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Original Article

Stent-Assisted Embolization for Acutely Ruptured Aneurysm

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Objective: The purpose of this study was to report the results of stent-assisted embolization performed at our hospital for acutely ruptured aneurysms.

Methods: This study consisted of 19 patients (4 men and 15 women) with acutely ruptured wide neck aneurysm who underwent stent-assisted coil embolization in acute stage between December 2016 and October 2020. Stent-assisted embolization in the acute stage was performed for very wide neck ruptured aneurysm only when balloon-assisted embolization was failed or was thought to be impossible. Factors related to poor clinical outcome were examined.

Results: There were nine internal carotid artery (ICA) aneurysms, four anterior communicating artery (AcomA) aneurysms, three basilar artery (BA) aneurysms, two vertebral artery (VA) aneurysms and one anterior cerebral artery (ACA) aneurysm. The stents used were one Neuroform EZ and 18 Neuroform Atlas (Stryker). The contrast of the bleb disappeared in all cases with obvious bleb. Complete obliteration was achieved in two cases, neck remnant was in ten, and body filling was in seven. Both of the complete obliteration cases developed thrombotic complications. Modified Rankin score of 0–2 was observed in eight patients (good clinical outcome), whereas that of 4–6 was observed in 11 patients (poor clinical outcome). Several factors possibly affected to poor clinical outcome were examined and only age over 80 years was statically different. Complications related to procedure occurred in five patients; two cases of in-stent thrombosis, one case each of MCA perforation, stent occlusion, and coil fracture.

Conclusion: Stent-assisted coil embolization using Neuroform EZ and Neuroform Atlas could be considered as an emergency treatment for acutely ruptured cerebral aneurysms with very wide neck. It is rarely indicated in patients with age over 80 years.

Keywords ▶ stent-assisted embolization, subarachnoid hemorrhage, Neuroform Atlas, ruptured aneurysm

Introduction

Since the introduction of coil embolization, there have been several advances in the devices used for the management of cerebral aneurysm. Recently, several adjunctive techniques expand the indication of coil embolization. Stent-assisted embolization is one such adjunctive technique that is extremely useful for wide neck aneurysms. However, it is not covered by insurance for acutely ruptured aneurysms; nonetheless, it is performed at advanced medical facilities even for acutely ruptured aneurysms.

This study reports the results of stent-assisted embolization performed at our hospital for acutely ruptured aneurysms in the acute stage. In addition, it discusses the applications of acute phase stent-assisted embolization.

Materials and Methods

This study consisted of 19 serial patients (4 men and 15 women) with acutely ruptured wide neck aneurysm who underwent stent-assisted coil embolization in the acute stage between December 2016 and October 2020 in our hospital. Embolization was performed within 72 hours after onset of subarachnoid hemorrhage. Surgical selection,

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clipping or coiling, was made based on the discussion between craniotomy team and intravascular team. If both were available, coiling was selected. Stent-assisted embolization was performed for very wide neck ruptured aneurysm only when balloon-assisted embolization was failed or was thought to be impossible. Their ages ranged from 46 to 91 years, with a mean age of 71.6 years (**Table 1**).

Factors possibly related to poor clinical outcome were examined. The factors examined were age, Hunt and Kosnik grade, maximum aneurysm diameter, the aneurysm location, trial coiling prior to the stent placement, presence of complications, and occurrence of rerupture.

Embolization

The initial setup for stent-assisted embolization was similar to that for an embolization procedure for a ruptured cerebral aneurysm without stenting. Heparin was administered immediately after inserting the guiding sheath. Activating clotting time (ACT) was controlled as two times of initial level. An 8-Fr balloon guiding catheter was generally used for internal carotid artery (ICA) aneurysms, whereas a 6-Fr or 8-Fr guiding catheter was used for an aneurysm at any other site. While setting the stent-assisted embolization, a gastric tube was inserted and clopidogrel was administered for 300 mg. The loading agent was prasugrel of 20 mg instead of clopidogrel in the latter nine patients. A microcatheter (Exceisior SL-10; Stryker, Kalamazoo, MI, USA) was navigated to the distal portion of aneurysm to guide the stent and another microcatheter was placed in the aneurysm dome for coil insertion. The aim of embolization was disappearance of a bleb, if there was obvious bleb. Clopidogrel, a daily dose of 75 mg, was continued for 6 months, and cilostazol, a daily dose of 200 mg, was additionally administered after embolization at least for 12 months. No aspirin, argatroban, or heparin was administered.

There were a little difference in embolization method between the early period (until December 2018) and the late period (beginning from 2019). The stent-assist embolization was following attempts of simple coiling and/or balloon assistance in the early period, but initial treatment without attempts in the late period. The ICA aneurysms were almost only target for stent-assist coiling in the early period, whereas the aneurysms other than ICA were also target in the late period.

Considering the lack of insurance coverage for stent placement in case of an acutely ruptured aneurysm, we conducted the procedure only after explaining the possibility that it would be necessary and ensuring that the family understood the financial implications. A clinical ethics committee was established at our hospital in 2020, which approved the acute phase off-label use of stent-assisted embolization (approved number: RinRin20-5).

Factors related to poor clinical outcome were examined using Student's *t*-test.

Results

There were nine ICA aneurysms, four anterior communicating artery (AcomA) aneurysms, three basilar artery (BA) aneurysms, two vertebral artery (VA) aneurysms, and one anterior cerebral artery (ACA) aneurysm. The stents used were one Neuroform EZ (Stryker) and 18 Neuroform Atlas (Stryker). Stent-assisted embolization was performed from the beginning in 11 patients, whereas following simple coiling in two and balloon-assisted coiling in five. External ventricular drainage was performed before embolization in three patients and after embolization in two, and lumber drainage was performed after embolization in six. No complication was observed related to drainage.

Table 2 summarizes the possibly related factors for poor clinical outcome (modified Rankin scale [mRS] score is 4 or worse). Age over 80 years alone shows statistically significant differences.

The contrast of the bleb disappeared in all cases (**Table 1**, **Fig. 1**). Complete obliteration was achieved in two cases, neck remnant was in ten, and body filling was in seven. Both of complete obliteration cases developed thrombotic complications. One AcomA aneurysm ruptured a day after the embolization (Case 16). The embolization result was neck remnant with disappearance of a bleb in this patient. The last coil was stretched and fractured during withdrawal. So, the tail of the fractured coil was navigated into the external carotid artery (ECA).

There were five cases with complications. They comprised two cases of in-stent thrombosis, one case each of middle cerebral artery (MCA) perforation by the stent shaft, stent occlusion, and coil fracture.

Additional embolization was performed in three cases during the follow-up period.

Discussion

The previous strategy for the embolization of very wide neck ruptured aneurysms in our hospital was partial

Table 1 Profile of the patients

	Age (Years)	Sex	H & K Grade	Site*	Maximum diameter (mm)	Trial	Stent (Neuroform)	Location of distal end of stent*	CSF drainage before embolization**	CSF drainage after embolization**	Result***	Re-rupture	mRS score (1M)	Re-embolization	Remark
1	46	F	3	VA	6	no	Atlas	PICA	no	V	BF	no	1		
2	47	F	5	ACA	6.2	no	Atlas	A3	no	L	CO	no	4		stent occlusion, Fig. 4
3	54	M	2	ICA	5.7	simple	Atlas	ICA	no	No	NR	no	0	12 M	
4	62	M	3	AcomA	4.3	no	Atlas	A2	no	L	NR	no	1		
5	64	M	5	AcomA	8	no	Atlas	A2	V	No	NR	no	4		
6	65	F	4	AcomA	11.1	rescue	Atlas	A2	No	L	NR	no	1	8 M	
7	67	F	2	BA	7.1	no	Atlas	PCA	No	No	NR	no	0		Fig. 2
8	69	M	3	ICA	8.2	balloon	Atlas	ICA	No	L	BF	no	4		in-stent thrombosis
9	69	F	3	VA	3	no	Atlas	PICA	No	No	CO	no	0		in-stent thrombosis, Fig. 3
10	71	F	2	ICA	10.5	balloon	Atlas	ICA	No	No	NR	no	0	6 M	
11	72	F	3	ICA	7	balloon	EZ	ICA	No	No	NR	no	0		
12	72	F	2	ICA	17	no	Atlas	ICA	No	No	NR	no	6		MCA perforation
13	80	F	4	ICA	9.1	balloon	Atlas	ICA	V	No	BF	no	4		
14	84	F	2	BA	16	no	Atlas	PCA	No	No	BF	no	6		
15	85	F	2	ICA	5.5	simple	Atlas	ICA	No	L	NR	no	4		
16	86	F	5	AcomA	17.5	no	Atlas	A2	No	V	NR	yes	6		
17	88	F	4	ICA	5	balloon	Atlas	PcomA	No	No	BF	no	6		
18	89	F	3	BA	6	no	Atlas	PCA	V	No	BF	no	4		Fig. 1
19	91	F	4	ICA	11	no	Atlas	ICA	no	L	BF	no	5		

* A2, 3: 2nd or 3rd portion of anterior cerebral artery, ACA: anterior cerebral artery, AcomA: anterior communicating artery, BA: basilar artery, ICA: internal carotid artery, PCA: posterior cerebral artery, PICA: posterior inferior cerebellar artery, PcomA: posterior communicating artery, VA: vertebral artery

** L: lumber drainage, V: external ventricular drainage

*** BF: body filling, CO: complete obliteration, NR: neck remnant

Table 2 Factors possibly related to poor clinical outcome

N = 19	Yes (poor outcome)	No (poor outcome)	P value
High age (≥80 years)	7 (7)	12 (4)	<0.01
H and K grade 4–6	7 (6)	12 (5)	0.07
Large diameter (≥10 mm)	6 (4)	13 (7)	0.62
Other than ICA aneurysm	10 (5)	9 (6)	0.75
Trial coiling prior to stent placement	7 (4)	12 (7)	0.96
Incomplete packing (BF)	7 (6)	12 (5)	0.07
Complication	5 (4)	14 (7)	0.29
Rerupture	1 (1)	18 (10)	0.41

BF: body filling; ICA: internal carotid artery

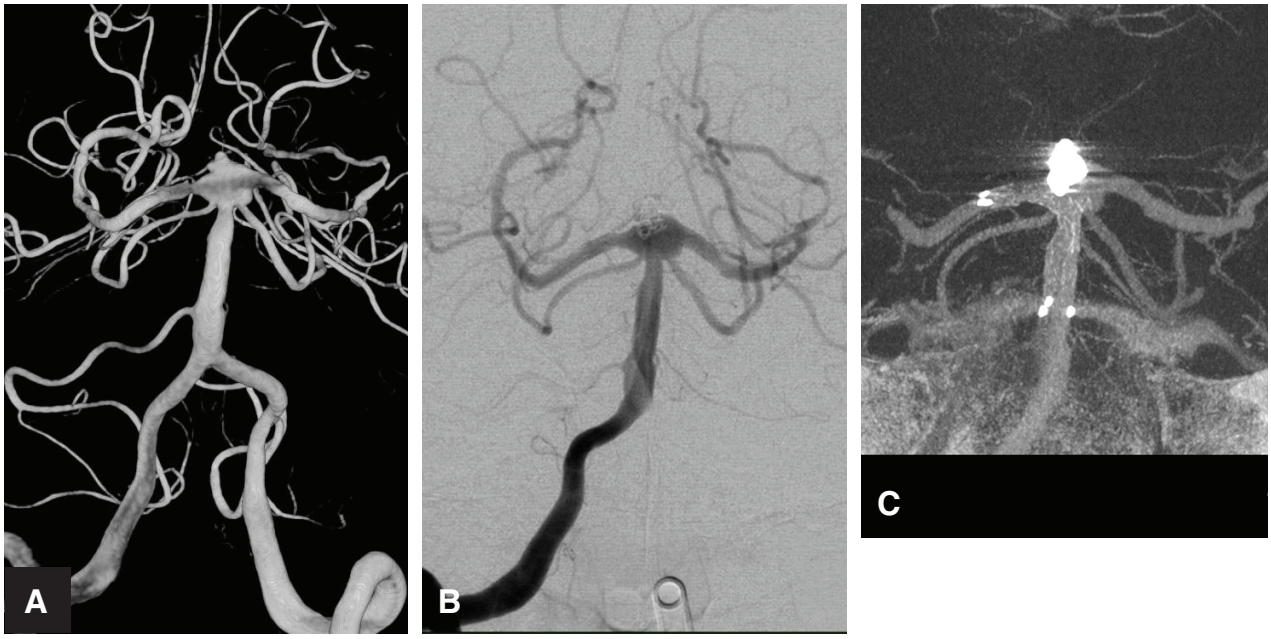

Fig. 1 Anteroposterior views of the right vertebral artery injection in case 18. (**A**) A 3D DSA prior to the embolization shows basilar tip aneurysm with obvious bleb on the top. Bilateral P1 and superior cerebellar artery originate from the aneurysm dome. (**B**) DSA following an embolization using two coils, namely 3 mm × 8 cm and 2.5 mm × 4 cm, and the Neuroform Atlas (4.5 × 21 mm). No visible bleb. (**C**) Cone beam CT following coil scaffolding by the embolization showing the stent.

embolization including the rupture point during the acute stage, followed by a supplemental stent-assisted embolization 2 weeks after the onset in chronic stage. Acute stage stent-assisted embolization have already been performed outside Japan during the aforementioned period and its effectiveness has also been reported.[1,2] A review published in 2011[3] reported a higher rate of complications and poorer outcomes, following an acute stage stent-assisted embolization, compared to cases without a stent. According to a South Korean study in 2014, acute stage stent-assisted embolization had an extremely limited range of indications.[4] Our hospital disapproved acute phase stent-assisted embolization based on the above-mentioned reviews.

However, some patients with acutely ruptured VA dissection underwent stent-assisted embolization in our hospital. This can be attributed to the significance of preserving the parent artery on the dominant side. The Japanese registry of neuroendovascular therapy 1 and 2 records the domestic cases that required stent assistance during the acute stage.[5] Furthermore, several domestic conference presentations have been made on the use of stent-assisted embolization during the acute stage. We first performed stent-assisted embolization in December 2016.[6] We decided to perform the procedure in situations with no other options after this case. We conducted eight cases of stent-assisted embolization out of 74 acutely ruptured saccular cerebral aneurysm cases since the policy revision

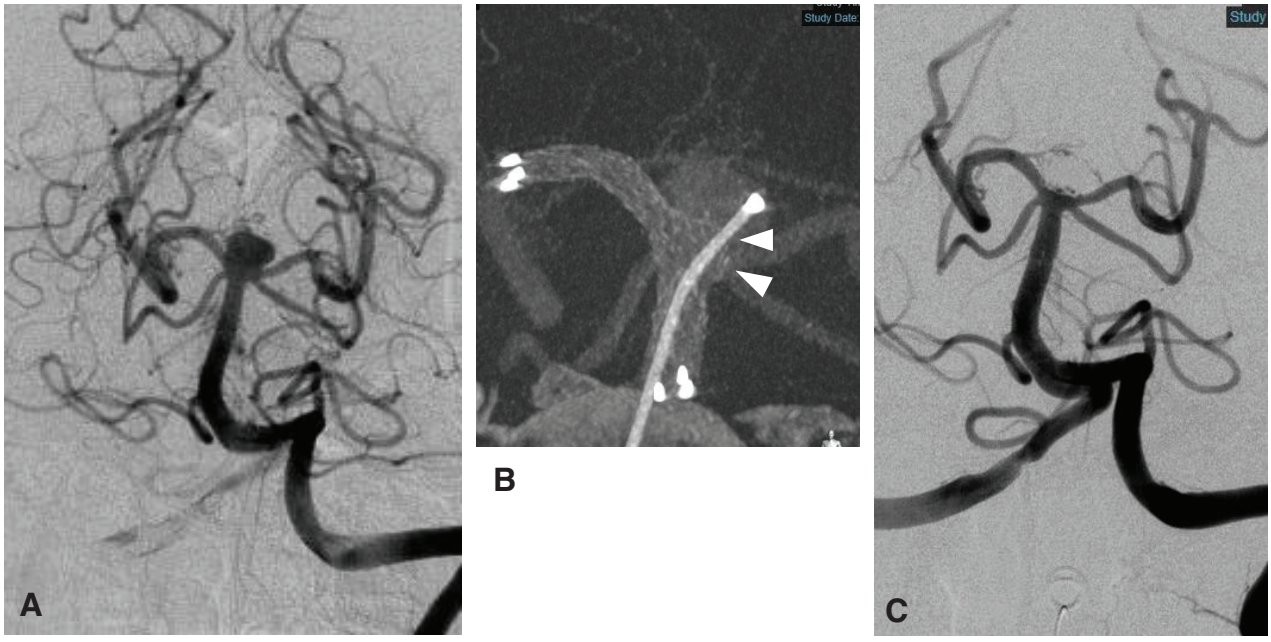

Fig. 2 Anteroposterior views of the left vertebral artery injection in case 7. (**A**) A DSA prior to the embolization shows basilar tip aneurysm. Bilateral P1 and SCA originate from the aneurysm dome. (**B**) Cone beam CT following the deployment of the Neuroform Atlas (4.0 × 21 mm). The stent is bulging and preserving the left P1 and left SCA (white arrowheads). (**C**) DSA following an embolization using nine coils with the preservation of the bilateral P1 and SCA. SCA: superior cerebellar artery

until the end of 2018. The use of acute phase stent-assisted embolization was slightly relaxed, from 2019 onwards. The primary change comprised considering stent assistance, following diagnostic angiography, without attempting simple coiling or balloon assistance. Moreover, the change included indicating the procedure for aneurysms with smaller diameters and at a peripheral position than the ICA. The aforementioned changes increased the rate of stent use for ruptured aneurysm embolization in the acute stage from 10.8% (8/74) to 18.0% (11/61) of cases. The reason why stent-assisted embolization rate is so high would be due to indication for coil embolization in our hospital. Surgical clipping was performed in 68 patients with acute subarachnoid hemorrhage in this same period. Most of them were MCA aneurysms (44/68). Our strategy is coil-first fashion, so we tend to perform stent-assisted embolization rather than surgical clipping if we encounter very wide neck aneurysm.

The Neuroform Atlas, the successor of Neuroform EZ, is a low-profile stent that can be delivered through an SL-10 microcatheter. SL-10 is the standard microcatheter for aneurysmal embolization, so it can be used for coil insertion and for stent placement in the same session. Neuroform Atlas stents are suitable for an artery with a diameter of up to 4.5 mm. They can fit into the bends owing to their open-cell design, thus increasing their suitability for ICA aneurysms. The Neuroform Atlas was reportedly effective for acutely ruptured aneurysms.[7–9] As the percentage of metal coverage is not high in these stents, they can be used safely even in the acute phase wherein thrombotic complications are a concern due to the inadvisability of strong antiplatelet therapy.[10,11] Moreover, its open-cell design facilitates an easy expansion of the Neuroform Atlas within the aneurysm beyond the parent artery diameter (**Fig. 2**). This quality allows the preservation of blood vessels, branching from the aneurysm.[12]

There were only eight patients with clinically good outcome (mRS 0–2) out of 19 patients (42.1%). The patient population in this study have wide neck aneurysm not treatable by stent-assist embolization else. The other option was surgical clipping, but our craniotomy team hesitated clipping because of high grade, high age, etc. So, the patients would be treated conservatively, if stent-assisted embolization was not performed. The outcome of the patients who were conservatively treated is very poor even in nowadays. Recent report showed that good outcome ratio of conservatively treated aneurysmal subarachnoid hemorrhage patients are about 10%.[13] So, the good outcome ratio of 42.1% is not so bad for the population in this study. Several factors were examined for clinically poor outcome, and age over 80 years was the only factor related to clinically poor outcome. The

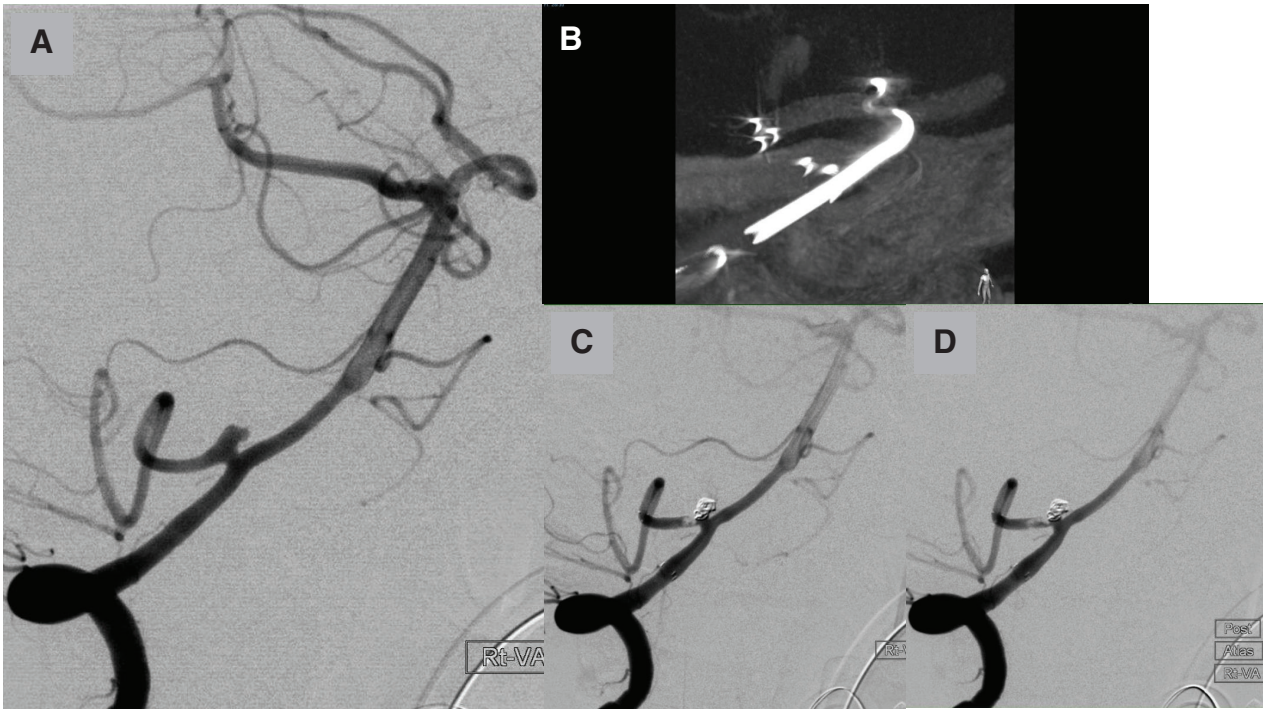

Fig. 3 Right anterior oblique views of the right VA injection in Case 9. (**A**) A 3D DSA prior to the embolization showing VA aneurysm. PICA originates from the aneurysmal dome. (**B**) Cone beam CT, following the deployment of Neuroform Atlas (3.0 × 21 mm), showing the scaffolding of coils by the stent. The DSA immediately after embolization, 3 mm × 8 cm and 2.5 mm × 4 cm. No visible bleb. (**C**) DSA after an embolization using three coils shows an in-stent thrombus at the site of coil placement. There was no neurological deficit. (**D**) DSA conducted 30 min later to that shown in (**C**). Ozagrel sodium has been intravenously administered during this duration. Thrombus still exists; however, there are no neurological deficits. Thus, the patient was returned to the ward. MRI revealed good patency of the right PICA, the following day (not shown). PICA: Posterior inferior cerebellar artery; VA: vertebral artery

clinically good outcome was 8 patients out of 12 in younger group (<80 years). We recommend stent-assisted embolization in acute stage is restrictedly indicated in patient over 80 years of age.

Our primary aim was an embolization of the assumed rupture site especially obvious bleb, without particular concerns about tight packing to the neck. Thus, we could achieve an embolization of the target site in all cases. Embolization grade was not related to poor clinical outcome. Furthermore, a rerupture occurred in one case that comprised an AcomA aneurysm with maximum diameter of 17.5 mm. We could achieve a considerably tight packing, including the assumed rupture site. The cause of rerupture was unlikely the primary goal of an assumed rupture site embolization, rather it may be best to not strive for a complete obliteration in acute stage stenting. This can be attributed to the occurrence of thrombotic complications in the two cases in which complete obliteration was achieved (**Fig. 3**). That may indicate that complete obliteration is too much for stent-assisted embolization in the acute stage.

Recent reports from overseas have identified the rupture prevention effect of acute stage stent-assisted embolization.[14–16] However, the incidence of thrombotic complications remains high. The use of antiplatelet drugs is recommended even in acutely ruptured cases while using a stent. The co-administration of a clopidogrel loading dose and aspirin is common in such cases.[17,18] We administer a 300-mg loading dose of clopidogrel alone, because we considered it preferable to avoid the administration of multiple antiplatelet drugs in acutely ruptured cases. This can be associated with our goal of preventing rebleeding and the low necessity of strong antiplatelet therapy with Neuroform Atlas. Stent occlusion occurred in one ACA case (**Fig. 4**). Glicoprotein (GP) IIb/IIIa inhibitors cannot be used in Japan; therefore, the aforementioned technique must be carefully performed in small artery, such as the ACA.

An acute stage stent-assisted embolization is an acceptable option for selected patients due to both the accumulation of knowledge from overseas cases and the introduction of new stents. However, the patients are not reimbursed for the stents due to the absence of an insurance coverage.

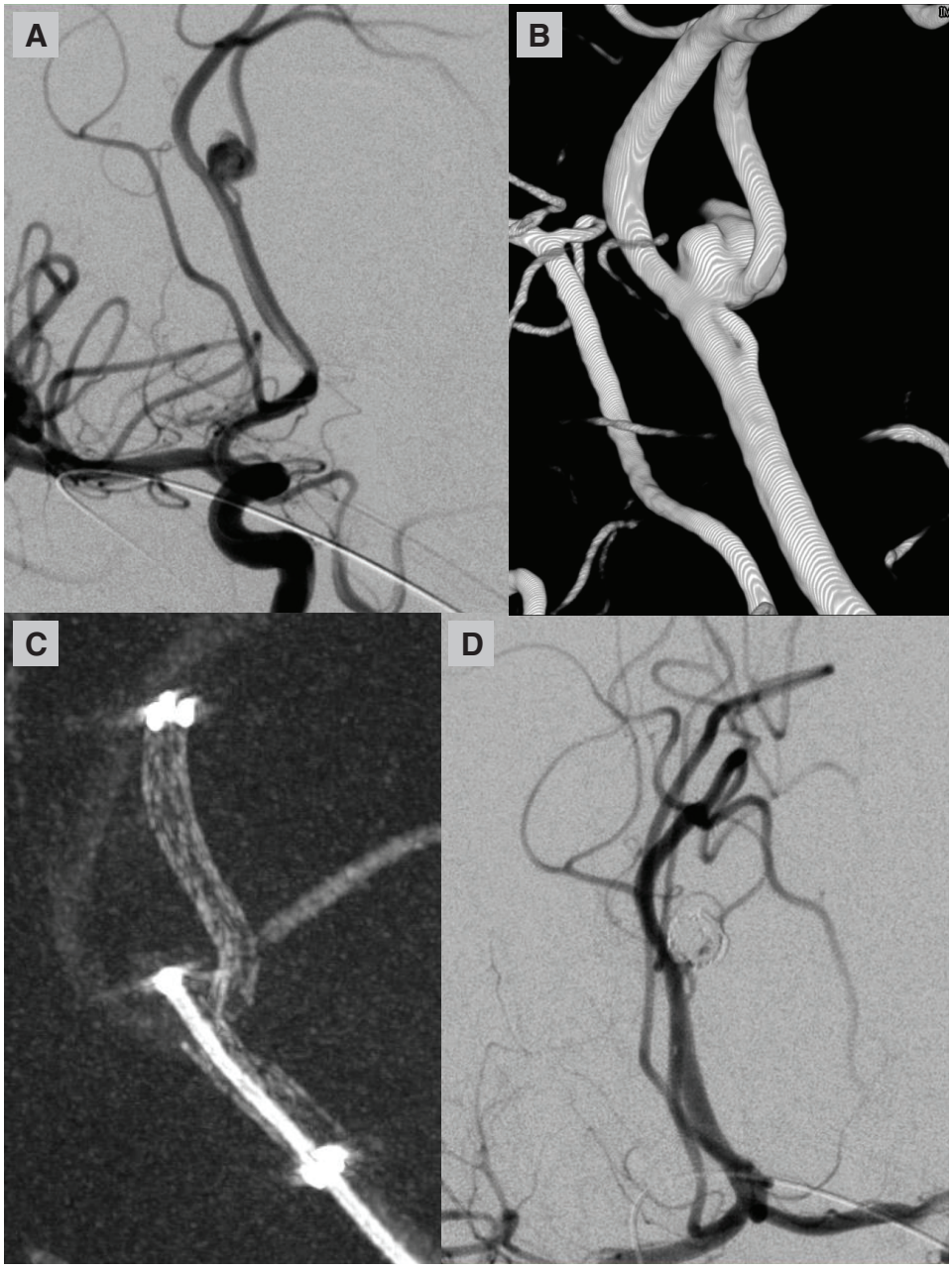

Fig. 4 Left anterior oblique views of the right internal carotid artery injection in case 2. (**A**) A DSA conducted prior to the embolization showing an aneurysm at distal end of the azygos anterior cerebral artery. (**B**) A 3D DSA showing the origin of the left pericallosal artery from the aneurysmal dome. (**C**) Cone beam CT, following the deployment of Neuroform Atlas (3.0 × 21 mm). The stent is bulging and preserving the left P1 and left superior cerebellar artery. (**D**) A DSA following an embolization using three coils. The left pericallosal artery is not visible. CT demonstrated cerebral infarction in the left pericallosal artery territory, the following day (not shown).

Therefore, we strongly advise caution against excessive off-label use.

Conclusion

Stent-assisted coil embolization could be considered as an emergency treatment for acutely ruptured cerebral aneurysms with very wide neck. It is, however, rarely indicated in patient with age over 80 years.

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Disclosure Statement

The authors declare that they have no conflicts of interest.

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