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MODIFICATION OF ENDOVASCULAR TREATMENT OF ANEURYSMS OF PATENT ANTERIOR COMMUNICATING ARTERY IN ABSENCE OF A1 SEGMENT HYPOPLASIA

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Abstract

A series of 63 patients harboring anterior communicating artery aneurysm is presented. The purpose of this study was to analyze the results of endovascular treatment of anterior communicating artery aneurysms.

We retrospectively analyzed 63 patients harboring anterior communicating artery aneurysms with pretreatment clinical and radiological features, including: age, Hunt&Hess grade, modified Fisher grade, aneurysm size, neck size, dome to neck ratio. Post-treatment clinical results were analyzed according to modified Rankin Scale, whereas anatomic results according to modified Raymond scale. Presence of clinical vasospasm and additional treatment for it was also discussed.

63 patients with anterior communicating artery aneurysms were treated in our clinic from July 2010 to March 2017 with endovascular coil embolization technique. Two aneurysms (3.2%) were unruptured, 4 (6.3%) were early (>21 days) ruptured and 57 (90.5%) presented with subarachnoid hemorrhage. From 63 treated aneurysms 7 were small, 49 were medium, 6 were large, and one aneurysm was giant. Fifty aneurysms had small neck, whereas 13 were wide-necked. A complete aneurysm occlusion was achieved in 49 cases (77.8%), a neck remnant was observed in 13 (20.6%) cases, and in one case (1.6%) residual filling of the aneurysm was detected. Concerning clinical outcome, 42 patients were independent at discharge, and 13 were dependent. In-hospital morbidity was 12.7% during first month. Intraoperative complications were observed in 9 (14.3%) cases. Eight patients developed clinical vasospasm, which required high dose (>50 mg) verapamil injection or balloon angioplasty. Six retreatments, 4 second endovascular interventions and two clippings were performed because of aneurysm regrowth during follow-up. No late rebleeding occurred during follow-up period.

Endovascular embolization is effective and less traumatic method for the treatment of anterior communicating artery aneurysm. Long period of follow-up is required to detect aneurysm regrowth and perform additional treatment to prevent late rebleeding.

Keywords: *anterior communicating artery aneurysm, coiling, endovascular treatment.*

Introduction

Intracranial aneurysms are a major source of devastating hemorrhagic stroke and delayed ischemic stroke. Up to 12% of patients with subarachnoid hemorrhage die before receiving medical attention, 40% of hospitalized patients die within 1 month after the event, and more than one-third of those who survive have major neurological deficits. The true incidence of cerebral aneurysms is unknown, but it is estimated at 1% to 6% of the population. The anterior communicating artery aneurysm is the most common location of intracranial aneurysms in most series [*Brisman J et al., 2006; Hernesniemi J et al., 2008*].

Antierior Communicating Artery (AComA) aneurysms are the most common site of intracranial aneurysms, accounting for about 30%–37% of intracranial aneurysms overall [*Andaluz N et al., 2003*]. In addition, the AcomA is the most com-

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mon location of intracranial aneurysm rupture, accounting for 40% of aneurysm-related subarachnoid hemorrhages [*Dehdashti A., et al, 2016*]. However, only 1-2% of detected aneurysms (10 - 30 per 100.000 per year) progress to rupture and spontaneous subarachnoid hemorrhages. Treatment for these aneurysms include microsurgical clipping and coil embolization. Since the introduction of the Guglielmi detachable coils in 1991 for the treatment of intracranial aneurysms, a growing number of ruptured and unruptured cases have been treated with endovascular techniques [*Meetings A et al., 1998*].

Introduction and advance of endovascular technique and development of new devices have made it possible to treat AcomA aneurysms using coil embolization more frequently. Endovascular treatment is an increasingly used method for the treatment of ruptured and unruptured aneurysms [*Murayama Y et al., 2003*], and demonstrates short-term clinical and angiographic efficacy as a therapeutic alternative to the surgical treatment of intracranial aneurysms. Furthermore, various adjunctive techniques have been used to facilitate coil embolization of these lesions, including neck re modeling using balloons or stent-assisted embolization [*Kwon O et al., 2006*], and several papers have reported good outcomes of endovascular coil embolization of AComA aneurysms. Patients with AComA aneurysms, either ruptured or unruptured, are frequently eligible for both open surgery (“clipping”) and endovascular repair (“coiling”).

Although randomized trials comparing clipping and coiling for the treatment of ruptured aneurysms have been published [*Koivisto T et al., 2000; Van der Schaaf I et al., 2005*], decision making between clipping and coiling for individual patients is complex. Few publications have addressed specifically the endovascular treatment of AcomA aneurysms [*Proust F et al., 2003*]. Because it has long been believed that geometric characteristics may be used to identify dangerous aneurysms at risk for rupture, continued attention has been placed on the contribution of AcomA morphology toward the risk of rupture. The association between morphologic factors and rates of rupture has become a common focus of research. Despite numerous investigations pertaining to the relationship between geometric characteristics of aneurysms and rupture, only a few consistent conclusions have been resulted [*Weir B, 2002*]. Furthermore, detailed anatomic characteristics and the effects of the multiple variations of these features have scarcely been reported. The growing evidence that hemodynamic factors play a fundamental role in the adequate treatment of aneurismal coiling [*Imbesi SG et al., 2003*] and the close correlation between the vessels and aneurysms anatomic architecture and the patterns of flow reinforce the need for a more meticulous anatomic analysis. In addition, some studies had revealed that coil embolization of AcomA aneurysm is feasible and effective and there is a tendency to increase coil embolization for treatment of AcomA aneurysms [*Elias T et al., 2003; Proust F et al., 2003; Birknes J et al., 2006; Guglielmi G et al. 2009; Finitsis S et al., 2010*]. It has been widely reported that aneurysm size and width linearly correlate with the risk of rupture of AcomA [*Jiang H et al., 2016*].

Moreover, J Choi and co-authors (2016) reported that AcomA size >7 *mm* was more likely to rupture. However, rupture of smaller anterior circulation aneurysms account for more cases of subarachnoid hemorrhages, perhaps because of the overall greater prevalence of smaller aneurysms. Bjlenga J. and co-authors (2006) found that aneurysms of the AcomA or distal anterior cerebral artery between 4 and 7 *mm* have similar odds of rupture to posterior circulation aneurysms. Given these findings, size was not deemed an independent risk factor for rupture of AcomA, posing a dilemma for clinicians to make treatment decisions for small unruptured AcomAs. Although numerous studies have concluded that aneurysm neck diameter is a major risk factor for aneurysm rupture overall, investigators solely looking at AcomAs have reported no significant difference in neck diameter between those that are ruptured or unruptured.

Pathologically, aneurysm neck diameter is in part related to abnormal hemodynamics. The size of the entrance to the aneurysm, which is indirectly reflected by the neck diameter of the aneurysm, in part results from changes in shear stress caused by blood flow. In addition, the impact from abnormal blood flow may further result in rupture of the aneurysm. Because some studies fail to show a correlation between aneurysm neck diameter and rupture, these findings suggest that aneurysm rupture must be affected by many other factors in addition to shear stress from abnormal hemodynamics. Overall, the findings suggest that size and width may predict AcomA rupture, but neck diameter likely does not [*Cai W et al., 2018*]. The International Subarachnoid Aneurysm Trial and International Study of Unruptured Intracranial Aneurysms clinical trials for group of patients for intracranial aneurysms have shown advantages of endovascular therapy over surgical clipping for a selected group of patients [*Molyneux A et al., 2002; Wiebers D et al., 2003*].

Anterior communicating artery and anterior cerebral artery aneurysms represented 45.4% of ruptured aneurysms in International subarachnoid aneurysm trial and 12.3% in International Study of Unruptured Intracranial Aneurysms. However, extrapolation of the results of these studies to the clinical practice is limited given the specific criteria used in the selection of cases. Generalizations based in our current knowledge are inappropriate and underestimate the complexity of intracranial aneurysms and their treatment. We report our experience of the endovascular management of unruptured and ruptured AcomA aneurysms during past 7 years, where we applied a modification of standard treatment.

Material and Methods

Patient population: We performed a retrospective analysis of 63 medical records of patients who underwent endovascular coil embolization of AcomA aneurysms in our clinic from July 2010 to March 2017. Eighteen patients were female (28.6%) and forty-five patients were male (71.4%). Their ages ranged from 18 to 75 years (mean age 49.9 years) **(Table 1).**

Clinical Presentation: Two aneurysms (3.2%) were incidental findings, 4 were early (>21days) ruptured and 57 (90.5%) presented with signs and symptoms of subarachnoid hemorrhage. From those, 53 had good-grade subarachnoid hemorrhage (H&H Grade 0 - 3) and 10 had poor-grade subarachnoid hemorrhages (H&H Grade 4.5). The amount of blood in the subarachnoid and intraventricular space was quantified according to the modified Fisher scale **(**Table 1**).**

Anatomical analysis: All of the aneurysm morphology were analyzed using the digital subtraction angiography. Morphological analysis involved aneurysm size, neck size, dome to neck ratio. Small aneurysms were defined as having a dome of <3 *mm*. Medium aneurysms had domes of 3 -10 *mm*. Large aneurysms had domes of 10-25 *mm*. Giant aneurysms had domes more than 25 mm. Small necks were defined as <4 *mm*; large necks, as ≥4 *mm*. Dome to neck ratios were categorized into ≥2 and <2.

Indication for Aneurysm Treatment : Generally we follow a policy of aneurysm repair (clipping or coiling) as soon as possible after aneurysm rupture. The patients with subarachnoid hemorrhage are primarily referred to the neurointerventional unit to appreciate suitability for endovascular treatment. If the endovascular technique is judged unsuitable or if there is an unsuccessful attempt to treat, the patient is referred for surgical clipping.

Embolization Technique: Endovascular treatment is always preceded by diagnostic digital angiography on a monoplanar system (Siemens Artis Zee, Germany) with additional multiple views. The final treatment result is always evaluated in the working projections with additional face and profile projections including the late venous phase to rule out thromboembolic complications. The procedures are performed with the patients under general anesthesia, and systemic heparinization is provided

Table 1.

Clinical characteristics of patients

Variables		Overall (%)
Age	Mean	49.9
	Range	18 - 75
Sex	Male	45 (71.4)
	Female	18 (28.6)
H&H Grade	Good (0-3)	53 (84)
	Poor (4-5)	10 (16)
Modified Fisher Scale	Grade 0	6 (9.6)
	Grade 1	5 (7.9)
	Grade 2	7 (11.1)
	Grade 3	17 (27)
	Grade 4	28 (4.4)
Modified Rankin Scale	Independent (0-2)	42 (66.7)
	Dependent (3-5)	13 (20.6)
	Death (6)	8 (12.7)

throughout with a dose of 1000 *IU/L* of IV heparin. At the end of the procedure, 50 *IU* per *kg* of the heparin was administered. If during embolization vasospasm was observed, first we used high dose of Verapamil or IV Nimodipine. In case of ineffectiveness, we proceeded with balloon-angioplasty. When a thromboembolic complication occurred, we used Inte-grillin 180 *mcg/kg* IV bolus, followed by 2*mcg/kg/min* IV for 1 day. If this failed, we used clot aspiration technique with Penumbra aspiration catheter. Endovascular treatment comprised selective catheterization of an aneurysm, delivery and detachment of coils until dense aneurysm packing was obtained, trying not to compromise the lumen of the anterior cerebral artery complex and the surrounding branches. In cases, when there was a patent AcomA and A1 segment hypo-/aplasia was not detected, we used embolization of AcomA as well. In case of coil migration or large-necked aneurysms balloon- or stent-assistance was utilized. The final anatomical outcome was assessed according to Raymond's classification [*Raymond J et al., 2003*]: a complete obliteration was recorded if there was no filling of contrast medium in the dome, body or neck. A residual neck involved residual filling of part of the neck and a partial occlusion involved filling of contrast medium in the aneurysmal dome. After the intervention, patients were closely monitored for vasospasm. The patients were discharged home on 21st day after hemorrhage if their condition became satisfactory.

Clinical and Angiographic Follow-up Studies were done three months, six months, one year, two years post embolization and thereafter as considered suitable. Angiographic follow-up was performed with digital subtraction angiography.

RESULTS

ANEURYSM MORPHOLOGY: Seven aneurysms (11.1%) were small, 49 aneurysms (77.8%) were medium, 6 (9.5%) were large, and 1 (1.6%) was giant. Fifty aneurysms (79.4%) had small necks and 13 aneurysms (20.6%) had wide necks. The dome-to-neck ratio was measured in all aneurysms. Forty-three (68%) had a dome-to-neck ratio <2, and 20 (32%) - ≥2. The most common variant of development associated with AcomA aneurysms was hypoplasia/aplasia of one of the A1 segments (30 cases; 47.6%) **(**Table 2**).**

ANGIOGRAPHIC RESULTS: A complete aneurysm occlusion was achieved in 49 cases (77.8%). A neck remnant was detected in 13 cases (20.6%), and in 1 case (1.6%) a residual filling of a portion of the aneurysm was observed **(**Table 2**).** In 10 cases, when there was a patent AcomA and A1 segment hypo-/aplasia was not detected, we used embolization of AcomA as well without any complication related to this.

CLINICAL RESULTS: All patients were clinically evaluated before hospital discharge using modified Rankin scale. Among them 13 (20.6%) were dependent according to modified Rankin scale (MRS 3-5), and 42 (66.7%) were independent (MRS 0-2) **(**Table 1**).** Only 8 cases of death were registered.

CLINICAL AND ANGIOGRAPHIC FOLLOW-UP: We performed clinical follow-up for 32 patients. These patients were examined by 1 of the members of the interventional neurosurgery service. Angiographic follow-up was obtained in 25 cases. Angiograms were performed between 3 months and 28 months from the original embolization (mean, 8 months). In the angiographic follow-up, 14 cases were unchanged (22.2%), 5 had minimal refilling around the aneurysm neck (7.9%) and 6 cases presented aneurismal recanalization (9.5%). In all 10 cases, when we embolized AcomA, there was no aneurysm recanalization registered in follow-up studies (Figure). All recanalization cases required further treat-

TABLE 2.

Anatomic characteristics of patients

Variables		Amount (%)
Aneurysm size	Small <3*mm*	7 (11.1%)
	Medium ≥3*mm* to <10mm	49 (77.8%)
	Large ≥10*mm* to <25*mm*	6 (9.5%)
	Giant ≥25*mm*	1 (1.6%)
Neck size	<4*mm*	50 (79.4%)
	≥4*mm*	13 (20.6%)
Dome-to-neck ratio	<2	43 (68%)
	≥2	20 (32%)
A1 hypo-/aplasia		30 (47.6%)
Raymond scale	1-complete obliteration	49(77.8%)
	2-neck remnant	13(20.6%)
	3-residual filling	1(1.6%)

Figure. A) *Diagnostic cerebral angiography, anterior-posterior view. Saccular aneurysm of AcomA (large arrow), patent AcomA (small arrow), right and left A1 segments of anterior cerebral artery.* ***B***) *Right carotid artery angiography – total occlusion of AcomA and aneurysm (small arrow).* ***C***) *Five month follow-up examination – absence of aneurysm refilling (small arrow)*

ment: 4 were considered to require a second embolization, and the other 2 cases have been managed by microsurgical clipping. All 5 aneurysms with minimal neck refilling were followed-up conservatively and looked stable over follow-up period.

Peri-Treatment Complications: Peri-treatment complications occurred in 9 cases (14.3 %). Aneurysmal rupture during treatment occurred in two cases. The bleeding was immediately stopped by instant insertion of coils. Thromboembolic episodes during treatment occurred in 5 patients. In four cases the episode was embolic and in one it was thrombotic and occurred at the aneurysmal neck region. These episodes resulted in one death in the case of an middle cerebral artery occlusion and accounted for additional neurological deficits in three patients. In one patient embolic complications were discovered on CT scan only. In one case there was an internal carotid artery dissection, which was managed by stenting. In one case intraarterial high dose Verapamil injection resulted in pulmonary edema and further death of patient two days after intervention. No post-treatment rupture and intraoperative death was registered in our series.

Additional Treatment: Symptomatic vasospasm occurred in eight (12.6%) patients with subarachnoid hemorrhages. Angioplasty was performed in two of these patients. Selective intra-arterial high dose verapamil (>50 *mg*) infusion during 1 hour was performed in 5 patients. One patient developed new CT ischemic lesions while sedated in the intensive care unit after the endovascular treatment.

Discussion

The AComA is the most common site of cerebral aneurysms, accounting for as many as 36% of aneurysms [*Brisman J et al., 2006*]. Treatment of these aneurysms includes microsurgical clipping and coil embolization. Since the introduction of the Guglielmi detachable coils in 1991 for the treatment of intracranial aneurysms, a growing number of ruptured and unruptured cases have been treated using endovascular techniques. In this study we present our first experience of endovascular treatment of anterior communicating artery aneurysms since introduction of this technique in Armenia in 2010. In our series endovascular treatment was attempted but failed in 2 cases, which occurred early in our practice. With introduction of new technical advancements, such as new microcatheters, guidewires, coils, assisting measures (balloons, stents), and strict judgement for suitability for endovascular treatment failure rate is diminished to zero. Complete occlusion of an aneurysm is a necessary treatment goal of both surgical and endovascular methods. Recanalization of incompletely treated aneurysms is well documented in the literature [*Koivisto T et al., 2000*]. In our series, the percentage of good angiographic occlusion (Raymond grade 1 and 2) achieved after initial treatment was 98.4% for ruptured aneurysms, which is the highest occlusion rate compared with other studies (Table 3). In the existing literature the rates of good angiographic occlusion range from 56.7% to 93% for anterior communicating artery aneurysms. A1 segment hypoplasia is

TABLE 3.

Literature review of outcomes of AComA aneurysms treated by coil embolization

Authors (year)	Study design	No of aneurysms	Unsuccessful attempt (%)	Good angiographic outcomes (Gr. I+II) (%)	Periprocedural complication rate (%)+++	Major recanalization or retreatment rate (%)
Moret J. et al. (1996)	Prospective	36	4 (12%)	21 (72.5%)	4 (11.1%)	4
EliasT. et al. (2003)	Prospective	30	0	17 (56.7%)	1 (3.3%)	3.3
Proust F et al. (2003)	Prospective	37	0	29 (78.4%)	5 (13.5%)	8.1
Birknes J. et al. (2006	Retrospective	123	12 (9.7%)	86 (69.9%)	6 (4.9%)	33.3
Gonzalez N. et al. (2008)	Retrospective	181	6 (3.3%)	167 (92.2%)	12 (6.6%)	11.3
Guglielmi G. et al. (2009)	Retrospective	306	12 (3.9%)	284 (93%)	17 (5.6%)	16.0
Finitsis S. et al. (2010)	Prospective	282	12 (4.3%)	230 (85.8%)	53 (18.7%)	19.0
Lee J. et al.(2015)	Retrospective	429	0	370 (86.2%)	4 (0.9)	7.9
Present study	Retrospective	63	2(3%)	62 (98.4%)	9 (14.3 %)	9.5

a common anatomical variant that is encountered frequently in patients with an AComA aneurysm [*Tarulli E et al., 2010; Krzyzewski R et al., 2014*]. In their study, Rinaldo L. and co-authors compared demographic and aneurysm characteristics of patients with and without A1 segment hypoplasia presenting with either a ruptured or an unruptured AcomA aneurysm. They found that patients with A1 segment hypoplasia were less likely to have a history of smoking and had larger aneurysms with a broader neck (i.e., lower dome-to-neck ratio). These results suggest that the hemodynamic changes resulting from a unilaterally hypoplastic A1 can precipitate aneurysm formation along the AcomA complex even in the absence of traditional risk factors. In cases, when AcomA was patent and there was no A1 segment hypo-/aplasia, we utilized technique of AcomA occlusion along with aneurysm embolization, which obviates hemodynamic shearing stress on AcomA aneurysm and prevents aneurysm recanalization, which we observed in all ten cases of our experience. In acute phase of a subarachnoid hemorrhage, our aim was first to secure the aneurysm from an eventual rebleeding. Attempts for a perfect treatment are made only if this does not involve excessive additional risk. This is even more important in the anterior communicating artery area were the involved arteries have a very small diameter. For ruptured aneurysms the outcome is conditioned by the initial clinical status: in the subgroup of patients with a good pre-treatment Hunt & Hess Grade (0-III), 75,5% were independent (MRS 0-2) [*Hunt W Hess R. 1968*]. In the subgroup of patients with a poor pre-treatment Hunt & Hess Grade (IV or V) only 30% had a good clinical outcome (MRS 0-2). This is a low rate, which corresponds to other reports on poor pre-treatment grade patients [*Bracard S et al., 2002; Weir R et al.,2003*]. The peri-treatment complication rate was 14.3%, resulting in mortality of 3.2% and a permanent morbidity of 4.76%. Previous reports have documented complication rates ranging from 8% to 17%, with morbidity rates of 3% to 6.5% and mortality rates of 0% to 6.5% [*Gruber et al., 1999, Solander Set al. 1999*]. In current studies the range of peri-treatment complications is 0.9%-18.7% (Table 3). The majority of peri-treatment complications were thromboembolic with a rate of 7.94%, a morbidity of 4.76% and a mortality of 1.6%. Additionally, one thrombotic episode occurred in the post-treatment period. In one patient thromboembolic complication was detected on follow-up CT scan only. The second most common peri-treatment complication was aneurysmal rupture during treatment that occurred in two cases (3.2%). The bleeding was immediately stopped by instant insertion of coils. In one case there was an internal carotid artery dissection, which was managed by stenting with Neuroform stent. In one case intra-arterial high-dose (80*mg*) verapamil injection resulted in pulmonary edema and further death of patient two days after intervention. No post-treatment rupture and intraoperative death was registered in our series. During a mean follow-up of 8 months there were 6 major (9.52%) and 5 minor (7.94%) recurrences. Raymond J. and co-authors (2003) report a recurrence rate of 33.6% with 20.7% major recurrences in a series of 501 aneurysms with a mean follow-up time of 31.3 months. Most recurrences occurred during the first year post-treatment, but some occurred even up to three years post treatment. Thus, extended follow-up seems to be mandatory. Four second endovascular retreatments and two surgical clippings were recorded. Most retreatments were performed during the first year after the initial treatment. There was no additional morbidity or mortality related to retreatments. In a series of 2759 aneurysms on different locations, the authors performed second retreatments in 350 (12.3%) aneurysms and three or more retreatments in 94 (3.4%) aneurysms with a low associated morbidity-mortality rate of 2.2% [*Henkes H et al., 2006*]. However, as the authors point out, the risk of retreatment has to be carefully weighted against the low risk of bleeding of partially filled aneurysms. The main limitations of our study were its retrospective nature and the lack of long clinical and angiographic follow-up data for a considerable percentage of patients.

Conclusion

Endovascular embolization is effective and less traumatic method for the treatment of anterior communicating artery aneurysm. Long period of follow-up is required to detect aneurysm regrowth and perform additional treatment to prevent late rebleeding. Occlusion of AcomA in case of its and A1 segments patency is safe and prevents aneurysm regrowth in selective cases.

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