Impact of Aneurysmal Neck Position in Endovascular Therapy for Anterior Communicating Artery Aneurysms

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Abstract
Anterior communicating artery (ACoA) aneurysms have a complex architecture and many variations, making endovascular therapy more difficult in some cases. The aim of this study was to investigate whether the neck position of an aneurysm was identifiable for determining the immediate angiographic success and procedural complications in the coiling of the ACoA aneurysms. We conducted a retrospective case review of 40 patients with ACoA aneurysms treated by endovascular therapy from 2008 to 2015. The mean age was 66.8 years. Thirty-five aneurysms were ruptured; five were unruptured. For the analysis, the patients were divided into two groups according to the neck position of aneurysms: the true ACoA group, 9 patients with the neck located on the ACoA itself; and the other ACoA group, 31 patients with the neck at the junction of the A1 and A2 portions of an anterior cerebral artery. Morphological characteristics (dome size, dome direction, rate of wide neck, and angulation of aneurysms in relation to the parent artery) were analyzed along with immediate angiographic results, volume embolization ratio (VER), and procedural complications. Small aneurysms with superior dome projection and acute angulation of the aneurysm direction occurred more often in the true ACoA group. The rates of complete obliteration, VER, and procedural complications were 33.3%, 32.3%, and 22.2% in the true ACoA group and 54.8%, 36.3%, and 6.5% in the other ACoA group, respectively. True ACoA aneurysms could present an anatomical difficulty in endovascular coiling. Aneurysmal neck position should be accurately assessed to achieve successful embolization of the ACoA aneurysms.

Key words: anterior communicating artery aneurysm, endovascular therapy, morphology, volume embolization ratio

Introduction
Anterior communicating artery (ACoA) aneurysms are the most common type of intracranial aneurysms.1) Due to the deep, midline location of these aneurysms and the number of important small perforating arteries arising from the ACoA, microsurgical neck clipping remains an arduous task. Since the International Subarachnoid Aneurysm Trial revealed the efficacy of endovascular treatment for ruptured aneurysms, endovascular therapy has commonly been performed for ACoA aneurysms.2) Furthermore, the continuing evolution of endovascular techniques and devices have dramatically changed the ability of endovascular coiling as a therapeutic alternative for ACoA aneurysms.3–5) However, ACoA aneurysms have a unique anatomical architecture and many variations, making endovascular therapy more difficult in some cases than others. Several investigators have described the morphological criteria for unsuccessful endovascular therapy; however, more detailed pre-therapeutic analyses of the anatomical features of ACoA aneurysms are still necessary.4,6–9) In the present study, we describe our experience with endovascular coil embolization for ACoA aneurysms. We performed a retrospective analysis of aneurysm morphology corresponding to both successful and unsuccessful endovascular therapy to assess the difficulties of coil embolization in terms of the neck position of aneurysms.

Materials and Methods
I. Patients
We performed a retrospective review of 347 medical records of patients from April 2008 through
March 2015 who underwent coil embolization for cerebral aneurysms at our university hospital and its affiliated hospitals. We included 40 patients who received therapy for ACoA aneurysms at those hospitals during that 8-year period. Twenty-six patients were women (65.0%) and 14 were men (35.0%). Their ages ranged from 44 years to 90 years, with an average age of 66.8 years. Thirty-five aneurysms (87.5%) presented with a subarachnoid hemorrhage, and 5 (12.5%) were incidental. Of these, 8 were categorized as Hunt and Hess Grade I, 6 as Grade II, 8 as Grade III, 10 as Grade IV, and 3 as Grade V. All cases presenting subarachnoid hemorrhage underwent coil embolization within 48 h after the primary hemorrhage. The aneurysm sizes ranged from 2.2 mm to 13.0 mm in diameter, with an average of 4.8 mm. Sixteen aneurysms (40.0%) were small, 21 (52.5%) were medium, 3 (7.5%) were large, and 20 (50.0%) were wide-neck aneurysms. We separated the patients into two anatomical groups according to the aneurysmal neck position located exclusively on the ACoA itself (true ACoA group) or at the junction between the A1 and A2 portions of an anterior cerebral artery (other ACoA group).

The indications for coil embolization included poor neurological grade, poor general condition, anticipated surgical difficulty, and refusal of surgery. The study design was approved by the ethics review board of our hospital.

II. Analyses of anatomical characteristics

We analyzed the aneurysmal morphology on digital subtraction and three-dimensional (3D) angiograms at the time of embolization. Several anatomic characteristics were recorded blindly with respect to the embolization results. These characteristics included dome size, superior/inferior direction of the aneurysm dome with respect to horizontal lines, the rate of wide neck aneurysms, and aneurysms angle, defined as the angle between the parent artery and the aneurysmal dome projection.

A small aneurysm was defined as that with a dome of < 4 mm at the largest diameter. Medium aneurysms were those with dome diameters of 4 mm to 10 mm. Large aneurysms were those with dome diameters of > 10 mm. Dome-to-neck ratios were categorized into those > 2 and those ≤ 2. Wide-neck aneurysms were defined as those having a dome-to-neck ratio of < 2, excluding the diameter of their neck size. The aneurysm angle was measured on 3D angiograms, according to Songsaeng et al.,9) as follows: first, the direction of the parent artery was determined by a line toward the aneurysm neck, and then, by a line from the aneurysm neck to the dome (Figs. 1, 2). The smallest angle between these two lines was determined. Measurements were done using a dedicated 3D workstation (Infinix Celeve-i, Toshiba Medical Systems Corporation, Otawara Tochigi).

III. Surgical procedures

All procedures were performed via the transfemoral approach, under general anesthesia. After placement of the sheath, systemic heparinization was achieved. Patients with unruptured aneurysms received 75 mg clopidogrel daily for 7 days before the procedures. After the procedures, all the patients received antiplatelet therapy for 3 months. Aneurysms were routinely embolized with coils through a 6 French guide catheter (Envoy, Cordis, Johnson & Johnson, Fremont, California, USA).
guide catheter in position within the prepetrous portion of an internal carotid artery, the aneurysm was accessed with a microcatheter (SL-10, Stryker, Kalamazoo, Michigan, USA). A soft-tipped microguidewire (Transend™, Boston Scientific, Natick, Massachusetts, USA; Chikai, Asahi Intecc Co. Ltd., Nagoya, Aichi) was used to steer the microcatheter. When necessary, the microcatheter tip was pre-steam-shaped to ease subsequent negotiation through the A1 segment into the aneurysm. The microguidewire with microcatheter was slowly advanced into the aneurysm. A single microcatheter technique was primarily attempted, and for wide-necked aneurysms, balloon assistance was performed according to the surgeon’s preferences. Coils were deployed into the aneurysm under “roadmap” conditions. The coils used were Guglielmi detachable coils (Boston Scientific, Natick, Massachusetts, USA), Target detachable coils (Stryker, Kalamazoo, Michigan, USA), and ED coils (Kaneka Medix Corp., Osaka). Dense packing was attempted in all aneurysms. Immediate post-treatment angiograms were used to assess the immediate extent of aneurysm occlusion after coil embolization. An embolization was considered complete obliteration when there was no contrast filling of the dome and neck of an aneurysm. A neck remnant was defined as residual filling of the neck of the aneurysm. Body filling was indicated by contrast medium in the neck and body of an aneurysm. Volume embolization ratio (VER) was calculated by the formula (coil volume/aneurysm volume) × 100%. VER of ≥ 25% and < 25% was considered high and low, respectively.

IV. Statistical analyses
All values are expressed as mean ± standard deviation. Mann-Whitney U test was used for all statistical analyses. Statistical significance was assigned to values of p < 0.05 or p < 0.01.

Results
There were 9 (22.5%) aneurysms in the true ACoA group and 31 (77.5%) aneurysms in the other ACoA group. The comparison of baseline characteristics including sex, age, and patients’ initial neurological status between the two groups showed no significant differences.

The sizes of the aneurysms were 3.2 ± 0.7 mm in the true ACoA group and 5.7 ± 3.0 mm in the other ACoA group (p = 0.002). All the aneurysms in the true ACoA group were small. Seven (22.5%; 7/31) of the aneurysms in the other ACoA group were small (p < 0.01). Six aneurysms in the true ACoA group (66.7%; 6/9) and 16 aneurysms in the other ACoA group (51.6%; 16/31) had superiorly oriented dome (p = 0.43). The number of aneurysms with wide necks was 5 (55.6%) in the true ACoA group and 15 (48.4%) in the other ACoA group (p = 0.71). The aneurysm angle was 100.3 ± 7.6° in the true ACoA group and 160.7 ± 24.0° in the other ACoA group (p < 0.01). The true ACoA group exhibited more acute aneurysm angle compared with that in the other ACoA group (Table 1).

The endovascular approach, rather than a microsurgical clip application, was chosen for the following reasons: poor neurological grade in 18 patients, poor general condition in 11, and anticipated surgical difficulty in 3 patients. Eight patients refused surgery.

Eighteen aneurysms (45.0%; 18/40) were treated with a combination of Target and ED coils, 13 aneurysms (32.5%; 13/40) were treated exclusively with Target coils, and 9 aneurysms (22.5%; 9/40)
were treated exclusively with Guglielmi detachable coils. In four (10.0%; 4/40) cases, the technique of balloon assistance was used. None of the cases required stenting.

Complete obliteration was observed in 20 cases (50.0%; 20/40). Neck remnant was observed in 17 cases (42.5%; 17/40). Body filling was observed in 3 cases (7.5%; 3/40). The rate of complete obliteration was 33.3% (3/9) in the true ACoA group and 54.8% (17/31) in the other ACoA group. There were no unsuccessful attempts of coil embolization. The average Ver was $32.3 \pm 8.5$ (32.3 ± 8.5% in the true ACoA group and 36.3 ± 10.9% in the other ACoA group). Among the small aneurysms in the other ACoA group, the Ver was $44.3 \pm 9.0$ and higher compared with the true ACoA group with significant difference ($p < 0.05$). Based on these findings, the true ACoA group had lower angiographical results compared with the other ACoA groups.

There were four procedure-related complications (10.0%; 4/40) in both groups combined; 2 (22.2%; 2/9) in the true ACoA group and 2 (6.5%; 2/31) in the other ACoA group. All those four cases with hemorrhagic complications due to coil perforations had initially presented with subarachnoid hemorrhage and small aneurysms. There were no cases of thromboembolic complications during the procedure (Table 2). The patients in the true ACoA group had a tendency to develop intraoperative hemorrhagic complications.

Regarding the clinical neurological outcome prior to discharge, 35 patients (87.5%) remained neurologically intact, improved, or unchanged from the initial clinical status. The post-treatment clinical examination revealed a permanent new neurological motor deficit in three cases (7.5%); mild in two, and severe in one case. Of these, two patients deteriorated due to severe vasoospasm, one deteriorated from disuse, i.e., muscle atrophy, due to severe pneumonia and old age. A total of two patients died (5.0%). Both patients were originally categorized as Hunt and Hess Grade V and died of intraprocedural rupture due to coil perforation.

**Discussion**

Interestingly, the anatomical characteristics were substantially different between the two groups. The true ACoA group had properties of small dome size and acute aneurysm angle significantly, and a tendency of a superior direction of the aneurysm dome, compared with those in the other ACoA group.

Reviewing the vascular anatomy, the diameter of the A1 segment of the anterior cerebral artery averaged around 2.5 mm, and that of the ACoA averaged from 1.2 mm to 1.5 mm, which is about half of the A1 segment diameter.10,11) Perlmutter et al. reported that the ACoA perforating branches arose mostly from the superior aspects of the parent artery (54%).10 From these anatomical characteristics, small size and superior dome projection could be observed frequently in the true ACoA group. Concerning
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In conclusion, we revealed the features of an ACoA aneurysm whose neck was located directly at the ACoA that strongly associated with each morphological factors of unsuccessful endovascular therapies. Consequently, incomplete obliteration and intraprocedural rupture in treating ACoA aneurysms with endovascular embolization are more common in the true ACoA aneurysms.

Conflicts of Interest Disclosure

The authors have no conflicts of interest and have registered online self-reported conflict of interest disclosure statement forms through the website for Japan Neurosurgical Society members.
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