Consecutive Endovascular Treatment of 20 Ruptured Very Small (<3 mm) Anterior Communicating Artery Aneurysms

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Key Words
Anterior communicating artery · Aneurysm · Coiling · Endovascular treatment · Ruptured anterior communicating artery aneurysms

Abstract
Background: Small aneurysms located at the anterior communicating artery carry significant procedural challenges due to a complex anatomy. Recent advances in endovascular technologies have expanded the use of coil embolization for small aneurysm treatment. However, limited reports describe their safety and efficacy profiles in very small anterior communicating artery aneurysms. Objective: We sought to review and report the immediate and long-term clinical as well as radiographic outcomes of consecutive patients with ruptured very small anterior communicating artery aneurysms treated with current endovascular coil embolization techniques. Methods: A prospectively maintained single-institution neuroendovascular database was accessed to identify consecutive cases of very small (<3 mm) ruptured anterior communicating artery aneurysms treated endovascularly between 2006 and 2013. Results: A total of 20 patients with ruptured very small (<3 mm) anterior communicating artery aneurysms were consecutively treated with coil embolization. The average maximum diameter was 2.66 ± 0.41 mm. Complete aneurysm occlusion was achieved for 17 (85%) aneurysms and near-complete aneurysm occlusion for 3 (15%) aneurysms. Intraoperative perforation was seen in 2 (10%) patients without any clinical worsening or need for an external ventricular drain. A thromboembolic event occurred in 1 (5%) patient without clinical worsening or radiologic infarct. Median clinical follow-up was 12 (±14.1) months and median imaging follow-up was 12 (±18.4) months. Conclusion: This report describes the largest series of consecutive endovascular treatments of ruptured very small anterior communicating artery aneurysms. These findings suggest that coil embolization of very small aneurysms in this location can be performed with acceptable rates of complications and recanalization.
Introduction

The anterior communicating artery (AComA) is the most common location of cerebral aneurysms harboring up to 30–37% of all treated aneurysms [1, 2]. Compared with other branch points of the circle of Willis, the AComA is the most common location for the occurrence of very small aneurysms (<3 mm) [3]. Amongst all ruptured aneurysms, the proportion of patients with very small aneurysms ranges from 12 to 18% [1, 4–8]. Treatment of very small aneurysms is frequently demanding, particularly for very small AComA aneurysms which present with a unique set of challenges for endovascular as well as open surgical treatment. Recent advancements in endovascular technologies have included improved access support devices, the ability to better track the microcatheters and stability, soft and complex-shaped coils, and modified balloon catheter designs. There are limited reports describing the safety and efficacy of current endovascular techniques in very small AComA aneurysms.

Methods

Patient Population

Patients with very small (<3 mm) AComA aneurysms were identified from a prospectively maintained database of consecutive patients with ruptured AComA aneurysms treated with an endovascular technique at our institution between July 2005 and July 2013. A review of their demographic data, clinical course, pre- and postprocedural imaging, procedural details and follow-up evaluations was then conducted (table 1).

Angiographic Assessment of Morphological Features

Anatomic characteristics including dome orientation, dome size, neck size, neck location, dome-to-neck ratios and the presence of hypoplasia/aplasia of ipsilateral or contralateral arterial segments were obtained. Aneurysmal dome position with respect to the axis of the pericallosal arteries was used to define orientation (anterior or posterior) [9]. The location of the aneurysm neck was either on the AComA or at the junction of the A1-A2 segment of the anterior cerebral arteries and the AComA. Aneurysm size was assigned based on the longest axis measurement. Very small aneurysms were predefined as 3 mm based on the definition applied in multiple prior series [7, 8, 10, 11]. The immediate angiographic result was evaluated by angiography in multiple projections. Aneurysm occlusion was graded based on the Raymond Grading Scale [12].

Endovascular Procedure

At our center, patients are treated under general anesthesia. Rotational 3D angiography is commonly used to determine working projections. Balloon assistance is used at the discretion of the treating physician. Patients are commonly heparinized during the procedure after dome protection is achieved with initial coiling unless overriding contraindications are present. Abciximab or Integrilin is available and used in select cases for the treatment of intraprocedure thrombus.

Assessment of Clinical and Procedural Outcomes

At our institution, patients are scheduled for clinic follow-up at 1 month, 3 and 6–12 months, and annually thereafter. A follow-up angiogram is performed on patients with treated ruptured aneurysms at 3–6 months. All outcomes were graded with the modified Rankin scale (mRS) [13], where 0 = no symptoms, 1 = no marked disability despite symptoms, 2 = ability to carry out all usual duties and activities, 3 = moderate disability requiring some help and ability to walk without assistance, 4 = moderately severe disability, inability to walk without assistance and to attend bodily needs without assistance, 5 = severe disability, bedridden, incontinent and need for constant nursing care, and 6 = death. Recanalization on follow-up angiogram was defined as any worsened grade of occlusion compared to the immediate post-procedural angiogram. The aneurysm long-term occlusion rate was assessed using the Raymond Grading Scale.
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Results

Patient Characteristics

A total of 188 AComA aneurysms were consecutively treated with endovascular therapy out of which 134 were ruptured. Twenty patients (14.9%) had ruptured very small (<3 mm) AComA aneurysms; 13 (65%) of them were females and 7 (35%) males, with a mean age of 58.4 ± 12.9 years. Fourteen (70%) patients had a Hunt-Hess grade of 1–3 and 6 (30%) patients had a Hunt-Hess grade of 4.

Morphologic Characteristics

The average maximum diameter was 2.6 ± 0.3 mm. The majority of the aneurysms had a wide neck as the dome-to-neck ratio was less than 2 for 13 (65%) of the aneurysms. Four (20%) aneurysms were bilobed. Aneurysm projection was anterosuperior in 11 (55%), anteroinferior in 6 (30%) and posterosuperior in 3 (15%) patients. Neck location was the AComA for 12 (60%) patients and the A1-A2-AComA junction for 8 (40%) patients. Aplasia of the A1 segment of the anterior cerebral artery was seen in 4 (20%) patients and hypoplasia in 4 (20%) patients (table 2).

Immediate Clinical and Angiographic Outcomes

Primary coiling was performed for 16 (80%) aneurysms and balloon assistance was used for 4 (20%). Stent assistance was not applied in any patient. Bare platinum coils were used in all cases. Complete aneurysm occlusion was achieved for 17 (85%) aneurysms and near-complete aneurysm occlusion for 3 (15%) aneurysms. Periprocedural complications included 1 (5%) thromboembolic event without symptoms or infarct in the territory of the involved artery and 2 (10%) intraoperative perforations (IOP) without clinical worsening or the need to place an external ventricular drain. The thromboembolic event was seen in a patient in whom additional cotreatment of a pericallosal artery aneurysm was being performed. This patient received intravenous Integrilin. None of the patients received abciximab.

Follow-up clinical and angiographic outcomes were as follows: median clinical follow-up was 12 ± 14.1 months and median imaging follow-up was 12 ± 18.4 months. There were no instances of rebleeding during follow-up. At the 3-month clinic follow-up, mRS score was 2 or less for 75%. It was 0 for 3 (15%) patients, 1 for 8 (40%) patients, 2 for 4 (20%) patients, 3 for 2 (10%) patients, 4 for 1 (5%) patient, 5 for 1 (5%) patient and 6 for 1 (5%) patient. The mortality was related to anaplastic astrocytoma, which was diagnosed during hospitalization. Of all the surviving patients, posttreatment clinical status either improved or remained stable and follow-up angiography with either digital subtraction angiography or MR angiography

Table 1. Clinical summary and outcomes of all patients

<table>
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<tr>
<th>Mean age ± SD, years</th>
<th>58.4 ± 12.9</th>
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<tr>
<td>Females</td>
<td>13 (65%)</td>
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<tr>
<td>Hunt-Hess grade</td>
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<tr>
<td>1–3</td>
<td>14 (70%)</td>
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<tr>
<td>4</td>
<td>6 (30%)</td>
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<td>5</td>
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<td>mRS score at 3-month follow-up</td>
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<tr>
<td>1–3</td>
<td>17 (85%)</td>
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<td>4</td>
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(MRA) was performed in all patients except the patient with an mRS score of 5 who declined further radiologic follow-up. At least one follow-up digital subtraction angiography followed by MRA was performed in 12 patients and in the remaining 6 patients, only serial MRAs were performed. Recanalization occurred in 2 (10%) aneurysms and both were retreated with stent assistance without any complications.

**Discussion**

We present the largest series of consecutive endovascular treatment of ruptured very small AComA aneurysms. Aneurysms involving the AComA complex are responsible for up to 40% of subarachnoid hemorrhage cases of which up to 18% can be from very small (<3 mm) aneurysms [1, 14]. Although the International Subarachnoid Aneurysm Trial (ISAT) [15] and the International Study of Unruptured Intracranial Aneurysms (ISUIA) [16] described anterior cerebral artery and AComA aneurysms representing 45.4 and 12.3% of all aneurysms, these studies excluded very small aneurysms. Very small aneurysms are challenging to treat with surgical as well as endovascular methods.

The surgical approach is challenging due to complex arterial relationships, risk of perforator occlusion, and risk of neuropsychologic and cognitive sequelae [9, 17]. Endovascular treatment of aneurysms in the AComA region is also faced with several unique challenges. Severe angulation of the A1 segment at its takeoff at the intracranial internal carotid artery bifurcation may affect microcatheter navigation and stability. Microcatheter movement and coil positioning can be considerably restricted due to the small size of the aneurysm sac [18], and slight displacement of the microcatheter within a small aneurysm could lead to rupture,
which would otherwise produce less impact in a larger aneurysm [19]. In addition, there is a higher risk of accidental placement of the coil or microcatheter in dangerous vicinity of the initial rupture site compared with larger aneurysms.

Rates of intraprocedural rupture during endovascular treatment of very small aneurysms have been reported to be up to 14%. In a series of 60 patients with very small (<3 mm) aneurysms in locations not restricted to the AComA, the overall intraprocedural rupture rate was 11.7% and the rupture rate among 21 of 60 (35%) aneurysms of the AComA distribution was 14% [8]. Another study [20] revealed an intraprocedural rupture rate of 13.5% in all ruptured aneurysms of <4 mm compared to the rest of the aneurysms, which had an intraprocedural rupture rate of 2.9%. In another series, out of the 7 intraprocedural ruptures of 264 total aneurysms, 4 of the aneurysms were ≤4 mm. None of these, though, were AComA aneurysms [18]. In a meta-analysis of small aneurysm data along with 71 patients treated at a single institution, the procedural rupture rate was 8.3% with an increased mortality rate of 2.4% [10, 21], and showed a procedural rupture rate of 7.2% for very small intracranial aneurysms. In contrast to these series, there have been reports of no intraprocedural ruptures in one series of endovascular treatment of 19 consecutive ruptured very small AComA aneurysms [22], in another series of 21 ruptured aneurysms of <3 mm, of which 11 were in the AComA complex [23], and in a series of 11 aneurysms of ≤3 mm in 11 patients, with 6 ACoA aneurysms [24]. One of the explanations of the lower rate of intraprocedural ruptures in some series could be a lack of frequent control angiography during endovascular coiling.

In our series, although there were no symptomatic complications, there were 2 intraprocedural perforations and 1 thromboembolic event. One of the IOPs occurred in a bilobed anterosuperiorly projecting aneurysm after placement of the first detachable coil and the other occurred in a bilobed anteroinferiorly projecting aneurysm after placement of the fifth coil. The aneurysm neck in both cases was located on the AComA rather than the A1-A2-AComA junction. Both aneurysms were small necked (dome-to-neck ratio >2). Rapid control of bleeding was achieved by administering protamine to reverse any intraprocedural anticoagulation and by placing additional coils into the ruptured segment to promote hemostasis. Balloon inflation for flow arrest was not used in either case. Posttreatment control angiography confirmed complete aneurysm occlusion and absence of any further contrast extravasation. Interestingly, both cases of IOP in our series were of a similar morphology. A thromboembolic event to the ipsilateral pericallosal artery occurred in a patient in whom a pericallosal aneurysm was additionally treated in the same session and balloon assistance was used. A thrombus formed in the pericallosal artery adjacent to the coil mass within the pericallosal aneurysm, and was partially obstructing the flow within the left internal frontal division. Intravenous heparin and intravenous Integrilin were administered with progressive resolution of the intraluminal thrombus with restoration of normal antegrade flow within the left internal frontal division. Though IOP has been associated with increased morbidity and mortality [10], there have been reports showing no significant impact on morbidity and mortality [7]. In our series of patients, neither the intraoperative rupture nor the thromboembolic events led to any clinical or radiologic deterioration.

To minimize the risk of intraprocedural ruptures for very small aneurysms, it is recommended to select the smallest, softest coil to avoid excessive manipulation and tension build-up in the aneurysm. The stiffest segment of a coil is its detachment zone which varies in length from 0.5 to 0.8 mm, and the distance between the distal end of the distal markers of the microcatheters and the detachment zone of the coil ranges from approximately 1.2 to 2.8 mm [25]. Therefore, placement of the distal marker of the selected microcatheter near the neck rather than deeper and slow withdrawal of the microcatheter at the end of coil placement may prevent any potential injury from the relatively stiff detachment zone. Balloon assistance has been employed to stabilize the microcatheter and to offer protection if intraoperative...
rupture occurs [8, 26], but, on the other hand, increased risk of procedural rupture has been described when the microcatheter is fixed by an inflated balloon [18, 27]. Utilization of balloon assistance at our institution is operator dependent and in cases where balloon is used, it is positioned across the neck but not inflated until the first loop of the coil is positioned in the aneurysm fundus (fig. 1).

The recurrence rate following endovascular treatment for all aneurysms in general has varied from 13 to 34% with the retreatment rate ranging from 4.7 to 20.8% [15, 28, 29]. For

Fig. 1. Balloon-assisted coil embolization. Middle-aged male presented with aneurysmal subarachnoid hemorrhage and found to have multiple cerebral aneurysms a A broad-necked AComA aneurysm arising at the junction with the left A2 segment measuring 2 mm in diameter, and a distal left A1 aneurysm arising from a posterior duplication of the AComA measuring 1 mm in diameter. b, c Due to the broad-necked configuration of this aneurysm, coil embolization was supported by using a balloon remodeling technique (shown after deflation).

Fig. 2. Recanalization requiring re-treatment. A patient in her 3rd decade with SAH found to have AComA aneurysm (a) projecting superiorly and to the left and measuring 3 mm in maximum diameter. b Treated with primary coiling. c Follow-up angiogram at 6 months showed a residual neck remnant measuring 2.5 mm in diameter. d This was re-treated with Neuroform-2 stent-assisted coiling. A patient in his 4th decade of life presented with SAH secondary to ruptured AComA aneurysm (e) emergently treated with coil embolization (f). g Four-month post-coiling angiogram revealed a region of recanalization within the previously coiled AComA aneurysm with 2 mm of regrowth seen at the aneurysm neck. h This was re-treated with Neuroform-3 stent-supported additional coil embolization.
very small aneurysms, retreatment rates have varied from 5 to 12% [7, 30]. In the present series, recanalization occurred in 2 (10%) aneurysms both of which had complete aneurysm occlusion on immediate postprocedural angiogram. Follow-up angiograms at 4 and 6 months showed regrowth with a neck residual of 2 and 2.5 mm, respectively. Both were treated with additional primary coiling and due to the broad-necked configuration of both aneurysms, stent assistance which was used across the aneurysm neck (fig. 2). Follow-up angiography at 6 months after retreatment showed no further recanalization in these 2 patients.

Limitations of our study are the single-center, retrospective design and a small sample size, which did not permit us to evaluate possible predictors of outcome. Additionally, the follow-up period is short, and long-term follow-up may provide a better understanding of long-term rebleeding and recanalization rates.

**Conclusion**

With the availability of softer coils and recent advances in access devices providing more distal support, coil designs, increased operator experience, availability of microcatheters and microguidewires that are easier to navigate, coil embolization should be considered for very small ruptured aneurysms and can be performed with acceptable rates of complications and recanalization.

**Disclosure Statement**

All authors have completed the ICMJE uniform disclosure form and declare no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years, and no other relationships or activities that could appear to have influenced the submitted work.

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