Comparison of endovascular and microsurgical management of 208 basilar apex aneurysms

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OBJECTIVE The deep and difficult-to-reach location of basilar apex aneurysms, along with their location near critical adjacent perforating arteries, has rendered the perception that microsurgical treatment of these aneurysms is risky. As a result, these aneurysms are considered more suitable for treatment by endovascular intervention. The authors attempt to compare the immediate and long-term outcomes of microsurgery versus endovascular therapy for this aneurysm subtype.

METHODS A prospectively maintained database of 208 consecutive patients treated for basilar apex aneurysms between 2000 and 2012 was reviewed. In this group, 161 patients underwent endovascular treatment and 47 were managed microsurgically. The corresponding records were analyzed for presenting characteristics, postoperative complications, discharge status, and Glasgow Outcome Scale (GOS) scores up to 1 year after treatment and compared using chi-square and Student t-tests.

RESULTS Among these 208 aneurysms, 116 (56%) were ruptured, including 92 (57%) and 24 (51%) of the endovascularly and microsurgically managed aneurysms, respectively. The average Hunt and Hess grade was 2.4 (2.4 in the endovascular group and 2.2 in the microsurgical group; p = 0.472). Postoperative complications of cranial nerve deficits and hemiparesis were more common in patients treated microsurgically than endovascularly (55.3% vs 16.2%, p < 0.05; and 27.7% vs 10.6%, p < 0.05, respectively). However, aneurysm remnants and need for retreatment were more common in the endovascular than the microsurgical group (41.3% vs 2.3%, p < 0.05; and 10.6% vs 0.0%, p < 0.05, respectively). Stent placement significantly reduced the need for retreatment. Rehemorrhage rates and average GOS score at discharge and 1 year after treatment were not statistically different between the two treatment groups.

CONCLUSIONS Patients with basilar apex aneurysms were significantly more likely to be treated via endovascular management, but compared with those treated microsurgically, they had higher rates of recurrence and need for retreatment. The current study did not detect an overall difference in outcomes at discharge and 1 year after either treatment modality. Therefore, in a select group of patients, microsurgical treatment continues to play an important role.

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KEY WORDS basilar apex; aneurysm; endovascular; microsurgery; clip ligation; outcomes; vascular disorders

Basilar apex aneurysms account for approximately 5%–8% of all cerebral aneurysms.5,7 They present numerous microsurgical challenges because of their deep and difficult-to-reach location, along with the presence of critical adjacent cerebrovascular structures, including perforating arteries.3,6 Lack of microsurgical expertise has further decreased the use of open techniques for clip ligation of these aneurysms. Morbidity and mortality for treatment of ruptured and unruptured aneurysms of this type are as high as 30.6% and 17.5%, respectively.16 As a result, there has been a rapid transition to endovascular management for aneurysms at this location.10

Unfortunately, recent studies have reported recurrence rates as high as 41%, with 26% needing retreatment during
long-term follow-up after endovascular treatment. Endovascular stent placement has been used to make endovascular treatment a viable option in wide-necked aneurysms and allow for increased packing densities. In this paper we examine the outcomes of patients treated at our institution and the need for retreatment of basilar apex aneurysms based on their hemorrhage status, other presenting data, and treatment modality. Importantly, the unique feature of this report is that it reflects the results of a balanced, multidisciplinary, and collaborative approach among microsurgeons and endovascular interventionists toward these aneurysms.

**Methods**

**Patient Population**

Following approval of the study from the Indiana University IRB, we performed a retrospective review of all patients with intracranial aneurysms whose records have been prospectively maintained in our institution’s database. This database includes information on all patients since 1977 presenting with intracranial aneurysms at either of two tertiary care hospitals in Indianapolis, Indiana: IU Health Methodist Hospital, and St. Vincent Hospital. A cohort of 208 consecutive patients was identified who underwent treatment for their basilar apex aneurysms from January 2000 to December 2012. We believe this time period allows a good comparison of relatively uniform and recent endovascular and microsurgical techniques. The diagnosis of a basilar apex aneurysm was made based on CT angiography (CTA), MR angiography (MRA), or digital subtraction angiography (DSA). If treatment was necessary, the patient was followed through hospitalization and follow-up outpatient visits. Patients who harbored an untreated basilar apex aneurysm or an aneurysm associated with an arteriovenous malformation were excluded from this study.

In this group, 23% (n = 47) of the patients underwent microsurgical clip ligation, and 77% (n = 161) received endovascular treatment for their aneurysms. An interventional neuroradiologist and a cerebrovascular neurosurgeon reviewed all cases before definitive treatment was rendered. Endovascular embolization was usually preferred over microsurgical treatment if the morphology of the aneurysm was appropriate for endovascular treatment, especially if the patient was older than 50 years of age. The criteria for application of the microsurgical approach included: an expectation that the treating physician would not be able to access or adequately place stable coils within the aneurysm; young age of the patient; anterior projection of the aneurysm; and unruptured status of the aneurysm. Essentially, we practiced the philosophy of “endovascular-first” in most patients, and especially those older than 50 years of age.

Data were recorded from admission until hospital discharge, death, or loss to follow-up. Presentation characteristics included patient age, sex, race, comorbidities, presenting symptoms, Hunt and Hess score (HH) on admission, number of aneurysms, aneurysm size (mm), and Fisher grade. Complications studied included medical (cardiac event, deep vein thrombosis, pulmonary embolus, pulmonary edema, or respiratory insufficiency), rehemorrhage, seizure, hydrocephalus, cerebral vasospasm, radiographic infarction, clinical stroke, cranial nerve deficits, paresis, and need for tracheostomy, permanent CSF diversion, or percutaneous endoscopic gastrostomy. Outcomes recorded include death before hospital discharge; patient Glasgow Outcome Scale (GOS) score at discharge, 6 months, and 1 year after treatment; and the occurrence of remnant or recurrent aneurysm neck, coil compaction, and need for retreatment. The method of embolization (coiling alone or stent-assisted coiling) and surgical approach (pterional or subtemporal) were recorded for all endovascular and microsurgical cases.

**Microsurgical Treatment**

From 2000 to 2012, we used relatively uniform microsurgical techniques for these cases. To be considered for microsurgical treatment, the aneurysm had to be within 5 mm above or below the posterior clinoid and point superiorly or anteriorly. Patients undergoing microsurgery underwent either a pterional craniotomy and generous exposure of their aneurysm following Sylvian fissure dissection, or a middle fossa craniotomy with subtemporal exposure of the basilar apex. A pterional craniotomy was used in most patients based on the preference of the involved surgeons. The additional orbitozygomatic osteotomy was rarely used, and mainly for “high-riding” aneurysms. Temporary occlusion of the basilar artery was obtained using a temporary clip or, occasionally, endovascular balloon occlusion when needed (Fig. 1). Etomidate (0.4 mg/kg) was administered 2 minutes before temporary clip application or inflation of the balloon, and repeated (0.2 mg/kg) every 20 minutes during the period of temporary occlusion.

In rare instances, hypothermic arrest was used (4%, n = 2). In most cases, straight fenestrated and/or simple straight clips were deployed. Careful microsurgical inspection of the origin of the basilar apex and the aneurysm neck was performed to avoid any significant compromise in the origin of the posterior cerebral arteries or perforator occlusion after clip placement (Fig. 2). Most patients underwent intraoperative blood flow micro-Doppler ultrasonography to ensure blood flow within the basilar apex and posterior cerebral artery after clip placement. Since 2007, we have used intraoperative indocyanine green or fluorescein videoangiography for qualitative assessment of blood flow within the parent, branching, and perforating vessels and to evaluate aneurysm obliteration. Select aneurysms underwent intraoperative cerebral DSA.

Patients were evaluated at follow-up by the treating physician at 3 months, 6 months, and 1 year following treatment, and then periodically based on the preference of the physician. Physical examinations and clinical outcomes were determined by the treating physician. Typical follow-up imaging studies (DSA, CTA, or MRA) were obtained immediately postoperatively and at 1-year after treatment followed by periodic imaging. Interpretation of the imaging studies was performed by board-certified neuroradiologists.
Endovascular Treatment

All endovascular procedures were performed with the patient under general anesthesia. Microcatheter, coil, and stent (when indicated) placements were performed with DSA and roadmap technology. For elective cases, patients were given a 5000-unit bolus of heparin after vascular access was obtained.

Stents were used in the setting of dome-to-neck ratios less than 1.5 and aneurysm neck diameters greater than 4 mm, and most typically in the elective setting. When a stent was anticipated, patients were administered daily doses of 325 mg of acetylsalicylic acid (ASA) and 75 mg of clopidogrel for 5 days prior to the procedure. Alternatively, 325 mg of ASA and 600 mg of clopidogrel were given within 24 hours prior to treatment.
Since 2010, a VerifyNow P2Y12 (Accumetrics) point-of-care test has been used by our practice. If patients were found to have a subtherapeutic level on their current regimen, they were given an extra 150-mg dose of clopidogrel. If they still had a subtherapeutic level the following day, patients were switched to prasugrel 10 mg daily. For patients who presented with aneurysmal subarachnoid hemorrhage (SAH), heparin was withheld until the dome or site of the anticipated rupture was protected with coils. Although balloon reconstruction was infrequently required, it was preferred over the use of antipatelet agents and stent placement during the acute aneurysmal SAH hemorrhage period. All patients underwent postoperative DSA, CTA, or MRA for confirmation of aneurysm obliteration.

**Statistical Analysis**

Minitab (version 16, Minitab Inc.) was used for statistical analyses. Pearson’s chi-square test of independence ($\chi^2$) and Student t-test were used to examine the main effects of aneurysm management (endovascular, microsurgical) on presentation characteristics, postoperative complications, and outcomes. Chi-square and t-tests also were used to compare coiling alone versus stent-assisted coiling, as well as periternal versus subtemporal microsurgical approaches. Probability values associated with Fisher’s exact test were reported for $2 \times 2 \chi^2$ tables. Yates correction for continuity was used if expected frequencies were less than 5 in $2 \times 2 \chi^2$ tables.

**Results**

In the database of 2529 patients, 208 consecutive basilar apex aneurysms were studied. Among these 208 patients, 161 received endovascular intervention and 47 underwent microsurgery (Table 1). The average patient ages were 54.1 and 46.8 years ($p < 0.05$) for those who underwent endovascular and surgical clip ligation, respectively. Sex, race, hypertension, smoking, hyperlipidemia, diabetes, and family history of aneurysms were not statistically different between the treatment groups (Table 1). Among all patients in both groups, 116 (56%) presented with SAH with an average HH grade of 2.4, average Fisher grade of 3.2, and average aneurysm size of 8.3 mm (Table 1). Importantly, evidence of SAH, Fisher grade, and aneurysm size did not significantly differ between the 2 treatment groups.

We analyzed postoperative complications based on the mode of treatment as shown in Table 2. Duration of hospital stay for all patients was 12.9 ± 12.1 days; there was no statistical difference between the 2 treatment groups. Cranial nerve deficits and mono- or hemiparesis were more common in the microsurgical group: 16.2% versus 12.9%. There were 3 in the endovascular group (Table 2).

### TABLE 1. Presentation characteristics by treatment type

<table>
<thead>
<tr>
<th>Variable</th>
<th>Endovascular</th>
<th>Microsurgical</th>
<th>Total</th>
<th>Statistic</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients (%)</td>
<td>161 (77.4)</td>
<td>47 (22.6)</td>
<td>208 (100.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yrs) Mean (SD)</td>
<td>54.1 (10.3)</td>
<td>46.8 (8.0)</td>
<td>52.4 (10.3)</td>
<td>$t = -5.09$</td>
<td>0.000</td>
</tr>
<tr>
<td>Range</td>
<td>31–78</td>
<td>32–64</td>
<td>31–78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% female</td>
<td>71.4</td>
<td>76.6</td>
<td>72.6</td>
<td>$\chi^2 = 0.488$</td>
<td>0.579</td>
</tr>
<tr>
<td>% Caucasian</td>
<td>97.5</td>
<td>100.0</td>
<td>98.1</td>
<td>$\chi^2 = 0.223$</td>
<td>0.637</td>
</tr>
<tr>
<td>% family aneurysm history</td>
<td>11.8</td>
<td>6.4</td>
<td>10.6</td>
<td>$\chi^2 = 1.129$</td>
<td>0.420</td>
</tr>
<tr>
<td>% hypertension</td>
<td>41.6</td>
<td>40.4</td>
<td>41.4</td>
<td>$\chi^2 = 0.021$</td>
<td>1.000</td>
</tr>
<tr>
<td>% smoking</td>
<td>70.2</td>
<td>66.0</td>
<td>69.2</td>
<td>$\chi^2 = 0.305$</td>
<td>0.593</td>
</tr>
<tr>
<td>% hyperlipidemia</td>
<td>13.7</td>
<td>10.6</td>
<td>13.0</td>
<td>$\chi^2 = 0.295$</td>
<td>0.805</td>
</tr>
<tr>
<td>% diabetes mellitus</td>
<td>5.6</td>
<td>8.5</td>
<td>6.3</td>
<td>$\chi^2 = 0.530$</td>
<td>0.496</td>
</tr>
<tr>
<td>% symptomatic</td>
<td>3.1</td>
<td>2.1</td>
<td>2.9</td>
<td>$\chi^2 = 0.124$</td>
<td>1.000</td>
</tr>
<tr>
<td>% ruptured</td>
<td>57.5</td>
<td>51.1</td>
<td>56.0</td>
<td>$\chi^2 = 0.611$</td>
<td>0.504</td>
</tr>
<tr>
<td>% SAH from another source</td>
<td>1.9</td>
<td>0.0</td>
<td>1.5</td>
<td>$\chi^2 = 0.063$</td>
<td>0.802</td>
</tr>
<tr>
<td>Mean (SD) admission HH grade*</td>
<td>2.4 (1.3)</td>
<td>2.2 (1.4)</td>
<td>2.4 (1.3)</td>
<td>$t = -0.73$</td>
<td>0.472</td>
</tr>
<tr>
<td>Mean (SD) Fisher grade†</td>
<td>3.2 (0.8)</td>
<td>3.2 (0.7)</td>
<td>3.2 (0.8)</td>
<td>$t = -0.41$</td>
<td>0.684</td>
</tr>
<tr>
<td>Mean (SD) no. of aneurysms</td>
<td>1.4 (0.8)</td>
<td>1.4 (0.8)</td>
<td>1.4 (0.7)</td>
<td>$t = 0.60$</td>
<td>0.550</td>
</tr>
<tr>
<td>Mean (SD) basilar tip aneurysm size in mm</td>
<td>8.2 (4.8)</td>
<td>8.6 (5.0)</td>
<td>8.3 (4.8)</td>
<td>$t = 0.38$</td>
<td>0.709</td>
</tr>
</tbody>
</table>

Boldface type indicates statistical significance.

* Ruptured cases only.
† Ruptured aneurysms are specific to the basilar apex, whereas SAH cases refer to aneurysms from another source.
patient who presented with HH Grade III suffered from an intraprocedural rehemorrhage following placement of 2 coils. Protamine was immediately administered and a follow-up angiogram demonstrated aneurysm occlusion. This patient was also discharged with a GOS score of 3.

As shown in Table 3, there was no statistically significant difference in mean GOS score at discharge or 1 year after either treatment method (4.1 ± 1.1, p = 0.287, and 4.6 ± 0.7, p = 0.173, respectively). The incidence rate of mortality before discharge was 4.8%, unrelated to the mode of treatment. Aneurysmal remnant (41.3% vs 2.3%, respectively; p < 0.05), recurrence (17.5% vs 0.0%, respectively; p = 0.001), and retreatment (10.6 vs 0.0, respectively; p = 0.015) were more common in the endovascular group. The average follow-up duration was 31.6 ± 35.7 months and 52.5 ± 43.5 months for endovascular (143/161 patients) and microsurgical (43/47 patients) cases, respectively.

Outcomes were further categorized and analyzed by treatment in the ruptured and unruptured settings (Table 3). There continued to be no statistical difference in GOS score at discharge or 1 year for either set of data. Remnants were significantly more common for aneurysms treated with endovascular therapies in the ruptured (46% vs 4%, p = 0.0001) as well as unruptured circumstances (34% vs 0%, p = 0.001). Recurrence rates were similarly noted to be higher in the endovascular group (ruptured 17% vs 0%, p = 0.036; unruptured 18% vs 0%, p = 0.057).

Endovascular Management and Need for Retreatment

An analysis of the 17 patients (10.6%) who were retreated after their initial endovascular intervention is shown in Table 4. Of these 17 patients, 4 (23.5%) required a second retreatment. Following their first retreatment, 8 (47%) demonstrated a remnant. Following the second retreatment, 2 (50%) harbored a persistent remnant. Five patients had their first retreatment during the same hospitalization as their initial treatment. All 5 of these patients had initially presented with SAH. The average time interval between the first and second treatments was longer than between the second and third treatments (15.6 vs 9.6 months, respectively). The average contrast-filling size at retreatment was 6.8 ± 3.9 mm and 5.3 ± 1.3 mm for the first and second retreatments, respectively.

For the first retreatment, 9 patients (53%) underwent intervention via stent-coiling, whereas 3 (75%) of the 4 with a second retreatment required stent-coiling. Retreatments were not without risk, as 6% (n = 1) of the patients developed clinical and radiographic cerebral vascular accidents. The average GOS score from discharge through 1-year follow-up was favorable for both groups, ranging from 4.7 to 4.9.

The methods of endovascular embolization of the aneurysms of patients in our study are shown in Table 5. Three of the initial 161 aneurysms were treated with balloon assistance. Because the number of these patients was low, they were grouped into the coiling-alone category. In total, there were 151 coil embolization–alone and 31 stent-assisted coil embolization procedures. A higher percentage of coil embolization–alone cases was associated with SAH (58.3% vs 19.4%, p = 0.000). There was no statistical difference between the 2 groups except in the incidence of recurrences requiring a subsequent treatment. Follow-up of initial endovascularly managed aneurysms found a 17.5% recurrence rate. A second recurrence was found in 63% of the initially coil embolized–alone aneurysms versus none of the stent-assisted coil embolized aneurysms (p = 0.009).

When we examined the rates of retreatment between
coil embolization cases with or without stent-assistance for the initial treatment, there did not appear to be a significant difference (11.9 vs 9.7%, respectively; p = 1.000). Of note, the radiographic infarct and clinical stroke rates were nearly double when a stent was required; however, this difference did not appear to be statistically significant.

**Microsurgical Approach**

Of the 47 microsurgically managed basilar apex aneurysms, 24 were performed with a pterional craniotomy and 23 with a subtemporal approach (Table 6). There were very few differences between these 2 groups. Right-side approaches were preferred, with only 4 of the 47 procedures performed from the left.

Hypothermic cardiac arrest was used in 2 (4.3%) of the operations. Intraoperative angiography was routinely used in 98%. Temporary clip ligation was more commonly used with the pterional approach (81% vs 30%, respectively; p = 0.001), whereas temporary balloon occlusion was slightly more common when using the subtemporal approach (14.3% vs 30.4%, respectively; p = 0.287). Although 78% (n = 17) had oculomotor nerve palsies following a subtemporal approach, only 29% (n = 7) had similar deficits following a pterional approach (p = 0.001). Radiographic and clinical evidence of stroke were found in 8 (17.0%) and 7 (14.9%) of microsurgically managed patients, respectively, without a significant difference between the 2 approaches. Although GOS score at discharge was better with a pterional approach (4.3 vs 3.6, respectively; p = 0.039), this statistical significance was lost at 1 year.

**Distribution of Procedures**

The number of endovascular and microsurgical procedures for basilar apex aneurysms over time is shown in Fig. 3, and demonstrates that although a variable number of patients with basilar apex aneurysms presented each year, there was an increasing tendency to treat these aneurysms endovascularly. Figure 4 shows the total number of aneurysms managed during the same period (2000–2012) at our institution. There is a relative decline in the use of microsurgical therapy with a significant increase in the use of endovascular modalities. During this period, the number of ruptured aneurysms that did not receive an interven-

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**TABLE 3. Outcomes by treatment type**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Endovascular</th>
<th>Surgical</th>
<th>Total</th>
<th>Statistic</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall outcome</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of patients (%)</td>
<td>161 (77.4)</td>
<td>47 (22.6)</td>
<td>208 (100.0)</td>
<td>t = −1.07</td>
<td>0.287</td>
</tr>
<tr>
<td>Mean (SD) GOS score at discharge</td>
<td>4.1 (1.2)</td>
<td>3.9 (1.1)</td>
<td>4.1 (1.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD) GOS score at 1 yr</td>
<td>4.7 (0.6)</td>
<td>4.4 (0.8)</td>
<td>4.6 (0.7)</td>
<td>t = −1.34</td>
<td>0.173</td>
</tr>
<tr>
<td>% mortality prior to discharge*</td>
<td>5.6</td>
<td>2.1</td>
<td>4.8</td>
<td>χ² = 0.953</td>
<td>0.462</td>
</tr>
<tr>
<td>% resulting in a remnant</td>
<td>41.3 (59/143)</td>
<td>2.3 (1/43)</td>
<td>32.3 (60/186)</td>
<td>χ² = 22.932</td>
<td>0.000</td>
</tr>
<tr>
<td>% resulting in recurrence</td>
<td>17.5 (25/143)</td>
<td>0.0 (0/43)</td>
<td>13.4 (25/186)</td>
<td>χ² = 8.685</td>
<td>0.001</td>
</tr>
<tr>
<td>Mean (SD) time from treatment to latest follow-up in days†</td>
<td>949.3 (1072.4)</td>
<td>1574.2 (1304.6)</td>
<td>1104.6 (1162.3)</td>
<td>t = 2.77</td>
<td>0.007</td>
</tr>
</tbody>
</table>

| Ruptured aneurysms             |              |          |         |           |         |
| No. of patients (%)            | 93 (79.5)    | 24 (20.5)| 117 (100.0) | t = −0.94 | 0.352   |
| Mean (SD) GOS at discharge     | 3.8 (1.2)    | 3.5 (1.2)| 3.7 (1.2) | t = −0.77 | 0.456   |
| Mean (SD) GOS at 1 yr          | 4.5 (0.7)    | 4.3 (0.9)| 4.5 (0.7) |           |         |
| % mortality prior to discharge* | 7.5          | 4.2      | 6.8     | χ² = 0.338 | 1.000   |
| % resulting in a remnant       | 46.3 (38/82) | 4.4 (1/23)| 37.1 (39/105)| χ² = 13.567 | 0.0001   |
| % resulting in recurrence      | 17.1 (14/82) | 0.0 (0/23)| 13.3 (14/105)| χ² = 4.531 | 0.036   |
| Mean (SD) time from treatment to latest follow-up in days† | 861.0 (983.0) | 1499.0 (1128.0)| 1024.0 (1053.0)| t = 2.42 | 0.021   |

| Unruptured aneurysms           |              |          |         |           |         |
| No. of patients (%)            | 68 (74.7)    | 23 (25.3)| 91 (100.0) |           |         |
| Mean (SD) GOS at discharge     | 4.6 (0.8)    | 4.4 (0.7)| 4.6 (0.8) | t = −1.42 | 0.162   |
| Mean (SD) GOS at 1 yr          | 4.9 (0.4)    | 4.5 (0.7)| 4.8 (0.5) | t = −1.50 | 0.160   |
| % mortality prior to discharge* | 2.9          | 0.0      | 2.2     | †         | †       |
| % resulting in a remnant       | 34.4 (21/61) | 0.0 (0/20)| 25.9 (21/81)| χ² = 9.295 | 0.001   |
| % resulting in recurrence      | 18.0 (11/61) | 0.0 (0/20)| 13.6 (11/81)| χ² = 4.173 | 0.057   |
| Mean (SD) time from treatment to latest follow-up in days† | 1052.0 (1169.0) | 1670.0 (1530.0)| 1201.0 (1282.0)| t = 1.57 | 0.129   |

* Boldface type indicates statistical significance.
* No additional patients had died at latest follow-up.
† Calculated as follows: date of last follow-up office visit − initial (index) treatment admission date.
‡ Chi-square test invalid because expected frequencies were < 1, or < 5 in 20% of cells.
TABLE 4. Retreated endovascular cases

<table>
<thead>
<tr>
<th>Variable</th>
<th>Retreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First</td>
</tr>
<tr>
<td>No. of patients/aneurysms (%)</td>
<td>17</td>
</tr>
<tr>
<td>% ruptured prior to retreatment</td>
<td>5.9</td>
</tr>
<tr>
<td>% recurrent following retreatment</td>
<td>29.4</td>
</tr>
<tr>
<td>% remnant following retreatment</td>
<td>47.1</td>
</tr>
<tr>
<td>Mean (SD) time between treatments in days*</td>
<td>479 (602)</td>
</tr>
<tr>
<td>No. treated during same hospitalization for previous treatment (%)</td>
<td>5 (29.4)</td>
</tr>
<tr>
<td>Mean (SD) aneurysm size at retreatment in mm</td>
<td>6.8 (3.9)</td>
</tr>
<tr>
<td>% stent assisted</td>
<td>52.9</td>
</tr>
<tr>
<td>% coiling alone</td>
<td>47.1</td>
</tr>
<tr>
<td>% vasospasm</td>
<td>5.9</td>
</tr>
<tr>
<td>% radiographic infarction</td>
<td>5.9</td>
</tr>
<tr>
<td>% clinical stroke</td>
<td>5.9</td>
</tr>
<tr>
<td>Mean (SD) GOS score at discharge</td>
<td>4.7 (0.7)</td>
</tr>
<tr>
<td>Mean (SD) GOS at 1 yr</td>
<td>4.9 (0.3)</td>
</tr>
<tr>
<td>Mean (SD) time from retreatment to latest follow-up in days†</td>
<td>914 (895)</td>
</tr>
</tbody>
</table>

* Calculated as follows: retreatment admission date – previous treatment admission date.
† Calculated as follows: date of latest follow-up office visit – previous treatment admission date.

Endovascular Management

Endovascular therapy has continued to play an ever-increasing and important role in the management of basilar apex aneurysms.21,22 The treatment trend at our institution is shown in Fig. 3. The treatment method most commonly used was endovascular coiling without stent assistance (83% of the endovascular cases). This is certainly more ideal with a ruptured aneurysm because antiplatelet agents are not needed preoperatively. The placement of an external ventricular drain and/or ventriculoperitoneal shunting is less risky when these agents have not been administered.

One of the challenges with endovascular therapy is the risk of aneurysm recurrence, which was first noted by Mericle et al. in 1998.23 Recurrence of 5% or more of the initial aneurysm volume has been reported in 11% and 22% of patients, with retreatment rates around 4.9%.21,22 Recently, Chalouhi et al.4 investigated long-term follow-up of completely coiled aneurysms and reported recurrence rates as high as 41% with a need for retreatment in 26%. Complication rates are typically low, but can be as high as 12.5%.22

An alternative strategy is balloon-assisted coiling of basilar apex aneurysms.21,29,31 Although this modality can facilitate more dense packing of wider-necked aneurysms, it does not require antiplatelet agents and can be used with patients with SAH. However, it requires either a larger base catheter or two access vessels (contralateral vertebral or one of the posterior communicating arteries). It also requires temporary flow arrest through the basilar apex and one of the posterior cerebral arteries. It is also possible that bilateral posterior cerebral arteries, superior cerebellar arteries, and the perforating vessels may need to be temporarily occluded. Despite these precautions and potential associated risks, balloon assistance has been shown to in-
crease the rates of occlusion of wide-necked aneurysms, during both the initial intervention and at follow-up.31

Stent-assisted coiling is a third alternative for endovascular management of wide-based basilar apex aneurysms. It requires antiplatelet agents varying from a daily ASA to dual antiplatelet agents, and the patient should be taking these agents at a therapeutic level.15 Either closed33,34 or open-cell12 stents may be used, and each has its own drawbacks and benefits. Other similar techniques, such as the balloon-stenting technique,33 or Y-stenting,9 and waffle-cone embolization,26 can be used to help reduce recurrence rates; these techniques were used with the patients in our study when appropriate. Our experience has shown that the use of stents reduces the incidence of recurrence, and stents were often used in the treatment of recurrent aneurysms to facilitate dense coil packing. The significant reduction in hospital length of stay for our patients who underwent stent-assisted coil embolization is related to the fact that the majority of these patients underwent elective procedures (67.7%), in contrast to those who underwent coil embolization alone (36.9%, p = 0.002).

### Comparison of Endovascular and Microsurgical Management

Whereas at the beginning of this review there was similarity in the volume of cases treated by means of endovascular and microsurgical modalities, endovascular treatment quickly became the modality of choice. If the neurointerventionalist believed a coil could remain in the sac comfortably with or without balloon remodeling in the ruptured setting, or with the use of a stent in the elective setting, endovascular treatment was pursued. While this was initially the treatment philosophy for patients 50 years of age and older, this practice spread over time to all basilar apex aneurysms. Even by the end of the study, microneurointerventionalist treatment quickly became the modality of choice. If the neurointerventionalist believed a coil could remain in the sac comfortably with or without balloon remodeling in the ruptured setting, or with the use of a stent in the elective setting, endovascular treatment was pursued. While this was initially the treatment philosophy for patients 50 years of age and older, this practice spread over time to all basilar apex aneurysms. Even by the end of the study, microneurosurgical consideration was pursued in patients if placement of stable coils could not be achieved, if the patient was young (< 50 years old), if there was anterior projection of the aneurysm, and if the aneurysm was unruptured.

We found a statistical difference only in patients' ages between the endovascular and microsurgical treatment groups; the latter were younger on presentation. In terms

### Table 5: Endovascular treatments by type of embolization

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coiling Alone</th>
<th>Stent-Assisted Coiling</th>
<th>Statistic</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients/aneurysms (%)</td>
<td>151 (83.0)</td>
<td>31 (17.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of all aneurysms that ruptured prior to treatment</td>
<td>58.3 (88/151)</td>
<td>19.4 (6/31)</td>
<td>$\chi^2 = 15.603$</td>
<td>0.000</td>
</tr>
<tr>
<td>% of index treatments that ruptured prior to first treatment</td>
<td>62.0 (88/142)</td>
<td>26.3 (5/19)</td>
<td>$\chi^2 = 8.733$</td>
<td>0.005</td>
</tr>
<tr>
<td>% of first retreatments that ruptured prior to second treatment</td>
<td>0.0 (0/8)</td>
<td>11.1 (1/9)</td>
<td>$\chi^2 = 0.017$</td>
<td>0.896</td>
</tr>
<tr>
<td>% of all treatments resulting in a remnant</td>
<td>42.8 (59/138)</td>
<td>38.5 (10/26)</td>
<td>$\chi^2 = 0.165$</td>
<td>0.629</td>
</tr>
<tr>
<td>% of index treatments resulting in a remnant</td>
<td>42.6 (55/129)</td>
<td>28.6 (4/14)</td>
<td>$\chi^2 = 1.031$</td>
<td>0.398</td>
</tr>
<tr>
<td>% of first retreatments resulting in a remnant</td>
<td>37.5 (3/8)</td>
<td>55.6 (5/9)</td>
<td>$\chi^2 = 0.554$</td>
<td>0.638</td>
</tr>
<tr>
<td>% of second retreatments resulting in a remnant</td>
<td>100.0 (1/1)</td>
<td>33.3 (1/3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of all treatments that recurred</td>
<td>20.3 (28/138)</td>
<td>7.7 (2/26)</td>
<td>$\chi^2 = 2.323$</td>
<td>0.170</td>
</tr>
<tr>
<td>% of index treatments that recurred</td>
<td>17.8 (23/129)</td>
<td>14.3 (2/14)</td>
<td>$\chi^2 = 0.110$</td>
<td>1.000</td>
</tr>
<tr>
<td>% of first retreatments that recurred</td>
<td>62.5 (5/8)</td>
<td>0.0 (0/9)</td>
<td>$\chi^2 = 7.969$</td>
<td>0.009</td>
</tr>
<tr>
<td>% of second retreatments that recurred</td>
<td>0.0 (0/1)</td>
<td>0.0 (0/3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of all treatments requiring retreatment</td>
<td>12.6 (19/151)</td>
<td>9.7 (3/31)</td>
<td>$\chi^2 = 1.27$</td>
<td>1.000</td>
</tr>
<tr>
<td>% of index treatments requiring retreatment</td>
<td>11.3 (16/142)</td>
<td>5.3 (1/19)</td>
<td>$\chi^2 = 0.640$</td>
<td>0.398</td>
</tr>
<tr>
<td>% of first retreatments requiring second retreatment</td>
<td>37.5 (3/8)</td>
<td>11.1 (1/9)</td>
<td>$\chi^2 = 1.639$</td>
<td>0.294</td>
</tr>
<tr>
<td>% of second retreatments requiring third retreatment</td>
<td>0.0 (0/1)</td>
<td>0.0 (0/3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD) HH score upon admission (ruptured cases only)</td>
<td>2.4 (1.3)</td>
<td>2.2 (1.8)</td>
<td>t = 0.26</td>
<td>0.809</td>
</tr>
<tr>
<td>Average (SD) length of inpatient stay in days</td>
<td>12.9 (11.7)</td>
<td>9.1 (11.0)</td>
<td>t = 1.72</td>
<td>0.092</td>
</tr>
<tr>
<td>% vasospasm</td>
<td>15.2</td>
<td>12.9</td>
<td>$\chi^2 = 0.110$</td>
<td>1.000</td>
</tr>
<tr>
<td>% radiographic infarction</td>
<td>10.6</td>
<td>21.9</td>
<td>$\chi^2 = 0.140$</td>
<td>0.753</td>
</tr>
<tr>
<td>% clinical stroke</td>
<td>9.9</td>
<td>16.1</td>
<td>$\chi^2 = 1.009$</td>
<td>0.634</td>
</tr>
<tr>
<td>Mean (SD) GOS at discharge</td>
<td>4.2 (1.1)</td>
<td>4.2 (1.3)</td>
<td>t = 0.14</td>
<td>0.892</td>
</tr>
<tr>
<td>Mean (SD) GOS at 6 mos</td>
<td>4.6 (0.6)</td>
<td>4.5 (0.7)</td>
<td>t = 0.61</td>
<td>0.547</td>
</tr>
<tr>
<td>Mean (SD) GOS at 1 yr</td>
<td>4.7 (0.6)</td>
<td>4.7 (0.6)</td>
<td>t = 0.14</td>
<td>0.893</td>
</tr>
<tr>
<td>Mean (SD) time from index treatment to latest follow-up in days‡</td>
<td>1042.8 (1136.1)</td>
<td>797.4 (963.5)</td>
<td>t = 1.14</td>
<td>0.262</td>
</tr>
</tbody>
</table>

Boldface type indicates statistical significance.

*Coiling-alone treatments consisted of 142 index treatments, 8 first retreatments, and 1 second retreatment (N = 151). Stent-assisted coiling treatments consisted of 19 index treatments, 9 first retreatments, and 3 second retreatments (N = 31).

† Chi-square test invalid because expected frequencies were < 1, or < 5 in 20% of cells.

‡ Calculated as follows: date of latest follow-up office visit − initial (index) treatment admission date.
of perioperative results, cranial nerve deficits were more frequent in the microsurgical group. Many of the post-treatment deficits were temporary and improved with rehabilitation. Despite the fact that these early postoperative deficits were more common in the microsurgical group, the final GOS results were not statistically different between the groups. When differentiating between treatment groups based on rupture status, the GOS score was found to be similar between the groups. This could in part be due to a lack of sensitivity of the GOS in measuring more subtle neuropsychological outcomes. Future studies need to consider this as an important measure for outcomes.

Remnants and recurrences were statistically more frequent in the endovascular group compared with the microsurgical group, which is consistent with other studies.24 Aneurysms treated in the ruptured setting were much more likely to have a remnant (46%) than when treated in the elective setting (34%). Rehemorrhage was more common in the endovascular group, although not statistically significant due to sample size. Other authors have reported that rehemorrhage occurs in 1.3% of patients with coiled basilar apex aneurysms and in 2.1% with partially coiled ones.13 Interestingly, the mortality rate was not statistically different between our 2 groups. Overall, the risk of rehemorrhage with aneurysm remnants is very small after coiling, and larger and longer-term studies are needed to

\[
\text{FIG. 3. Graph showing the number of basilar apex aneurysms (y-axis) treated per year by either endovascular or microsurgical approaches. Figure is available in color online only.}
\]

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Variable} & \text{Pterional} & \text{Subtemporal} & \text{Statistic} & \text{p Value} \\
\hline
\text{No. of patients (%)} & 24 (51.1) & 23 (48.9) & \chi^2 = 0.022 & 1.000 \\
\text{% ruptured prior to treatment} & 50.0 & 52.2 & \chi^2 = 0.001 & 0.975 \\
\text{% with remnant} & 0.0 (1/21) & 4.6 (1/22) & \chi^2 = 0.001 & 0.975 \\
\text{Mean (SD) HH score upon admission (ruptured cases only)} & 1.8 (1.3) & 2.5 (1.5) & t = -1.17 & 0.254 \\
\text{Mean (SD) length of inpatient stay in days} & 13.2 (14.6) & 16.7 (14.2) & t = -0.83 & 0.410 \\
\text{% right-sided approach} & 87.5 & 95.7 & \chi^2 = 1.002 & 0.609 \\
\text{% micro-Doppler} & 52.4 (11/21) & 17.4 (4/23) & \chi^2 = 5.981 & 0.025 \\
\text{% intraop angiography only} & 90.5 (19/21) & 95.7 (22/23) & \chi^2 = 0.463 & 0.599 \\
\text{% indocyanine green fluorescent imaging only} & 0.0 & 0.0 & \dagger & \dagger \\
\text{% both intraop angiography & indocyanine green fluorescent imaging} & 9.5 (2/21) & 0.0 (0/23) & \chi^2 = 0.625 & 0.429 \\
\text{% temporary clip} & 81.0 (17/21) & 30.4 (7/23) & \chi^2 = 11.299 & 0.001 \\
\text{% temporary balloon occlusion assistance} & 14.3 (3/21) & 30.4 (7/23) & \chi^2 = 1.630 & 0.287 \\
\text{% hypothermic cardiac arrest} & 4.8 (1/21) & 4.4 (1/23) & \chi^2 = 0.434 & 0.510 \\
\text{% vasospasm} & 16.7 & 17.4 & \chi^2 = 0.004 & 1.000 \\
\text{% radiographic infarction} & 12.5 & 21.7 & \chi^2 = 0.710 & 0.461 \\
\text{% clinical stroke} & 12.5 & 17.4 & \chi^2 = 0.222 & 0.701 \\
\text{% oculomotor palsy} & 29.2 & 78.3 & \chi^2 = 11.369 & 0.001 \\
\text{Mean (SD) GOS score at discharge} & 4.3 (1.0) & 3.6 (1.1) & t = 2.12 & 0.039 \\
\text{Mean (SD) GOS score at 1 yr} & 4.6 (0.8) & 4.3 (0.8) & t = -1.17 & 0.254 \\
\text{Mean (SD) time from treatment to latest follow-up in days} & 2072.8 (1140.1) & 1099.4 (1297.7) & t = 0.255 & 0.015 \\
\hline
\end{array}
\]

SAH from another source, retreatments, recurrences, and regrowths are not presented because there were none. Boldface type indicates statistical significance.

* Total clipping treatments consisted of 47 index treatments with no retreatments.
† One case in which the initial subtemporal approach was re-attempted with a pterional approach on the same side was counted as a pterional approach for analysis.
‡ Chi-square test invalid because expected frequencies were less than 1 or less than 5 in 20% of cells.
§ Calculated as follows: date of latest follow-up office visit – initial (index) treatment admission date.
reliably detect the difference between the benefits of more definitive durable microsurgical ligation compared with the risk of rehemorrhage from aneurysm remnants or retreatment.

Despite these findings, microsurgical treatment of these aneurysms declined over the course of the study. This is in part due to the relative ease of access and treatment of these aneurysms endovascularly in comparison with microsurgery (Fig. 3). Further development of endovascular devices may reduce the concerns of recurrence, retreatment, and most importantly, rehemorrhage. However, this creates a new concern for lesions that cannot be treated endovascularly. The microsurgical lesions become more difficult, due both to their complexity and reduced experience of practitioners and trainees. As a result, it would be wise to concentrate the treatment of these aneurysms at high-volume teaching centers where consideration of microsurgery is an option.

Based on this retrospective experience that is confounded by the biases of treating physicians, we recommend the “endovascular-first” strategy in patients older that 50 years of age. Younger patients should be considered for microsurgical clipping of the aneurysms that are accessible (relative to the posterior clinoid) and harbor favorable morphological features for microsurgery. The presence of calcification should lead one to seriously consider endovascular options.

Conclusions

Microsurgical treatment of basilar apex aneurysms is associated with a higher rate of early postoperative deficits than endovascular treatment. Despite this, the clinical outcome at 1 year is no different between patient groups undergoing clipping versus coil embolization. However, posttreatment remnants, recurrences, and retreatment of basilar apex aneurysms are significantly more common among endovascularly managed aneurysms. The use of endovascular stents appeared to reduce these remnants and recurrences. The consequences of these residual aneurysms require further long-term follow-up studies. In a select group of patients, microsurgical treatment continues to play an important role.

References

19. Kriish A, Krayenhul B, Sercl D, Binkmaz K, Kadri PA: Re-

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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Conception and design: Bohnstedt. Acquisition of data: Cohen-Gadol, Bohnstedt, Ziemba-Davis, Sethia, Payner. Analysis and interpretation of data: Cohen-Gadol, Bohnstedt, Ziemba-Davis, Sethia, Payner. Drafting the article: Cohen-Gadol, Bohnstedt, Ziemba-Davis, Sethia. Reviewing the article: all authors. Reviewed submitted version of manuscript: Cohen-Gadol, Bohnstedt, Sethia, Payner, DeNardo, Scott. Approved the final version of the manuscript on behalf of all authors: Cohen-Gadol. Statistical analysis: Cohen-Gadol, Bohnstedt, Ziemba-Davis, Sethia. Administrative/technical/material support: Bohnstedt, Ziemba-Davis, Sethia, DeNardo, Scott. Study supervision: Cohen-Gadol, Bohnstedt, Sethia, Payner, DeNardo, Scott.

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