<td>7</td>
<td>proximal</td>
<td>IV</td>
<td>selective coiling</td>
<td>unilat cerebellar infarcts</td>
<td>no</td>
</tr>
<tr>
<td>6</td>
<td>71, M</td>
<td>4</td>
<td>distal</td>
<td>I</td>
<td>vessel occlusion</td>
<td>unilat cerebellar infarcts</td>
<td>no</td>
</tr>
<tr>
<td>7</td>
<td>63, F</td>
<td>10</td>
<td>proximal</td>
<td>III</td>
<td>selective coiling</td>
<td>IOR</td>
<td>yes</td>
</tr>
<tr>
<td>8</td>
<td>59, M</td>
<td>6</td>
<td>distal</td>
<td>IV</td>
<td>vessel occlusion</td>
<td>unilat cerebellar infarcts</td>
<td>no</td>
</tr>
<tr>
<td>9</td>
<td>67, F</td>
<td>5</td>
<td>proximal</td>
<td>0</td>
<td>selective coiling</td>
<td>IOR</td>
<td>no</td>
</tr>
</tbody>
</table>

* H & H = Hunt and Hess; IOR = intraoperative rupture.

### Table 4: Causes of death in the series

<table>
<thead>
<tr>
<th>Age (yrs), Sex</th>
<th>Aneurysm Size (mm)</th>
<th>Aneurysm Location</th>
<th>H &amp; H Grade</th>
<th>Procedure</th>
<th>Procedural Complications</th>
<th>Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>67, F</td>
<td>8</td>
<td>proximal</td>
<td>IV</td>
<td>selective coiling</td>
<td>severe vasospasm w/ posterior circulation infarcts</td>
<td></td>
</tr>
<tr>
<td>50, F</td>
<td>2.5</td>
<td>proximal</td>
<td>IV</td>
<td>selective coiling</td>
<td>severe vasospasm w/ posterior circulation infarcts</td>
<td></td>
</tr>
<tr>
<td>60, M</td>
<td>7</td>
<td>proximal</td>
<td>IV</td>
<td>selective coiling</td>
<td>unilat cerebellar infarcts</td>
<td>severe, global hypoxic brain injury (from cardiac arrest)</td>
</tr>
<tr>
<td>71, F</td>
<td>5</td>
<td>proximal</td>
<td>III</td>
<td>selective coiling</td>
<td></td>
<td>septic shock</td>
</tr>
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</table>
Posterior inferior cerebellar artery aneurysms

TABLE 5: Glasgow Outcome Scale score at follow-up in patients presenting with SAH

<table>
<thead>
<tr>
<th>GOS Score</th>
<th>No. of Aneurysms (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>2 (4.3)</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>8 (17)</td>
</tr>
<tr>
<td>4</td>
<td>10 (21.3)</td>
</tr>
<tr>
<td>5</td>
<td>27 (57.4)</td>
</tr>
<tr>
<td>total</td>
<td>47</td>
</tr>
</tbody>
</table>

artery, superior cerebellar artery, or contralateral PICA appears also to be sufficient to prevent or limit the extent of cerebellar infarctions in many cases. Nevertheless, it is important to assess the presence and extent of collateral supply before considering parent vessel occlusion, as surgical intervention with bypass grafting remains a valuable option when collateral flow is insufficient.14,15,20,25 Overall, our study suggests that endovascular treatment of PICA aneurysms with or without vessel trapping can be performed with low morbidity.

The results of this study suggest that overall clinical outcomes with endovascular therapy are favorable in patients harboring PICA aneurysms, as 82% of all patients and 78.7% of those who sustained an SAH achieved a good outcome in the present series. These findings are in line with previous studies,3,5,19,21,24 as good outcomes with endovascular therapy were reported in 68% of patients by Mericle et al.,21 74% of patients (34 of 46) by Peluso et al.,24 and 100% of patients (22 of 22) by Lv et al.19 Collectively, these data strongly support the use of endovascular therapy in the treatment of ruptured and unruptured PICA aneurysms. Importantly, however, our study highlights a major limitation of endovascular treatment of PICA aneurysms, namely a high rate of aneurysm recanalization. As such, aneurysm recurrence and re-treatment rates were as high as 22.9% and 18.8%, respectively. Even more concerning are the alarming high rates of recurrence in selectively coiled aneurysms, reaching 21.2% in proximal aneurysms and as much as 50% in distal aneurysms. The only plausible explanation for the high rate of recanalization is the fact that many aneurysms are suboptimally packed (distal aneurysms in particular) to preserve the patency of the parent artery and also possibly to an underlying etiology of dissection for some distal aneurysms. Accordingly, only 63.4% of all aneurysms in our series were completely occluded following endovascular embolization. For these reasons, it is of utmost importance to obtain angiographic follow-up for PICA aneurysms in general and those treated with endosaccular coiling in particular (especially distal lesions). Our results contradict the disparate findings of Mericle et al.21 who were able to achieve excellent aneurysm occlusion in 100% of their patients (30 of 30) and reported no recurrences at follow-up (15 of 15). The small number of patients with available angiographic follow-up (15 of 30) in their series, as well as the short follow-up time (average of 9 months), could explain the apparent discrepancy with our results. Comparisons with other series also remain limited because few authors provided separate recurrence rates for selective aneurysm coiling. Regardless, at least in our experience, PICA aneurysms appear to have a high propensity to recur, especially when treated with endosaccular coiling. Despite this potential drawback, the rate of rehemorrhage was fairly low (1.4%) in this series, which proves that PICA aneurysms can be reliably secured with endovascular therapy.

Our results suggest that endovascular therapy has a favorable safety-efficacy profile in PICA aneurysms. However, the best treatment option in this patient population remains largely unknown. In fact, no studies have directly compared surgical and endovascular treatment of PICA aneurysms in terms of perioperative morbidity and patient outcomes. In a few comparative studies, PICA aneurysms were included in the larger heterogeneous group of vertebral or posterior circulation aneurysms.5,8,23 In short, these studies reported no significant difference in overall patient outcomes between the two treatment options, although a higher incidence of neurological complications was consistently found in surgical patients. Our study was not designed to identify the best treatment modality for PICA aneurysms. Nevertheless, morbidity rates and overall patient outcomes in our study compare favorably with surgical series.1,9 Based on our findings, we believe that endovascular therapy could be a reasonable first-line option for proximal PICA aneurysms. This is further corroborated by the challenges posed by surgical clipping of these aneurysms and the high incidence of postoperative lower cranial neuropathy with resultant dysphagia, diplopia, hoarseness, and aspiration pneumonia.1,9 On the other hand, our study suggests that endovascular therapy has a less favorable efficacy profile in distal PICA aneurysms particularly when treated with selective coiling, with significant technical challenges and high recurrence rates. When sufficiently distal, embolization with a liquid embolic agent of distal PICA aneurysms holds significant promise for treating these aneurysms. Because surgical treatment is usually straightforward and can be undertaken with little morbidity in these aneurysms,26 we believe that microsurgery remains an equally effective and valuable option in this subset of patients.

TABLE 6: Recurrence and re-treatment rates for PICA aneurysms

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rate (no. of patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Proximal Aneurysms</td>
</tr>
<tr>
<td>recurrence</td>
<td>20% (7 of 35)</td>
</tr>
<tr>
<td>re-treatment</td>
<td>17.1% (6 of 35)</td>
</tr>
</tbody>
</table>
This study has some limitations that stem primarily from its retrospective design and the heterogeneity of the study population. The absence of comparison with a surgical group also precludes any confident conclusion as to the best treatment modality in this setting. Despite these limitations, this study provides important data pertaining to the feasibility, safety, and efficacy of endovascular therapy in PICA aneurysms.

Conclusions

In this study, we investigated the feasibility, safety, and efficacy of endovascular therapy in the largest series of PICA aneurysms to date. We found that endovascular treatment can be undertaken with high success rates and low morbidity even with proximal or distal trapping of the parent vessel. Excellent patient outcomes with adequate protection against rehemorrhage were also achieved. However, our study highlights a serious limitation of endovascular therapy, namely a high recurrence rate after selective endosaccular coiling, especially in distal lesions. The importance of long-term angiographic follow-up after endosaccular coiling of PICA aneurysms cannot be overstressed. Future advances in microcatheters, embolic agents, stents, and techniques will undoubtedly further improve the feasibility, safety, and efficacy of endovascular therapy in PICA aneurysms.

Disclosure

Dr. Dumont is a consultant for ev3 and Stryker Neurovascular. Dr. Jabbour is a consultant for ev3, Codman Neurovascular, and Mizuho. Dr. Tjoumakaris is a consultant for Stryker Neurovascular. Dr. Gonzalez is a consultant for ev3.

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