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Management of Proximal (A1 Segment) Anterior Cerebral Artery Aneurysms: A Literature Review

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Abstract

Proximal or A1 segment anterior cerebral artery (ACA) aneurysms are rare aneurysms. They have certain unique properties when compared to all other intracranial aneurysms. They are smaller and prone to an early rupture. Thus, they need an aggressive intervention even when they are less than 7 mm in size. The technical difficulties that arise in their management are based on their location along the length and circumference of the ACA. Accordingly, they have been variously classified in literature. Their intimate relationship to the medial lenticulostriate perforators and the recurrent artery of Heubner is the prime factor in determining the surgical or endovascular strategy and outcome. These aneurysms are commonly associated with vascular anomalies, needing a thorough interpretation of preoperative angiograms. Though there are many series reporting the clinical features and management outcome of proximal ACA aneurysms, all are limited by a small sample size due to the rarity of the pathology. In this article, the pertinent literature related to the surgical nuances associated with dealing with A1 segment aneurysms is reviewed. The clinical presentation, associated anatomical characteristics, microsurgical management, role of endovascular therapy, and outcome are discussed.

Keywords
- proximal A1 segment
- aneurysm
- microsurgical clipping
- endovascular therapy
- anterior cerebral artery
- surgery

Introduction

Proximal (A1) segment anterior cerebral artery (ACA) aneurysms are rare and represent less than 1% of all intracranial aneurysms.[1–5] The high risk of intraoperative perforator injury, encountering an anomalous anatomy, and the presence of a small or a sessile aneurysm, make both surgical and endovascular management challenging. The frequent rupture and re-rupture of these aneurysms, the development of a parenchymal hematoma, and the difficulty in visualizing an aneurysm of this segment on angiography further complicate the treatment process. There are only a few case series and reports of A1 segment aneurysms.[1] We reviewed the literature to develop a consensus on their clinical presentation, anomalous anatomy, surgical nuances, endovascular management, and outcome.

Surgical Anatomy and Anomalies of Proximal ACA

The most accepted classification of ACA divides it into five segments, A1 to A5. The A1 segment, also known as the

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proximal segment, the precommunicating segment, or the horizontal segment, lies in the segment of ACA between the points of internal carotid artery (ICA) bifurcation and the origin of anterior communicating artery (AComA). Rest of the segments of ACA are the following: From the AComA to the genu is termed as the A2, the infracallosal or the vertical segment; the part of ACA running along the genu to the body of corpus callosum is called the A3 or the precallosal segment; from the distal point of the A3 segment to the coronal suture is termed the A4 (supracallosal) segment; and the distal part of the ACA from the coronal suture is termed as the A5 (posterocallosal) segment. This classification is at variance with the common misconception that the bifurcation of ACA should be considered as the dividing point between A4 and A5 segments. The bifurcation of ACA occurs mostly at the A3 segment when the main vessel trunk divides into the pericallosal and callosomarginal arteries.[1,6,7]

The proximal ACA, after its origin from the ICA lateral to the optic chiasm, travels medially and anteriorly over the optic nerve (in 30% cases) or the optic chiasma (in 70% cases).[6] The length of the A1 segment is variable, ranging from 7.2 to 18 mm (average 12.7 mm).[8] Multiple perforating branches arise from the A1 segment, more from its proximal part, gradually reducing in number distally. Most of these perforators arise from the posterosuperior surface and they rarely take origin from the inferior surface.[9] They may range from 2 to 15 (average 8) in number and their size varies from 1.5 to 3 mm. Their mean diameter is 2.3 mm.[6,9] They supply the chiasma, anterior third ventricle, and anterior hypothalamus. Their injury during proximal ACA aneurysm dissection, clipping, or their occlusion on coiling can lead to behavioral and cognitive impairment, including alteration in sensorium, without the development of any motor deficits. Another important branch that arises from the A1 segment in around 14% of the cases is the recurrent artery of Heubner.[8] It is usually encountered at the A1 segment of ACA on retracting the frontal lobe. It runs along with the proximal ACA retrogradely from its origin to end in the anterior perforated substance. It supplies the anterior part of the caudate nucleus, the anterior third of putamen, the anterior part of globus pallidus externus, the inferior portion of the anterior limb of the internal capsule, and the uncinate fasciculus. When injured, it may lead to contralateral hemiparesis with dominant faciobrachial weakness. Thus, the perforators and the recurrent artery of Heubner are the important branches of proximal ACA that need to be meticulously preserved during either surgical or endovascular intervention.

An anomalous anatomy of the proximal and distal ACA is frequently encountered with proximal ACA aneurysms.[10–15] Misidentification of vessels, leading to an injury to them, or resulting in an incorrect placement of the clips may occur. Hence, a preoperative knowledge of the anomalous anatomy, aided by angiographic findings may prevent intraoperative surprises and misadventures. The anomalies of proximal ACA are associated with nonregression of the ventral or the dorsal ophthalmic artery (VOA and DOA). The VOA arises from the ACA, and DOA from the cavernous ICA. They fuse to form the primitive ophthalmic artery, which later becomes the definitive ophthalmic artery. Failure of regression of DOA leads to the anomalous origin of ACA from the cavernous ICA. This anomaly poses a risk of aneurysm development. A1 segment fenestration is the most common anomaly noted with these aneurysms.[10] It may result from incomplete fusion, partial duplication, or persistence of a remnant plexiform anastomosis between the primitive olfactory artery and the ACA.[13,16–18]

The anatomical status of AComA and distal ACA may also vary and is equally important in deciding the surgical strategy. The presence of AComA allows the possibility of trapping the aneurysm as a collateral flow through the contralateral proximal ACA is provided. The proximal ACA segment may be single, multiple, or fenestrated. The variants of distal ACA have been classified by Baptista et al,[19] as azygous or unpaired (involving a common trunk in the A2 segment; type I), bihemispheric (which gives branches to both hemispheres; type II), and accessory (there is an additional vessel arising from AComA accompanied by two hypoplastic ACA in the A2 segment; type III) ACA.

Etiopathogenesis of Proximal ACA Aneurysms, and Their Classification

The A1 segment aneurysms are rare, with only a few case series reported on their surgical and endovascular management (►**Fig. 1** and ►**Table 1**).[10,20,21] Turbulent blood flow at the wide fenestration of proximal ACA or at the point of origin of the medial lenticulostriate arteries causes hemodynamic stress. This may be the underlying etiopathogenesis. It is backed by the finding that most A1 segment aneurysms are in their proximal part as compared to distal. It also explains why these aneurysms are blister-like and tend to rupture early.[22,23] These aneurysms are commonly associated with bilateral, co-occurrence of other intracranial aneurysms.[2,10,24–27] Giant proximal ACA aneurysms are rare.

The proximal A1 aneurysms were earlier classified by Wakabayashi et al and Yasargil.[20,28] Later Bhaisora et al classified these aneurysms based on the site of origin as proximal (near ICA bifurcation), distal (near AComA), and intermediate (between proximal and distal ends). They were further classified as anterior, posterosuperior, and posteroinferior based on the origin of neck of the aneurysm in relation to the circumference of the A1 segment. The classification is based upon the anatomical relationship of the aneurysm to its location, allowing for an adequate preoperative planning while anticipating the surgical difficulty. The proximal A1 segment aneurysms are the most common varieties followed by the middle and distal segment aneurysms.[10,21,29,30] Most of them originate and project posteriorly.[29,31] Concerning the morphology, saccular aneurysms are the most common aneurysms encountered, and most proximal A1 segment aneurysms are of this variety. Fusiform and dissecting aneurysms are more commonly seen in the middle A1 segment.[32,33] Blister aneurysms are also commonly seen

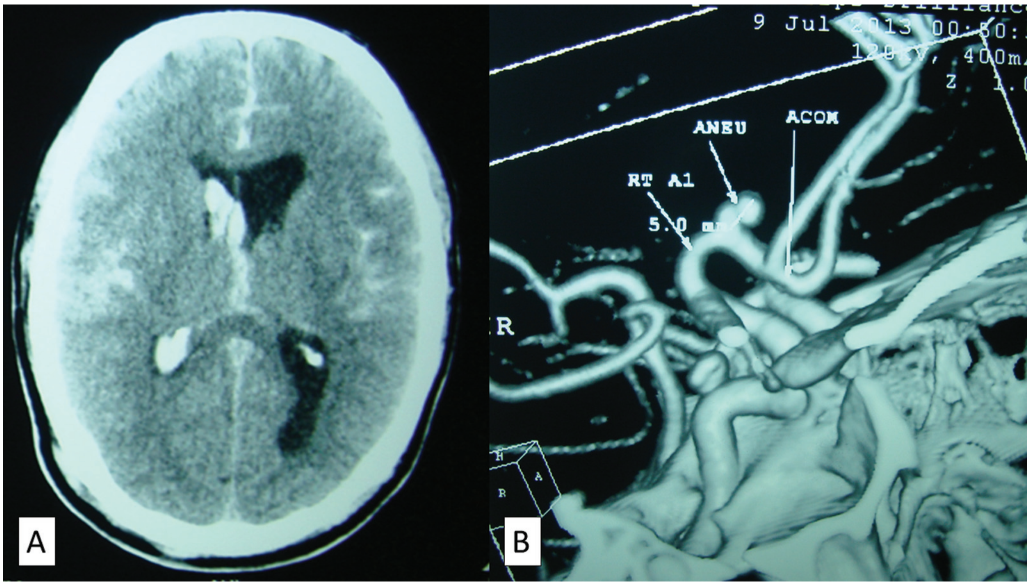

Fig. 1 Plain computed tomography (CT) scan showing diffuse subarachnoid hemorrhage along with intraventricular bleed. Ventriculomegaly is also present. The three-dimensional reconstruction CT angiography showed a 5-mm saccular aneurysm arising from the mid portion of A1 segment anterior cerebral artery (ACA). It is seen arising from the posterosuperior surface of ACA and is directed superiorly.

in the A1 segment of ACA. Ding et al suggested a similar classification system but they identified only the proximal (type I) and distal (type II) types based on the location of aneurysm longitudinally along the A1 segment of ACA. These were further subclassified based on the direction of fundus of the aneurysm. They included the fusiform or dissecting aneurysms as a separate subtype (termed the type III aneurysms). Most studies confirmed that the most common direction of the aneurysm in the proximal A1 segment is posterior, inferior in the middle segment, and superior in the case of distal A1 segment of ACA.[1,11,30] A classification system encompassing the aneurysmal relationship to the perforators in the vicinity, the status of distal flow/collateral circulation to distal ACA, the aneurysm morphology, and the associated anomalous anatomy would be a more comprehensive one in deciding the surgical strategy for proximal ACA aneurysms.

Clinical Presentation of Proximal ACA Aneurysms

Proximal ACA aneurysms frequently present following their rupture or are diagnosed as co-aneurysms with another ruptured aneurysm. Most studies concluded that the risk of rupture is higher in these aneurysms as compared to aneurysms at other sites. They are relatively smaller as compared to aneurysms at other sites.[11,20,27,31] A1 segment aneurysms often rupture when they are relatively smaller in size compared to other aneurysms.[30] The mean size of ruptured A1 segment aneurysms varied from 3.2 to 7 mm in the available literature.[3,27,29,34] Kim et al reported no significant relationship between the location of an aneurysm on the A1 segment and the risk of rupture; however, a higher rate of rupture in the distal A1 segment aneurysms was noted. The association with gender and side was variable in different studies. However, most studies reported A1 segment aneurysms to be more common in males and on the right side.[2,3,10,20,25,27,34–40]

Following the rupture of the aneurysm, most patients presented in a poor Hunt and Hess grade (grade 3–5).[1,26,27,34] Patients with distal as compared to proximal A1 segment aneurysms had relatively poorer grades. Occurrence of intraventricular bleed and acute hydrocephalus is common following their rupture.[2,10] Ruptured aneurysms, especially the posterosuperiorly directed ones, commonly may present with intracerebral hematoma involving the frontal gyrus in 16 to 29% cases.[1–3] A1 segment aneurysms have been reported in all age groups, but most of the series reported them in the mean age group ranging from 50 to 60 years.[1–3,34] The proximal A1 aneurysms occur in a relatively younger age group. Also, relatively younger patients were reported to present with a ruptured proximal A1 aneurysm.[11]

Radiological Features

The A1 segment aneurysms are frequently missed on angiography (computed tomographic angiography and digital subtraction angiography [DSA]) due to their small size, associated hematoma, overlapping A1 segments and perforators, associated multiple aneurysms at other sites, parent vessel vasospasm, and their being near the skull base. They are frequently misdiagnosed as ICA bifurcation aneurysms or as AComA aneurysms due to the close anatomical situation between these sites and a similar pattern of subarachnoid hemorrhage (SAH).[11,41] In some cases, especially in the case of posterosuperiorly directed aneurysms, where the fundus is embedded in the

Table 1 Reported series of A1 segment aneurysms treated with microsurgical clipping with number of cases ≥ 10

Series	Number of cases	Incidence	Age	Male gender	SAH	IVH	ICH	Right side	H HG	Location			Direction			Multiple	Anomaly	Size, mm			Mortality	Morbidity
				%						P	M	D	A	PS	PI			O	R	U		
Yasargil 1984[27]	14	1.4	46	100	14	–	1	4	–	2	6	6				3	1				1	GR 12, MD 12
Wakabayashi et al 1985[19]	10	2.1	48	33	8	–		9	–	7	2	1				4	2	3.6			1	GR 7
Suzuki et al 1992[10]	38	0.88	51	61	30	–	5	18	–							17	24				3	GR 34, MD 1
Hino et al 2002[25]	11	3.4	60	45	7	–	2	5	–	11	0	0				8	1	5.4			0	GR 10, MD 1
Dashti et al 2007[2]	23	0.8	–	–	12	–	3	14	–							16	–	4(1–15)			0	
Lee et al 2010[26]	20	0.59	52.15 (39–69)	20	18	–	1	10	–	9	11					4	3	6.9			1	GR 15, MD 2, SD2
Bhaisora et al 2014[1]	14	0.98	38.02 (5–68)	57	13	8	2	7	<3 = 8 iv = 5	6	1	7	2	5	7	2	6	(3–15)			3	GR 6, MD 3, SD 2

Abbreviations: GR, good response; HHG, Hunt and Hess scale; ICH, intracerebral hemorrhage; IVH, intraventricular hemorrhage; MD, major disability; SAH, subarachnoid hemorrhage; SD, sudden death.
Note: Location: P, proximal; M, middle; D, distal. Direction: A, anterior; PS, posterosuperior; PI, posteroinferior. Size: O, overall; R, ruptured; U, unruptured.

orbitofrontal cortex, there may be only parenchymal hematoma with no SAH following aneurysmal rupture.[1]

The various characteristics of the aneurysm as described in the classification of proximal ACA aneurysms should be evaluated on preoperative radiology. In addition to these points, the size of the fundus and its neck, presence of intracerebral hematoma and the associated mass effect, the Fisher grade of SAH (if SAH is present), and presence of hydrocephalus must be assessed (►**Table 1**).

Giant aneurysms of proximal ACA are rare.[42–46] When present, a cross-flow study across the AComA may be essential in the cases where clipping and reconstruction of the aneurysm are not possible, and these kind of aneurysms may require trapping. Multiple aneurysms have been reported in 10 to 70% of the cases.[2,10,20,21,25,26,30]

Management of Proximal ACA Aneurysms

Given the high risk of rupture of a small sized A1 segment aneurysm, obliteration of the aneurysmal sac is always recommended even when these kind of aneurysms are diagnosed incidentally.[2,3,11,27,30] This is against the recommendation for management of aneurysms at other locations, where definitive treatment is often deferred until the size of the aneurysm is more than 5 mm.[27,44–46]

Both microsurgical clipping and endovascular management of proximal ACA aneurysm are viable options. Most authors recommend microsurgical clipping due to the unfavorable anatomy present for the successful carrying out of endovascular management, like a small sessile aneurysm with a fragile wall present in the proximal ACA aneurysms. A variable vessel anatomy, multiple perforator origin, and A1 segment hypoplasia or aplasia may further tilt the balance in favor of surgical management.[2,37,47,48] These same characteristics make microsurgical clipping a challenging task as well. A formal comparison between the clinical outcome and cost-effectiveness between the two treatments options is still lacking.

Microsurgical Clipping

The microsurgical clipping of proximal ACA aneurysms requires an ipsilateral standard pterional craniotomy. The patient's head is kept in a neutral position with slight (10–20 degrees) rotation to the opposite side. Jang et al reported a greater turning of the head in proximal A1 segment aneurysms, as often a posterior direction of the fundus is encountered.[11] Minimally invasive techniques like the supraorbital keyhole approach or a modified pterional approach with a limited craniotomy may also be employed.[2] However, the variable anatomy that is often associated with these aneurysms is a specific deterrent in the utilization of these minimally invasive approaches.

Splitting of the proximal Sylvian fissure and opening of the optico-carotid cistern are the initial steps in all cases. Care is taken to avoid any retraction of the frontal lobe. Deep and wide splitting of the Sylvian fissure helps to avoid undue frontal lobe retraction.[1,34] Following cerebrospinal fluid release from the cisterns, adequate space is available to continue further dissection. The ICA or the middle cerebral artery is traced to the A1 segment of ACA. The aneurysm neck is then defined. In selected cases, the frontal horn of the lateral ventricle can be tapped through the modified Paine's point to relax the brain. Resection of the gyrus rectus, which is helpful in facilitating exposure in case of AComA aneurysms, is contraindicated in proximal ACA aneurysms, as the gyrus will be encountered distal to the aneurysm while approaching from the pterional route.

As perforators are encountered more often in the proximal than in the distal part of the A1 segment, and are arising and are being directed posterosuperiorly, aneurysms in this region need a careful dissection and clipping to avoid their injury.[49] They are most difficult to clip among all other types of A1 segment aneurysms, especially when sessile.[1] The posterosuperiorly directed aneurysms may be embedded in the frontal lobe, preventing a frontal lobe retraction during the exposure to avoid an early rupture of the aneurysm.[1,3] Distal and anteriorly directed aneurysms are easier to clip and can be approached with a wide Sylvian fissure splitting. The identification of the course of recurrent artery of Heubner is of particular importance in the case of the distal A1 segment aneurysms.[3] Thus, an adequate preoperative planning concerning the relationship between aneurysms and the perforators in the proximity is the key step for an A1 segment aneurysm management. The inferiorly directed aneurysms are rare. When present, they may adhere to the optic chiasma or the optic nerve.[3] The fundus of these aneurysms may often overlap the parent artery and their neck may have to be dissected meticulously from the trunk of the parent artery.[34]

A proximal temporary clip over the A1 segment may be hazardous due to a possible perforator injury, especially in cases where there is no collateral flow through the AComA. Similarly, distal temporary clips may aggravate the vasospasm in the A2 segment of ACA. Thus, temporary proximal as was as distal clip application may be attempted only in dire needs where there is premature rupture of the aneurysm, and is often not carried out routinely.

Surgical clipping gets difficult in the case of proximal A1 segment aneurysm due to the posterior direction of their fundus in most cases, in association with perforator origin at the neck, and the neck of the aneurysm being overlapped by the A1 main trunk.[11,27,30] Maiti et al suggested the use of the smallest possible clips to avoid clip rotation and subsequent tortuosity of the parent vessel.[3,34] Reinforced wrapping, use of fenestrated clips, and reconstruction using tandem clipping are the possible options for sessile or fusiform aneurysms.

Jang et al highlighted the important role of the endoscope, especially the 30- or 60-degree ones, in visualizing the perforators and in the detection of their kinking, in otherwise blind spots.[11] Intraoperative indocyanine green and micro-Doppler are other important intraoperative adjuncts that may aid in the successful clipping of these aneurysms, as they are helpful in avoiding the inclusion of perforators, the main trunk of the blood vessel or other anomalous vessels within the clips.

The reported surgical outcome in various series of proximal ACA aneurysms has been comparable to the outcome of aneurysms at other sites. Good recovery has been reported in 75% ($n = 15$), moderate disability in 10% ($n = 2$), and death in 5% ($n = 1$) of the patients in a surgically treated series of proximal ACA aneurysms by Lee et al. The outcome correlates with the preoperative neurological status or the preoperative Hunt and Hess grade.[1]

Endovascular Treatment

With successive improvements in the endovascular techniques, more and more complex aneurysms have been managed with a good outcome. Multiple series, though with small sample sizes, have reported successful endovascular management. They have also frequently described the associated technical difficulties.[2,10,20,21,31,34,50–52]

Due to the common encountered proximal location and the posterior direction of A1 segment aneurysms, the tip of the microcatheter needs to be curved and conformed on a case-to-case basis. Different shapes like the "S shape," "Z-shape," or "straight" tip of microcatheters have been reported.[29,53] Successful utilization of stent-assisted coiling, balloon-assisted coiling, and flow-diverters have been reported in recent series.[29] Perforator infarction remains a significant complication and a definitive evidence of their safety needs further investigation.[54,55]

A major drawback with endovascular management of proximal ACA aneurysms is their incomplete occlusion ►**Tables 2** and **3**. Kim et al reported that incomplete occlusion of the aneurysm is more common in proximal A1 segment aneurysms (22.2%) as compared to the middle and distal sites (10%). Zhang et al reported complete occlusion in 80% of their cases at follow-up evaluation.[29] Most perforating arteries may not be visible on DSA.[31,34] This may lead to their inadvertent occlusion and the subsequent development area of an infarcted are at the corresponding site. Procedure-related complications following endovascular management of these aneurysms have been reported in 15.8% of the patients by Liu et al.[56]

Conclusion

Proximal ACA aneurysms are rare and are anatomically unique. They have a distinct clinical presentation and are also special in terms of the decision making required for their management. It is recommended to aggressively obliterate the proximal ACA aneurysms even when they are small. Both microsurgical clipping and endovascular therapy have reported good outcomes, with progressive improvement in the management with endovascular therapy. These aneurysms pose technical challenges during their management due to their unique location, their fundi being surrounded by perforators, and the unique morphology of the parent vessel.

Table 2 Reported series of A1 segment aneurysms treated with endovascular therapy with $N \geq 10$

Series	No cases	Incidence	Age	Male gender	SAH	IVH	ICH	Right side	H &H	Location			Direction			Multiple	Anomaly	Size, mm			Mortality	Morbidity
				%						P	M	D	A	PS	PI			O	R	U		
Chang et al 2011[46]	12	1.64	51	25	3	–	–	6	G0: 9 G2: 3	9	3	1	2	2	9	8	–	4.4	4.5	4.3	1	GR 12
Xiaochuan et al 2013[50]	15	–	53.9	13.3	0	–	–	–	G 0: 15					15			–	5.12				GOS 5: 15
Ko et al 2013[54]	11	–	55.6	36.3	5	–	–	8	< 3: 9, > 4: 2	5	4	2	1	4	6	4	–					mRS 0: 10 mRS 2: 1
Cho et al 2014[30]	48	–	57.8	45.8	7	–	–		< 3: 46, > 4: 2	39	6	5				33		3.9				GOS 3: 1 GOS 4: 1 GOS 5: 46
Liu et al 2016[55]	38	1.7	53.8	12	20	–	–	21	< 3: 19 4: 1	22	7	9	4	1	33	10	12		3.6	6.1	1	mRS 0: 34 1 = 3
Zhang et al 2017 [28]	30		50.6	59.4	19	2	2		1–2: 15 3–4: 4							9		3.2				mRS 0–1 = 22 3 = 1 5 = 1
Li et al 2020[51]	15	1.25	50.9	20	15			8	< 3: 11 > 4: 4							8					2	mRS0: 6 1 = 5 4 = 1 5 = 1

Abbreviations: GOS: Glasgow Outcome Scale; GR, good response; H&H, Hunt and Hess scale; ICH, intracerebral hemorrhage; IVH, intraventricular hemorrhage; mRS, modified Rankin scale; SAH, subarachnoid hemorrhage.
Note: Location: P, proximal; M, middle; D, distal. Direction: A, anterior; PS, posterosuperior; PI, posteroinferior. Size: O, overall; R, ruptured; U, unruptured.

Table 3 Reported series of A1 segment aneurysms treated with microsurgical clipping and endovascular therapy with $N \geq 10$

Series	No cases	Incidence	Age	Male gender	SAH	IVH	ICH	Right side	HHG	Location			Direction			Multiple	Anomaly	Size, mm			Mortality	Morbidity
				%						P	M	D	A	PS	PI			O	R	U		
Park et al 2013[33]	15	1.8	56.1	40	7			10	< 3: 6 4: 1	14		1	1	3	7	6	2	3.26			1	GR Sx 8 Endo 3 SD Sx 1
Maiti et al 2016[3]	17	1.71	52.5	37.5	8		2	6	< 3: 6 4: 2	8	4	5	4	11	2	8	5	5.46	4.38	6.23	1	GR Sx 4 Endo 6
Ding et al 2017[34]	42	1.76	54	53.6	34			23	1–2: 25, 3–4: 13	26	0	9		16	19	7	7	< 5: 27 > 5: 15			3	GR 33 MD 4
Yilmaz et al 2014[35]	15	2.1		33		4	3	7		13		2				5	5				0	GR 15
Kim and Lim 2019[29]	32	1.89	31–83	53	18			19	G0: 13 1–3: 12 G4–5: 6	16	7	7	2	6	22	13	13	4.1			2	SD 1

Abbreviations: Endo, endovascular; GR, good response; HHG, Hunt and Hess scale; ICH, intracerebral hemorrhage; IVH, intraventricular hemorrhage; MD, major disability; SAH, subarachnoid hemorrhage; SD, sudden death; Sx, surgery.
Note: Location: P, proximal; M, middle; D, distal. Direction: A, anterior; PS, posterosuperior; PI, posteroinferior. Size: O, overall; R, ruptured; U, unruptured.

Conflict of interest
None declared.

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