[15, 18]. In addition, they are often associated with high morbidity and mortality rates. While BBA is usually a tiny and broad-necked aneurysm, such an aneurysm occasionally demonstrates a relatively saccular-like shape on an angiogram. Additionally, the pseudoaneurysm sac often assumes a saccular shape.

In this paper, the authors present their experience in treating these saccular-shaped BBAs endovascularly with coil packing.

Methods and materials

Patient population

The authors reviewed the records of all patients with ICA BBAs who presented with SAH who underwent endovascular treatment between January 2006 and August 2010 in Nagoya University Hospital and its affiliated hospitals. Nine saccular-shaped ruptured BBAs in nine patients (one male and eight females; mean age of 51.3 years, range 38–76) were treated with coil packing of the saccular cavity. Those patients were diagnosed as ruptured BBAs by typical angiographical findings, or any rapid configurational change in the aneurysm. Aneurysms that appeared to be authentic saccular types [18, 21] were excluded. Clinical features, treatment methods, procedure-related complications, and clinical and angiographic outcomes were retrospectively evaluated.

Clinical and angiographic follow-up

Using the Hunt and Hess grading system, initial clinical assessments were performed on admission. Clinical outcomes were evaluated at discharge or clinical follow-ups according to their Glasgow Outcome Scale (GOS) scores. GOS indicates score 1: good recovery (GR), 2: moderate disability (MD), 3: severe disability (SD), 4: vegetative state (VS), and 5: death (D). Each patient's clinical status at the last follow-up was defined as the final outcome.

An angiographic follow-up was performed at least once before discharge. After discharge, an MR angiogram (MRA) and/or X-ray imaging study were performed once a week for about 1 month, and once every 2–4 weeks for 3 months, postoperatively. A subsequent follow-up interval was scheduled, depending on the interventionalists' requirement. Whenever these images indicated an aneurysm recurrence, an angiogram was considered for minute investigation.

Endovascular treatment

Neurosurgeons and interventionalists have thoroughly discussed the issue of treatment strategy. Endovascular coil embolizations were chosen after considering angiographical images, patient clinical condition, and the procedural risks of complication compared to other treatment options.

All procedures were conducted with the patient in a state of general anesthesia or deep sedation. A 6-Fr sheath was inserted at the femoral artery, and a 6-Fr guiding catheter was placed at the ICA. A 10-type microcatheter was meticulously navigated to the aneurysm with a microwire guide. A balloon microcatheter was navigated to the ICA C1–C2 portion where the BBA neck was located.

Detachable coils were carefully inserted into the cavity and deployed in the usual manner. When the coil loops easily protruded into an ICA and were not compactly placed within the sac, they were deployed with balloon assistance. However, the balloon was inflated as moderately as possible, given that ICA BBAs were potentially fragile and posed a risk of rupture. Softer coils were preferred in coil selection. No stent-assisted coil embolization was performed, since intracranial stents were not then available in Japan.

Heparin was usually not given either during or after the procedure, nor was antiplatelet therapy administered during the periprocedural period.

Results

A clinical and interventional summary is presented in Table 1. Patients' Hunt and Hess grades were II in 1, III in 4, IV in 3 and V in 1. Three patients were treated in an acute period (0–3 days after onset), two in a subacute period (6–13 days after onset), and four in a chronic period (after 14 days after onset). In both subacute cases, initial angiograms did not clearly show the aneurysm, whereas repeated angiograms obtained in the subacute period disclosed the BBA. Therefore, treatment was performed in the subacute period. Seven BBAs were treated by balloon-assisted coil embolization, while the two remaining BBAs were embolized without balloon inflation, though a balloon catheter was on standby at the ICA.

In case 8, saccular coil embolization was initially planned for the early period. However, the detachable coils were not compactly stabilized inside the pseudoaneurysm sac and readily protruded into the ICA despite the balloon assistance, which resulted in aneurysm trapping with parent artery occlusion. ICA trapping was successfully performed while preserving the posterior communicating artery (PcomA) and the anterior choroidal artery (AchoA). However, postoperatively, severe ischemia was induced by initial brain damage and subsequent vasospasm. Thus, a large hemispheric infarction developed, and the patient died 13 days after the procedure.

One (11.1%) intraoperative rupture occurred during coil insertion into the aneurysm sac (case 6). In that case,

Table 1 Summary of clinical characteristics, treatment, and clinical angiographic outcomes in nine patients with BBAs of the ICA

Case number	Age	Sex	Side	Hunt and Hess grade	Adjunctive technique	Treatment period[a]	Intraprocedural rupture	Recurrence	Clinical outcome (GOS)[b]
1	50	F	Rt	II	Balloon standby	Acute	None	None	GR
2	50	F	Lt	III	Balloon-assisted	Subacute	None	Yes (twice)	GR
3	39	F	Lt	IV	Balloon-assisted	Acute	None	Yes	GR
4	66	F	Lt	IV	Balloon-assisted	Chronic	None	None	GR
5	52	F	Rt	V	Balloon-assisted	Chronic	None	NA	D
6	76	F	Lt	III	Balloon-assisted	Chronic	Yes	None	MD
7	39	M	Rt	III	Balloon-assisted	Chronic	None	None	GR
8	52	F	Lt	III	Balloon-assisted (Coil embolization not achieved. Trapping performed)	Acute	None	NA	D
9	38	F	Lt	IV	Balloon standby	Subacute	None	None	GR
	Mean age 51.3 (range 38–76)	M, 1 (11.1%)	Rt, 3 (33.3%)	II, 1 (11.1%)	Balloon-assisted, 6 (66.7%)	Acute, 3 (33.3%)	1/9 (11.1%)	2/7 (28.6%)	GR, 6 (66.7%)
		F, 8 (88.9%)	Lt, 6 (66.7%)	III, 4 (44.4%)	Balloon standby, 2 (22.2%)	Subacute, 2 (22.2%)			MD, 1 (11.1%)
				IV, 3 (33.3%)	Trapping, 1 (11.1%)	Chronis, 4 (44.4%)			D, 2 (22.2%)
				V, 1 (11.1%)					

[a] Treatment period. Acute, day 0–3 after onset, Subacute, 4–13, Chronic, after 14

[b] GOS, Glasgow Outcome Scale; GR, good recovery; MD, moderate disability; D, death

NA, not available

recourse to balloon inflation immediately after recognizing the extravasation of contrast medium and further coil deposition, resulted in terminating the bleeding. Post-procedural computed tomography (CT) revealed a small increase of SAH, and the patient's clinical condition slightly deteriorated. As a result, though the patient gradually recovered in the following months, she still suffers a minor motor deficit, as well as moderate neuropsychological impairment (GOS score, 2). In that case, no aneurysm recurrence or rebleeding was observed in the follow-up study.

Six patients (66.7%) had excellent clinical outcomes (GOS score, 1) and two (22.2%) had fatal outcomes (GOS score, 5).

During the follow-up period (mean 18.9 months, range 4–48), two out of seven (28.6%) aneurysms that presented with angiographical recurrence were both treated with saccular coil embolization (cases 2 and 3). Those recurrences emerged within several weeks after embolization without rebleeding. The remaining four aneurysms (71.4%) were completely resolved during the follow-up period.

Illustrative cases

Case 2

A 50-year-old woman visited the emergency department, complaining of severe sudden onset of headaches, and a CT scan revealed diffuse SAH. She was diagnosed as a Hunt and Hess grade III-SAH. However, the angiogram carried out on the next day demonstrated neither any apparent intracranial aneurysm nor other bleeding source. (Retrospectively, a small irregularity at the anterior wall on the right ICA was suspected) (Fig. 1a). The patient was, therefore, treated conservatively. Repeated angiogram obtained 10 days after onset revealed a right ICA aneurysm that showed a saccular-like shape (Fig. 1b). Therefore, coil embolization was performed with balloon assistance. A total of three coils were inserted into the aneurysm cavity (Fig. 1c). No procedural complications occurred. The patient was discharged without any neurological deficit. The follow-up angiogram obtained 4 weeks later demonstrated an aneurysm recurrence (Fig. 1d). The aneurysm neck was enlarged, and the coil mass was compressed. A second embolization uneventfully resolved this recurrence (Fig. 1e). During the following 9 months, re-recurrence of the aneurysm gradually developed (Fig. 1f). This time, a third embolization was done without complications (Fig. 1g, h). After 2 years, no aneurysm recurrence has been observed. The patient has shown no neurological deficit, and her clinical outcome is excellent (GOS score, 1).

In this case, the fact that initially coiling of only the pseudoaneurysm sac, which had no normal wall corresponding to the dissected part of the ICA, could not dispose of the lesion completely, and could not prevent the aneurysm recurrence. However, it might prevent the fatal rebleeding, and finally, after the repeated embolizations, the lesion was entirely resolved.

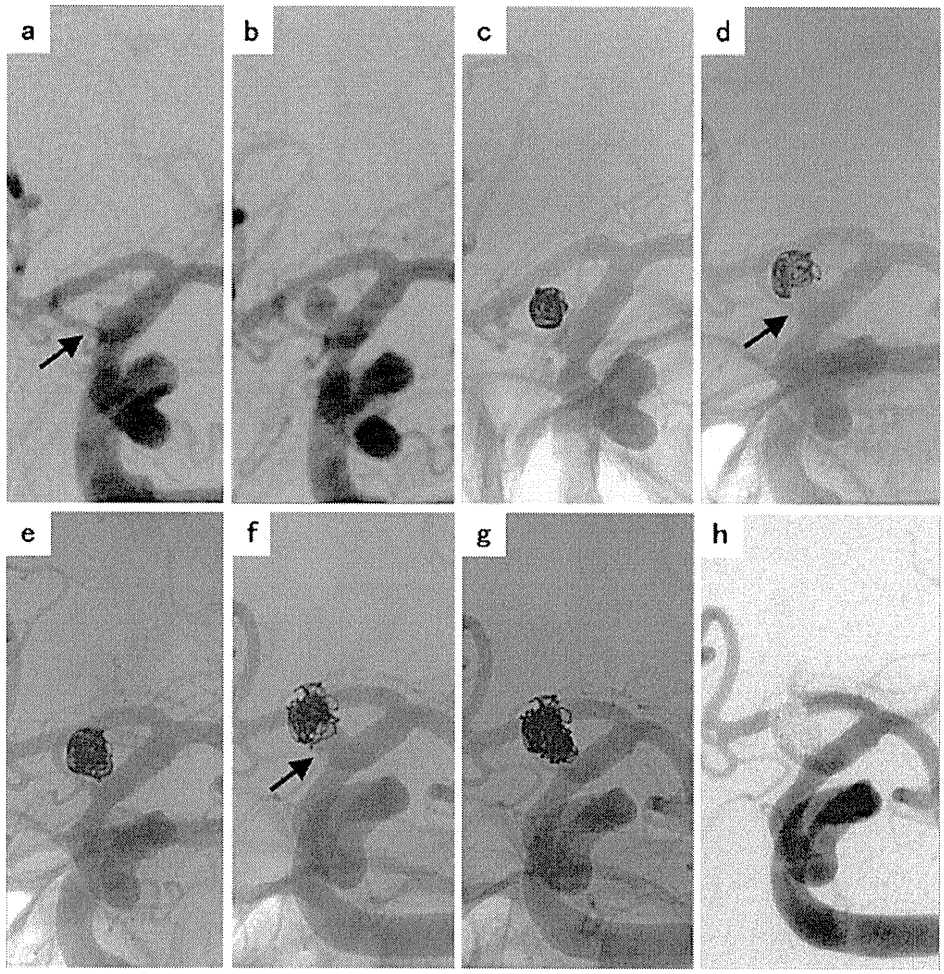

Fig. 1 Case 2. **a** Left ICA angiogram acquired the day after symptom onset demonstrating a suspicious small irregularity at the anterior wall on the ICA *(arrow)*. **b** Repeated angiogram 10 days later disclosing a saccular-shaped BBA of the ICA. **c** Angiogram acquired after endosaccular embolization by a balloon-assisted technique, showing near complete occlusion of the aneurysm. **d** Angiogram 1 month later, demonstrating coil compaction and regrowth of the aneurysm *(arrow)*. **e** Angiogram obtained after second embolization. **f** Angiogram 9 months later, revealing regrowth of the aneurysm neck *(arrow)*. **g**, **h** Angiogram obtained after third embolization (**g** non-subtraction image, **h** subtraction image) demonstrating complete occlusion of the BBA

Case 7

A 39-year-old man presented with a Hunt and Hess grade III-SAH. Cerebral angiogram demonstrated a broad-based bulge on the anterior wall of the right distal ICA (Fig. 2a, b). The patient underwent a right frontotemporal craniotomy and wrapping of this unclippable BBA without an intraprocedural rupture. On postoperative day 10, MRA revealed a remarkable configurational change in the aneurysm with a rapid growth of the pseudoaneurysm sac (Fig. 2c, d). In this patient, both PcomA and AchoA originated so close to the aneurysm that ICA trapping was believed to be impossible. Since his aneurysm seemed to be amenable to endovascular coiling, he was then treated by coil embolization of the saccular pseudoaneurysm sac on postoperative day 14. A total of four coils were placed inside the sac with balloon assistance (Fig. 2e, f), and no complications (including an aneurysm rerupture) occurred during the procedure. The patient recovered well at discharge and returned to his usual job despite a very mild neuropsychological impairment (GOS score, 1). Follow-up MRAs obtained 3 and 16 weeks later demonstrated no aneurysm recurrence (Fig. 2g, h). The anterior wall of the ICA was found to have become smooth at a 16-week MRA (Fig. 2h).

In this case, packing of the aneurysm cavity might achieve the stabilization of the weak part of the lesion without full exclusion of the vessel wall itself. That effect helped the spontaneous remodeling of the affected ICA.

Discussion

Clinical features of BBAs

Internal carotid artery BBAs are characterized by extremely fragile and thin walls that make therapeutic management difficult and hazardous, both surgically, as well as endovascularly [15, 18]. BBAs exclusively arise at non-branching sites of the supraclinoidal ICA, and are variously referred to as "dorsal wall" [21] and "anterior wall" ICA aneurysms [20], or "ICA trunk aneurysm" [18]. BBAs usually present various typical angiographical findings (e.g., tiny hemispheric bleb, broad-based bulge, irregular protrusion of the anterior wall of

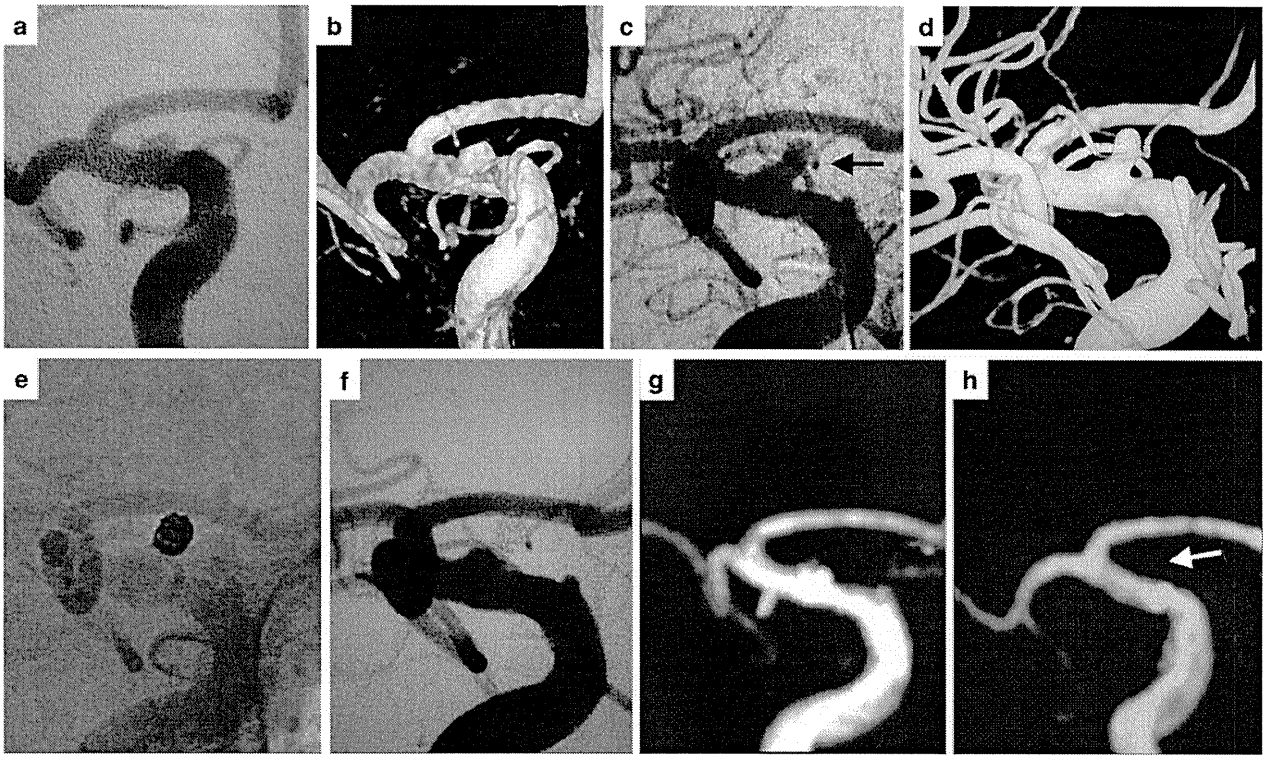

Fig. 2 Case 7. **a** Right ICA angiogram acquired the day after symptom onset demonstrating a BBA; broad-based bulge on the anterior wall of the right distal ICA. **b** Initial three-dimensional (3D) reconstruction angiogram also showing the BBA of the ICA. **c**, **d** (**c** conventional angiogram, **d** 3D angiogram): Angiogram obtained 14 days after wrapping that discloses a remarkable configurational change in the aneurysm with a rapid growth of the pseudoaneurysm sac *(arrow)*. **e**, **f**: Angiogram acquired after coil embolization by a balloon-assisted technique, showing complete occlusion of the pseudoaneurysm sac. **g**, **h** MRA performed 3 and 16 weeks after embolization, respectively, demonstrating no regrowth of the aneurysm. Anterior wall of the ICA was found to have become smooth at a 16-week MRA *(arrow)* (**h**)

the ICA, and rapid configurational change or regrowth). In our series, ruptured BBA patients were diagnosed based on these findings. Aneurysms that appeared to be authentic saccular type, which could be considered ordinary aneurysms with an obviously firm neck and a saccular dome, were excluded in order not to confuse the matter. The pathogenesis of BBAs remains unclear. Several studies suggest that BBA may not be a true saccular aneurysm, but rather a specific type of pseudoaneurysm or dissecting aneurysm [7, 21]. Ishikawa and his colleagues reported in their article that BBA appears to be a laceration of the carotid wall based on degeneration of the internal elastic lamina [7]. Hemodynamic stress probably plays an important role in the formation of BBAs because the anterior wall of the ICA is curved, where the flux of blood flow impinges on the vessel wall. Mizutani et al. classified cerebral dissecting aneurysms into four types. According to their classification, BBAs may be type 4 dissections. Type 4 dissections have focal defects of the internal elastic lamina covered by a thin layer of fibrous tissue and adventitia, and lack the usual collagenous layer, a condition similar to a BBA [17]. Therefore, treatment should not be focused on the BBA sac alone, but also on the affected wall of the ICA itself. Thus, as in a ruptured vertebral artery dissecting aneurysm, ICA trapping seems to be the most favorable treatment method. However, ICA trapping should not be indicated for all patients with BBAs. Depending on the case, the insufficient collateral flow and the originating sites of the essential branches, such as PcomA and AchoA, may make ICA trapping not feasible [19].

Clinical aspects of saccular embolization for BBAs

Though BBA is usually a tiny and broad-necked aneurysm, it often shows rapid configurational changes and occasionally demonstrates a relatively saccular-like shape; a pseudoaneurysm sac often assumes a saccular configuration [13]. The authors treated these saccular-shaped BBAs endovascularly with coil packing of the saccular cavity. This strategy can preserve the ICA flow, though the risks of regrowth and rebleeding remain.

Our series demonstrated satisfactory clinical results and acceptable complication rates, with seven out of nine

patients (77.8%), with BBA showing good outcomes (GOS scores, 1–2). Though embolization itself cannot dispose off the lesion completely, we consider that it may temporarily reduce the lesional activity. Consequently, that effect helps the affected ICA wall to heal spontaneously over a period of several weeks or months [16].

Actually, in some cases, the occlusion of a BBA initially achieved by saccular embolization can prevent recurrence and rebleeding for a long period. In other cases, embolization may also temporarily prevent recurrence and rebleeding, though it may be insufficient to prevent BBA regrowth/rebleeding. Thus, a very short-term angiographic follow-up is mandatory. In our series, two of seven patients (28.6%) who had a regrowth of their aneurysm underwent an additional coil embolization, uneventfully. Subsequently, both recurrent BBAs have been stable. Fortunately, rebleeding was not observed in our series.

As for the treatment time, it might be better to wait until the subacute or chronic phase when the wall of the lesion becomes more stable and sometimes progresses to a more saccular appearance for coil embolization to be successful, while not overlooking the risk of aneurysm rerupture.

Recently, there have been some reports on the endosaccular embolization of BBA [1–4, 13–15, 19, 23]. Table 2 shows a summary of BBAs treated by saccular coil embolization previously described in the literature (initial stent-assisted coil embolization cases are excluded). Among those 22 cases, 15 (68.2%) saccular coil embolizations were not followed by additional treatment. Intraoperative ruptures occurred in only two (9.1%). Although the recurrence/regrowth rate was high (38.1%), in 14 of 22 patients (63.6%), a good recovery was confirmed. As for the treatment time, the acute period and subacute/chronic period were 9 (40.9%) and 13 (59.1%) of 22 patients, respectively. These results were similar to the data obtained in our series.

Technical aspect of saccular embolization for BBAs

In fact, BBAs are difficult to treat with coil embolization, owing to their small size, wide neck, and location, making it technically difficult to place coils in the cavity [15]. Appropriate steam-shaping of the microcatheter tip and a balloon-assisted technique may help to overcome the difficulty of coiling the BBA. An appropriately-shaped microcatheter tip and positioning of the balloon in ICA help to prevent catheter kickback during embolization. Moreover, a balloon positioned across the BBA may be used to dam the flow of the ICA if a BBA were to rupture during the procedure. Among our cases, only one intraprocedural rupture

Table 2 Summary of 22 patients with BBAs of the ICA undergoing endosaccular embolization, previously described in the literature and our series

Authors	Case number(s)	Hunt and Hess grade	Treatment period	Procedure	Intraprocedural rupture	Clinical outcome	Recurrence/Reglowth
Ahn JY, et al. [1]	1	III, 1	Acute, 1	Coil, 1	None	GR, 1	None
McNeely PD, et al. [14]	1	II, 1	Subacute, 1	Wrap→Coil→Coil, 1	None	GR, 1	1
Tanoue S, et al. [23]	1	IV, 1	Chronic, 1	Coil, 1	None	MD, 1	None
Ezaki Y, et al. [4]	1	IV, 1	Chronic, 1	Surgery attempt→Coil, 1	None	MD, 1	None
ParK JH, et al. [19]	3	II, 2	Subacute, 2	Coil→Coil, 1	1	GR, 1	3
		IV, 1	Chronic, 1	Coil→Stent/Coil, 1		VS, 2	
				Wrap→Coil→ET, 1			
Doorenbosch X, et al. [3]	1	II, 1	Chronic, 1	Coil→Stent, 1	None	GR, 1	None
Meling TR, et al. [15]	3	II, 1	Acute, 3	Coil, 2	None	GR, 2	NA
		IV, 1		Coil (attempt)→ET, 1		D, 1	
		V, 1					
Baskaya MK, et al. [2]	1	IV, 1	Acute, 1	Coil→DT with bypass, 1	None	GR, 1	1
Lee CC, et al. [13]	1	II, 1	Acute, 1	Coil→Proximal occlusion, 1	None	GR, 1	1
Our cases	9	II, 1	Acute, 3	Coil, 7	1	GR, 6	2
		III, 4	Subacute, 2	Coil→Coil, 2		MD, 1	
		IV, 3	Chronic, 4	Wrap→Coil, 1		D, 2	
		V, 1		Coil (attempt)→ET, 1			
Total	22	II, 7 (31.8%)	Acute, 9 (40.9%)	Coil alone, 15 (68.2%)	2/22 (9.1%)	GR, 14 (63.6%)	8/21 (38.1%)
		III, 5 (22.7%)	Subacute, 5 (22.7%)	Coil→Stent, 2 (9.1%)		MD, 3 (13.6%)	
		IV, 8 (36.4%)	Chronic, 8 (36.4.%)	Coil→Trap, 5 (22.7%)		VS, 2 (9.1%)	
		V, 2 (9.1%)				D, 3 (13.6%)	

Coil, saccular coil embolization; Trap, trapping; Stent/Coil, stent-assist coil embolization; Wrap, wrapping; DT, direct trapping; ET, endovascular trapping

GR, good recovery; MD, moderate disability; VS, vegetative state; D, Death; NA, not available

occurred, and balloon inflation then proved very useful to control the bleeding (case 6).

Stent-assisted coil embolization may be a useful and considerable option for stabilizing the inserted coils inside such a tiny aneurysm [9, 10, 12, 19]. However, the presence of a stent makes microcatheter manipulation difficult, and perioperative anticoagulate/antiplatelet therapy is mandatory for intracranial stenting. Moreover, from a technical standpoint, stent deployment within the affected ICA, potentially involves the risk of vessel rupture.

In their recently published paper, Hong and colleagues presented a variation of the semi-jailing, stent-assisted technique as applied to blister-type aneurysms [5]. Coils are first placed in the vicinity of the aneurysm neck, and the stent is subsequently deployed to constrain the coils within the aneurysm. This technique seems to be a new treatment option, but the technical difficulty and potential risk related to stenting must be further investigated.

Alternative treatment

Various surgical strategies have been reported, including parallel clip placement, wrapping, clip-on wrapping, and ICA trapping with, or without a bypass. Regardless of the surgical modality, direct surgical approaches pose a high risk of premature intraoperative rupture and ICA laceration [15, 18, 21, 22]. As was shown in one of our cases (case 7), wrapping of the aneurysm does not seem to prevent regrowth.

Recently, an extracranial–intracranial (EC–IC) high-flow bypass, followed by trapping of the aneurysm occluding the ICA, has been reported [2, 6, 8]. This strategy may achieve complete aneurysm occlusion, thus, preventing severe postoperative cerebral ischemia due to ICA occlusion. However, preparing a high-flow bypass for SAH patients still poses a technical difficulty, while the direct approach to ICA results in a higher incidence of premature rupture.

Various endovascular strategies have also been documented, including endovascular trapping [19], overlap stenting, and flow-diverter stenting [9, 11, 12]. Endovascular ICA trapping is an optimal treatment for patients' tolerance to ICA obstruction. However, it is difficult to precisely evaluate the result of balloon occlusion tests for SAH patients, as shown in one of our cases (case 8). Furthermore, as was already mentioned, endovascular trapping is unsuitable when PcomA or AchoA originates too close to the lesion. Although an EC–IC bypass and endovascular trapping also constitute one treatment option, the risk of thromboembolic or hemorrhagic complications must also be considered in this combined therapy.

Overlap stenting or flow-diverter stenting can preserve the flow of a parent vessel and may overcome the drawbacks of saccular embolization [9, 11, 12]. However, the potential risk of regrowth/rebleeding in relation to perioperative anticoagulate/antiplatelet therapy remains. Recurrent SAHs during anticoagulate/antiplatelet therapy may prove fatal for the patient. Furthermore, as already mentioned, stent deployment within the affected ICA runs the potential risk of vessel rupture. However, it is expected that the development of new stent technology that promotes vascular neointima formation and generates less platelet activation and aggregation might suffice to overcome such problems.

Conclusions

Endovascular coil embolization can be considered as an alternative treatment option for the saccular-shaped BBAs in selected patients for whom ICA sacrifice is not feasible.

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Conflict of interest None.

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Retrospective Survey of Endovascular Treatment for Ruptured Intracranial Aneurysm in Japan: Retrospective Endovascular Subarachnoid Aneurysm Treatment (RESAT) Study

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Abstract

Annual retrospective surveys of 20 to 31 medical centers performing endovascular treatment of cerebral aneurysms in Japan from 1997 to 2008 were performed to analyze technical and clinical outcomes of endovascular treatment for ruptured cerebral aneurysm. Patients treated with dome embolization using bare platinum coils within 14 days after onset were retrospectively selected, and clinical features, and technical and clinical outcomes at discharge were studied. Retrospective Endovascular Subarachnoid Aneurysm Treatment (RESAT) 1 covers patients treated from 1997, when the Guglielmi detachable coil was introduced, to 2002, just after International Subarachnoid Aneurysm Trial was reported. RESAT 2 to RESAT 7 were conducted annually between 2003 and 2008. Among 5,624 patients with ruptured aneurysms treated within 14 days after onset, 4,782 patients were treated by dome embolization using platinum detachable coils. The patients in this large retrospective survey included 35.8% aged over 70 years, 36.6% with posterior circulation aneurysms, and 29.3% with poor grades (Hunt and Kosnik grades IV and V). The proportion of patients aged over 70 years tended to increase each year from 33.4% in RESAT 1 to 39.8% in RESAT 7, and the proportion of those with posterior circulation aneurysms decreased from 44.2% in RESAT 1 to 23.8% in RESAT 7 ($p<0.001$). Overall technical success was obtained in 4,666 patients (97.6%), and favorable clinical outcome (good recovery and moderate disability) at discharge was obtained in 88.0% of grade I–III cases and 73.6% of grade I–V cases. Procedure-related morbidity was 2.9% and mortality was 0.8%. Despite this survey involving high proportions of aged, posterior circulation, and poor-grade patients, the technical success rate and immediate clinical results were relatively favorable. The patient prognosis and aneurysm changes must be investigated over a longer period, together with the effects of the introduction of new endovascular devices for cerebral aneurysms.

Key words: subarachnoid hemorrhage, ruptured aneurysm, endovascular treatment, clinical survey, International Subarachnoid Aneurysm Trial

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Introduction

Subarachnoid hemorrhage is associated with mortality rates of 32% to 67% and long-term dependence in 10% to 20% of survivors because of the resultant brain damage.[5] Early treatment within 24 to 72 hours has been recommended for ruptured aneurysms, because the risk of subsequent rupture is high, with approximately 20% of patients experiencing another rupture in the first 2 weeks after subarachnoid hemorrhage.[8]

Following the introduction of Guglielmi detachable coils (GDCs) in Japan in 1997, surgical and endovascular treatment modalities have been available for ruptured cerebral aneurysms. Initially, surgically difficult aneurysms such as basilar bifurcation aneurysms were treated using detachable platinum coils.[4] However, a prospective randomized trial, the International Subarachnoid Aneurysm Trial (ISAT), reported that endovascular treatment of ruptured cerebral aneurysms with detachable coils was superior to surgical clipping as defined by the proportion of patients dead or disabled at 1 year among 2,143 of 9,559 patients deemed suitable for either therapy.[10] Since then, coil embolization has been increasingly used as an alternative to surgical clipping. More recently, the risk of death at 5 years was significantly lower in the coiled group than in the clipped group in the long-term follow up of the patients registered in the ISAT.[9]

The Retrospective Endovascular Subarachnoid Aneurysm Treatment (RESAT) studies 1 to 7 tried to determine the status of endovascular treatment for ruptured aneurysms in Japan from the GDC launch until just before the ISAT report was published for comparison with the ISAT data, and to elucidate how ISAT influenced the top Japanese medical centers annually from 2003 to 2008.

Clinical Material and Methods

A total of 13,711 patients with ruptured or unruptured cerebral aneurysms underwent endovascular treatment conducted by members of the study group (from 31 different institutions; both surgical and endovascular treatments were possible, and endovascular treatments were conducted by board-certified senior trainers) between January 1997 and December 2008. Among them, 5,624 patients underwent endovascular treatment, of whom 4,782 patients were treated by dome embolization using platinum detachable coils within 14 days after onset. These 4,782 patients were analyzed in this study.

The following clinical factors were studied: age, sex, location and size of the aneurysm, duration after onset, neurological grade (Hunt & Kosnik grade), technical complications and type (ischemic, hemorrhagic, or others), and repeated bleeding and retreatment within the annual study period. The Glasgow Outcome Scale (GOS) of disability at discharge was used for evaluation of patient outcome. A death was included in the mortality rate if it occurred within the annual study period. Morbidity was evaluated when the patient was discharged from the institute.

Timing, indication, and method of endovascular treatment and perioperative therapy such as antithrombotic therapy, cerebrospinal fluid drainage, and management for cerebral vasospasm after subarachnoid hemorrhage were all determined by each institute. Technical success was defined as successful dome embolization with parent artery preservation regardless of degree of aneurysm obliteration.

All analyses were performed with SAS software (SAS Institute Inc., Cary, N.C., U.S.A.). Ordered categorical data were examined by Mantel-Haenszel X2 statistics. Mann-Whitney U tests were used to compare the non-parametric data, and unpaired t-tests were used to compare normally distributed data.

Results

The numbers of registered patients and institutes participating in RESAT 1-7 are summarized in Table 1. The mean number of patients treated with dome embolization within 14 days at each institute increased annually from 12.4 in RESAT 1 to 26.8 in RESAT 7.

The proportion of female patients showed no significant serial change during the period of this study (Fig. 1). The distribution of ages of the patients is shown in Fig. 2. The proportion of patients aged

Table 1 Numbers of registered patients and institutes participating in RESAT 1-7

	Survey period	No. of patients	No. of institutes	Calculated no. of patients in an institute in a year
RESAT 1	1997-2002	1488	20	12.4
RESAT 2	2003	439	23	19.1
RESAT 3	2004	418	23	18.2
RESAT 4	2005	617	31	19.9
RESAT 5	2006	696	28	24.9
RESAT 6	2007	566	24	23.6
RESAT 7	2008	562	21	26.8

Patients treated by dome embolization within 14 days after onset were included in this study. The calculated annual number of patients treated with dome embolization at each institute increased from 12.4 to 26.8.

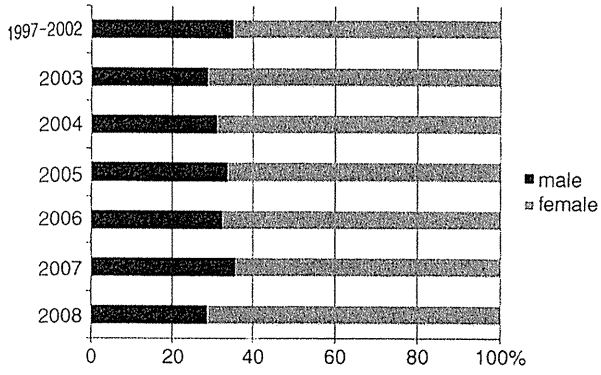

Fig. 1 Sex distribution of the patients in RESAT 1-7. Each bar shows the proportion of patients registered in each study. There were no significant changes in the sex ratio between the studies.

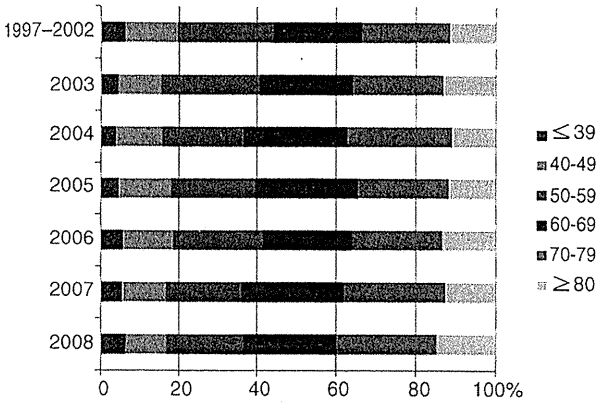

Fig. 2 Age distribution of the patients in RESAT 1-7. The distribution of patient ages is shown. The proportion of patients aged over 70 years tended to increase each year from 33.4% in RESAT 1 to 39.8% in RESAT 7.

over 70 years tended to increase each year from 33.4% in RESAT 1 to 39.8% in RESAT 7. The neurological grade of the patients evaluated before treatment is shown in Fig. 3. The proportion of patients with Hunt and Kosnik grades I-III was 70.7% in this study, and gradually increased from 67.2% in RESAT 1 to 72.1% in RESAT 7, although the difference was not statistically significant.

The distribution of aneurysm size was as follows: less than 5 mm in 38.6%, 5-10 mm in 48.8%, 11-24 mm in 11.6%, and 25 mm or more in 1.0%. There was no significant change in the size of the aneurysm by year (data not shown). In contrast, the proportion of posterior circulation aneurysms significantly decreased from 44.2% in RESAT 1 to 23.8% in RESAT 7 ($p<0.001$) (Fig. 4).

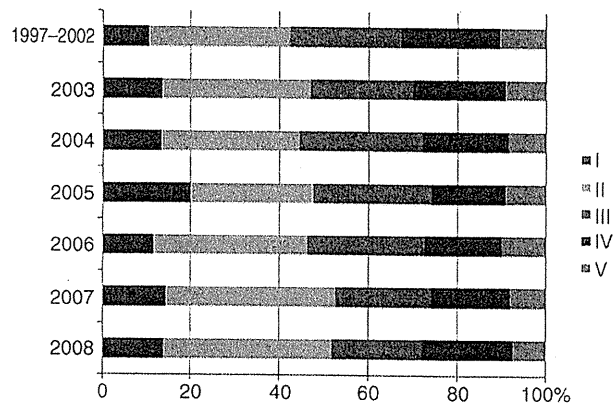

Fig. 3 Hunt and Kosnik grade before treatment in RESAT 1-7. The neurological grade of the patients before treatment is shown. The proportion of patients with Hunt and Kosnik grades I-III was around 70% and almost constant in this study.

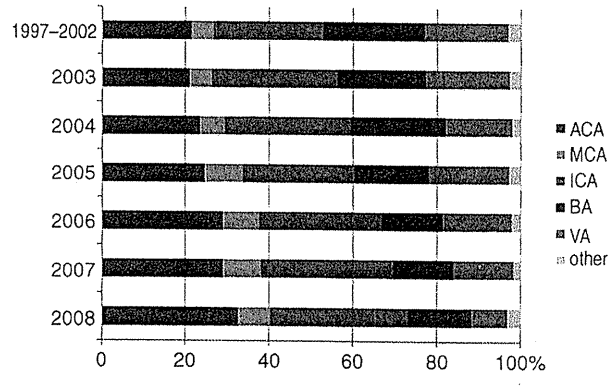

Fig. 4 Location of the aneurysms in RESAT 1-7. The proportion of posterior circulation aneurysms, such as vertebral artery (VA) or basilar artery (BA), significantly decreased from 44.2% in RESAT 1 to 23.8% in RESAT 7 ($p < 0.001$). ACA: anterior cerebral artery, ICA: internal carotid artery, MCA: middle cerebral artery.

The proportion of cases with early treatment within 72 hours after onset was consistently above 80% in this study (data not shown). Overall technical success was obtained in 4,666 patients (97.6%), and this value remained between 96.5% and 99.3% throughout the study.

In this study, clinical outcome was evaluated by GOS at discharge separately for patients with Hunt and Kosnik grades I-V and I-III. Overall favorable clinical outcome, good recovery and moderate disability by GOS, was obtained in 73.6% of the patients with grades I-V (Fig. 5 *upper*) and in 88.0% of the patients with grades I-III (Fig. 5 *lower*). Favorable clinical outcome was obtained in more

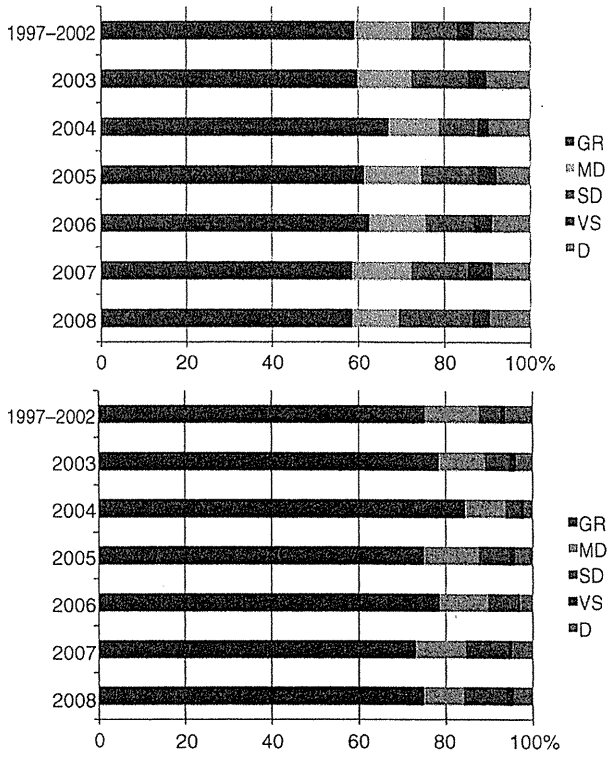

Fig. 5 Overall outcome (Glasgow Outcome Scale: GOS) of the patients at discharge in RESAT 1–7. Clinical outcome was evaluated by GOS at discharge for all the patients including those with Hunt and Kosnik grades I–V (*upper*) and I–III (*lower*). *Upper*: Overall favorable clinical outcome, good recovery (GR) and moderate disability (MD) on GOS, was obtained in more than 70% of cases in each study and the average was 73.6%. *Lower*: The rate of favorable clinical outcome, GR and MD on GOS, was more than 84% in each study and the average was 88.0% in this group. D: dead, SD: severe disability, VS: vegetative state.

than 84% of the patients with grades I–III and 70% of patients with grades I–V throughout the study (Fig. 5).

Procedure-related morbidity was 2.9% and mortality was 0.9%. Morbidity was 0.7% and mortality was 0.6% for hemorrhagic events. Morbidity was 2.0% and mortality was 0.3% for ischemic events. Morbidity was 0.2% for other events.

Discussion

ISAT has encouraged many related commentaries and letters since publication in October 2002.[1,7,12,14] The standard of neurointerventional treatments was asserted to be different at European centers to Japanese centers. However, the Japanese status of endovascular treatment for ruptured intracranial aneurysms has not been described, except for a small series from a single center. The purpose of RESAT 1 was to determine the Japanese status of endovascular treatment for ruptured aneurysms from the GDC launch until just before the ISAT report was published, and to compare these results with the ISAT data obtained 2 months after allocation, although clinical outcome was evaluated at discharge in this study.[10,11] The following surveys were conducted to elucidate how the ISAT influenced the Japanese medical centers annually from 2003 to 2008.

Patient characteristics in this study tended to be different from those in ISAT.[10,11] Regarding age, 5.8% of patients were older than 70 years in ISAT; in contrast, the proportion was 35.8% in RESAT. In terms of neurological grade, 93% of patients were grades I–III in ISAT compared with 70.7% in RESAT. Furthermore, 97.1% of the aneurysms were located at anterior circulation in ISAT compared with 63.4% in RESAT. RESAT included patients who might have been excluded in ISAT, leading to an unfavorable outcome. To compare RESAT with ISAT, only the patients with grades I–III in both studies were analyzed. In ISAT, favorable outcome was obtained in 74.6% of patients at 2 months after allocation compared with 89.1% at discharge in RESAT. Thus, the overall clinical results of RESAT were rather better than those of ISAT.

In RESAT 2, endovascular treatment became the first-line treatment for ruptured cerebral aneurysm at all but 2 centers, indicating that ISAT had an impact on Japanese centers and increased the rate of endovascular treatment. RESAT 2–7 were subsequently performed annually and showed interesting trends. Although there was no significant change in the proportion of elderly or poor-grade patients, the proportion of posterior circulation aneurysms decreased year-on-year. Therefore, the application of endovascular treatment widened to anteriorly located aneurysms, which were previously treated by clipping.

On the other hand, disclosure of the favorable results of RESAT seemed to motivate the participants to conduct endovascular treatment for aneurysms for which either therapy was deemed suitable. In Japan, endovascular treatment was mainly performed by neurosurgeons. This might be an important factor in improving the overall results of treatment for ruptured aneurysms.

We recognize the disadvantages of endovascular treatment such as recanalization, repeated bleeding, and retreatment after procedure.[2,3,6,13] Repeated bleeding from the target aneurysm was observed 2.5

times more frequently in the coiled group.[11] Therefore, follow up of the treated patients is important. We are planning to investigate the clinical events, such as repeated bleeding and retreatment, after treatment in RESAT.

This series of surveys has determined the Japanese status of endovascular treatment for ruptured aneurysms since GDC was launched. Despite this survey involving high proportions of elderly, posterior circulation, and poor-grade patients, the technical success rate and immediate clinical results were relatively favorable. It is necessary to investigate the patient prognosis and aneurysm changes over a longer period, together with the effects of the introduction of new endovascular devices for cerebral aneurysms.

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最新の脳血管内治療

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Key words：脳血管内治療，塞栓術，ステント留置術

Abstract
新しい血管内治療デバイスの認可と導入，高度な治療技術の開発，血管イメージング技術の向上，低侵襲医療の希望の増加から，脳血管内治療の適応と需要は増大傾向にある。本稿では，本邦で行われている脳血管内治療について，その現状と近未来の将来展望について概説する。

はじめに

脳血管内治療は脳血管撮影を元にX線透視下にマイクロカテーテルを用いて脳血管病変を治療する方法であり，元来神経放射線医療の中の介入的治療の一つとして発達してきた。体を大きく切らないですむ利点が好まれ，体に優しい「低侵襲な」治療として内視鏡治療とともに近年需要が急速に伸びている。近年新しいデバイスや医薬品の認可についてスピードアップがはかられ，続々と新しい脳血管内治療用デバイスが認可されており，治療戦略の改善や新しい適用による治療効率や安全性の向上が見込まれている。

これらの進歩は，新しい血管内治療デバイスの開発導入による他，血管イメージング技術の向上から治療ターゲットの理解がすすみ，血管内アプローチを用いた診断や機能評価によって治療がより精密に行えることができるようになってきたことも影響している。

ここでは脳血管内治療の概要について，疾患別に近年の変化を俯瞰する。

1. 脳動脈瘤

脳動脈瘤は，動脈の一部，主として分岐部が袋状にふくらんだものであり，破裂すれば致死性の高いクモ膜下出血を生じる。その治療法には，開頭して瘤の柄部をクリップでつまむクリッピングと，動脈の中から瘤の中にコイルを詰めて血液の流入を遮断する瘤内塞栓術がある。このコイル塞栓術の治療件数は年々増加の一途をたどっている。欧米においては破裂動脈瘤の全治療の半数以上となっており，本邦においても血管内治療を第一選択とする施設が増加している。使用するコイルは極めて柔らかい純プラチナ製のフィラメントをコイル状に巻いて螺旋形状をつけたものを使用することが多い。現在その種類は様々な形状，サイズがそろっており，他に機能付加も加えたコイルが登場している。瘤内器質化と瘤口の内膜修復が促進されるbioactive coilの他，コイルの表面にコーティングされたハイドロジェルが膨張して塞栓率を高めるタイ

Neuroendovascular therapy-up to date-：Shigeru Miyachi, Department of Neurosurgery, Nagoya University Graduate School of Medicine

プのコイルも使用可能となっている。

一方，非常に柄部の広い瘤においては，コイルが親血管へ逸脱してしまうため，バルーンカテーテルを用いてコイルを瘤内へとどめおかせる方法が一般的になっている。さらに広い瘤口の動脈瘤についても，昨年より認可されたステント様の血管形成デバイス（商品名Enterprise®: Codman）をおいて永久的にコイルの突出を防ぐ方法が広まりつつある（図1）。欧米ではステントの編み目を細かくしてさらに整流効果により瘤内への血流を抑制して血栓化を高めるflow-diverter stentも使用されている。これらにより広柄動脈瘤や紡錘状動脈瘤，mass effectを呈する瘤に対し，血管内治療適応が拡がることが期待される。

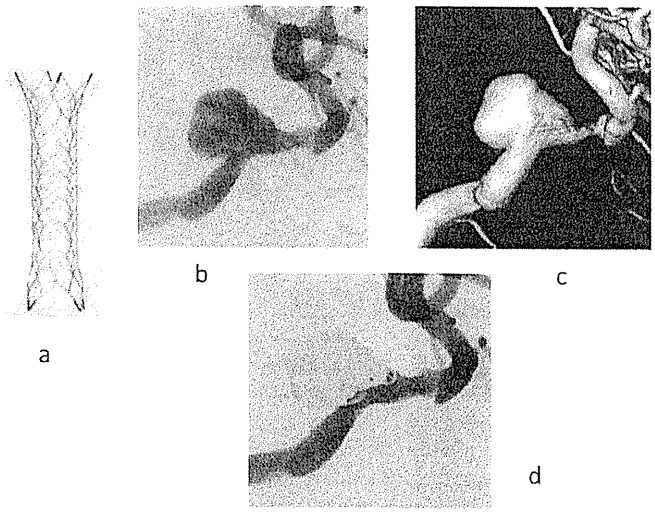

図1　広柄内頸動脈瘤に対するステント様血管形成デバイス（Enterprise®）(a)を用いたコイル塞栓術。
術前の内頸動脈側面像(b)と三次元DSA画像(c)。術後の血管撮影(d)で親動脈の開存は良好で，瘤の完全閉塞が得られた。

破裂動脈瘤にたいするクリッピングとの棲み分けは，長期成績と合併症率を考慮したrisk-benefit assessmentから適応決定がなされることが重要である。また未破裂動脈瘤については，近年脳ドックによる発見率が大変高くなっているが，脳ドックガイドラインなどに準じ，経過観察と外科的治療との間で同様のアセスメントが行われる必要がある。

2. 脳動静脈奇形

脳動静脈奇形は脳の動脈と静脈の間に糸くず状の小さなシャント血管（nidus）を介して直接静脈側へ流出する先天性の血管奇形である。強い血流ストレスがかかることと異常な血管構造のために出血したり，シャントによる盗血が原因でけいれんが生じたりする。治療は，摘出術が基本であるが，深部や到達困難な例については定位的放射線治療も行われる。血管内治療は，細いマイクロカテーテルをnidus付近まで到達させ，その栄養動脈を閉塞することによりシャント血流を減ずることを目的として行われる。手術，定位放射線治療の前処置で，出血のリスクを減少させ治療の有効性を高める意味で有用であるが，後治療の合併症を減らすのにも役立っている。塞栓物質としては従来接着性の高い重合型液体塞栓物質であるn-butyl cyanoacrelate(NBCA)が一般的に用いられている。また，AVMの7-20%に合併するとされる動脈瘤のうち，nidus内の動脈瘤(intranidal aneurysm)は出血源として重要であり，再出血を防ぐために血管内より処理されることが多い。

一昨年，ethylene vinyl alcohol copolymerを有機溶媒(DMSO)で溶解した新しい析出型の液体塞栓物質(商品名：Onyx®: EV3)が本邦でも保険収載された（図2）。この塞栓物質はnidusへの到達性がよくNBCA使用例では10%前後であった塞栓術のみでの根治例が40%まで上昇したとの報告もある。本邦では摘出術前の塞栓術として認められているが，極めて速い

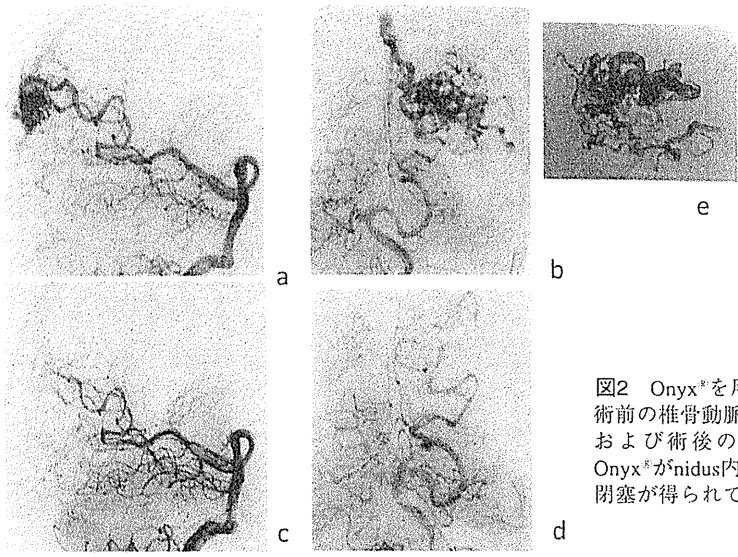

図2　Onyx®を用いた脳動静脈奇形塞栓術術前の椎骨動脈撮影側面像(a)，正面像(b)および術後の側面像（c），正面像(d)。Onyx®がnidus内にcastをつくり，ほぼ完全閉塞が得られている。

シャント疾患には不向きであること，カテーテル抜去時に困難があることなどの問題があるため，慎重な適用が必要である。

3. 硬膜動静脈瘻（DAVF）

硬膜動静脈瘻（DAVF）は，頭蓋底部および静脈洞部に生じた硬膜上の後天性動静脈シャント疾患である。海綿静脈洞，横静脈洞など静脈洞付近に生じるタイプと，導出静脈にシャントして　頭蓋内へ逆流するタイプがある。前者は経静脈的に頸静脈を上行して，シャントのある罹患部をコイルで塞栓する方法で，最も根治的である。近年の三次元撮影法の進歩によりshunt部の描出が鮮明となり，特に超選択的造影法により血管解剖の把握がしやすくなったことで，シャント部位のみをターゲットとした塞栓が可能となってきた。一方，前頭蓋底や頭蓋頸椎移行部など静脈洞を介さないタイプの塞栓術は，経動脈的にアプローチし，シャント部位を選択的に液体塞栓物質で止める方法がとられる。前述の静脈洞タイプにおいても，液体塞栓物質の計画的，超選択的な使用により，十分シャント部位まで塞栓物質を到達させれば完全閉塞が得られる（図3）。

このほか，合併する静脈洞閉塞に対し，順行性流出路をつくり，シャント血流を逃がして危険な頭蓋内静脈逆流から解放するというコンセプトから，ステントを留置して静脈洞形成も行われている。一方，近年では定位的放射線治療の有用性が報告されてきており，血管内治療不能例や遺残例に対して用いられている。

4. 頸動脈狭窄

頚部頸動脈の動脈硬化性狭窄は，欧米に比べ本邦では比較的頻度が少なかったが，生活習慣の欧米化に伴い，全身動脈硬化性血管病（Atherothrombosis）の1つとして著増している。治療法としては抗血小板剤，スタチンなどを中心とした内科的薬物療法以外に，症候例や高度狭窄例については，動脈硬化により内膜下にたまった粥腫（プラーク）をくりぬいて再開通させる頚動脈血栓内膜剥離術（CEA）が行われてきた。血管内より低侵襲に行える方法として，病変部をステントで拡張させる方法（Carotid stenting :CAS）が近年CEAハイリスク例に適用されている。2008年に初めての自己拡張型のステント(商品名：Precise®: Cordis)が認可され，昨年にはメッシュの形が

異なるもう一つのステント（商品名：CarotidWall EZ®：Boston Scientific）も使用可能となった。ステントはプラークを血管壁に押しつけて内腔を広げるものであるが，デバイス通過時及び血管拡張時にプラークの一部が末梢へ飛散して脳梗塞を生じる危険がある。そこで，一時的に病変末梢の親動脈をバルーンカテーテルで閉塞して，わき出したプラークの破片（デブリス）を後で吸引する方法(バルーンプロテクション)や，細かいネット型のフィルターでデブリスを回収する方法（フィルタープロテクション）で合併症を予防する（図4)。どの方法を選択するかは，プラークの量，質的判断によっており，術前のプラークイメージングが重要である。海外の報告では，CEAに比べてCASの成績が芳しくないが，本邦ではプラークイメージに基づく適切なプロテクション法の使用により，CASの治療成績は世界的にもトップレベルにある。

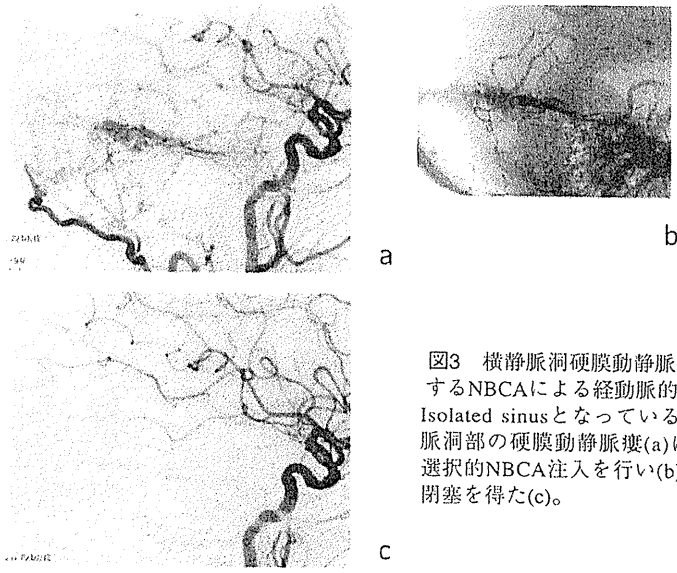

図3　横静脈洞硬膜動静脈瘻に対するNBCAによる経動脈的塞栓術
Isolated sinusとなっている左横静脈洞部の硬膜動静脈瘻(a)に対し，選択的NBCA注入を行い(b)，完全閉塞を得た(c)。

一方，頻度は多くないが過潅流，亜急性期ステント内血栓症，再狭窄などの問題があり，治療選択と適応について，まだ解明すべき点が残されている。

5. 頭蓋内動脈狭窄

日本人をはじめアジア人では頭蓋内主幹動脈の狭窄性病変が多く，虚血性脳卒中の10-20%に関与することが報告されている。いくつかの薬物療法による臨床研究において，症候性の高度狭窄例の中には抗血小板剤の他，血管拡張薬，降圧薬，スタチンなどによる血管拡張作用やプラーク退縮作用を目的とした薬物療法といった内科的治療に抵抗性の脳動脈狭窄症が少なからず含まれるという報告がある。血管内治療としては，頸動脈と同様，細く柔らかいバルーンカテーテルを用いたバルーン拡張術やステント留置術による狭窄部の拡張が主体である（図5)。これまで保険適用外の冠動脈用のステントを用いた血管形成が行われてきたが，海外では広く使用され，現在本邦で治験中の自己拡張型ステントが大変期待されている。再狭窄率が頸動脈に比べてやや高い点など，今後克服すべき問題はあるものの，バルーンによる拡張のみで生じる解離や閉塞などの急性期合併症を防ぐためのレスキューとしても有用である。

6. 急性期脳虚血

心原性または頚部の動脈由来の脳塞栓症は，広範囲の脳梗塞を来たし，極めて重度の後遺症を残す。従来，本邦では脳塞栓に対し，主としてウロキナーゼを用いた局所線溶療法が行われてきた。線溶療法のみで不十分な場合には，ガイドワイヤーなどで塞栓子を破砕する方法や，バルーンカテーテルを用いた

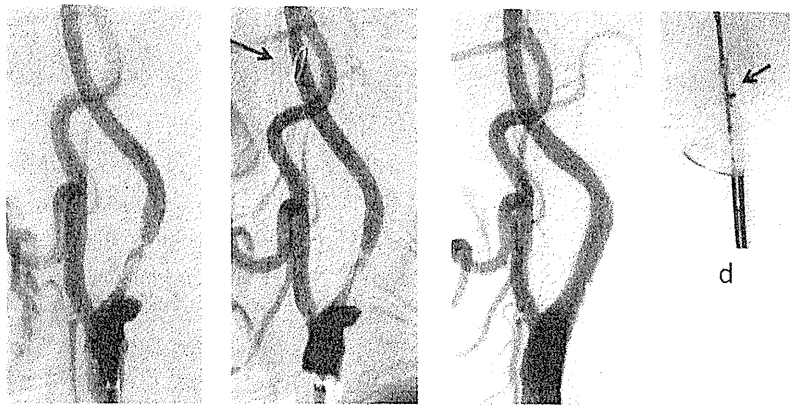

図4　頚部内頸動脈狭窄に対するフィルタープロテクションを用いたステント留置術
左高度内頸動脈狭窄(a)に対し，フィルター(Filterwire EZ®)(b:矢印)を遠位部においてステント留置を行い，良好な拡張を得た(c)。フィルターの中には補足された血栓が認められる(d:矢印)。

direct PTAが行われている。

一方，脳梗塞急性期に対する組織プラスミノゲン活性化因子（tPA）アルテプラーゼの静注療法（IV-tPA）の有効性が明らかとなり。本邦においては6年前より脳虚血超急性期の第一選択となった。厳しい適応基準があり，発症時刻が特定できる例において3時間以内の投与が原則であるため，実際の適用率は10～20%程度である。現在適用機会を高めるために，t-PA適用患者の現場でのトリアージ，t-PA取り扱い病院への搬送時間の短縮，投与までの時間の拡大（4.5時間まで）などの取り組みがなされている。しかし，t-PA無効例，あるいは非適応例についての治療に関してはやはり血管内治療のフロンティアとなる。その手段として近年特に有用とされているのが薬剤に頼らない機械的再開通である。方法としては前述の機械的破砕以外に血栓の捕捉を行うネットのついたカテーテルや吸引を行うカテーテルがあり，血栓をからめとるタイプの血栓retriever（Merci®: Century Medical）が昨年本邦でも認可され，急速に普及している。大変stiffなデバイスで，血管を引き延ばすことで出血性合併症が生じることが難であるが，高い再開通率が得られるため，今後の脳血管閉塞に対する超急性期再開通率を高める意味で今後使用機会が増えると思われる。

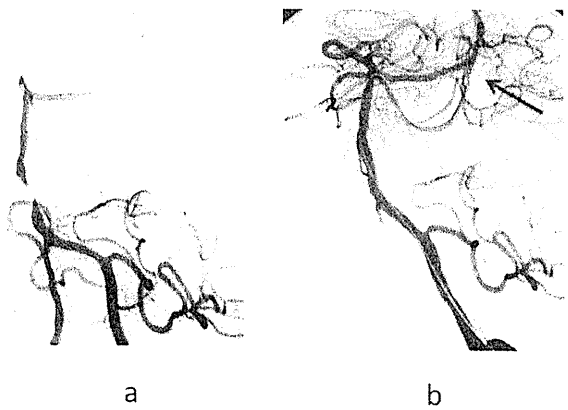

図5　脳底動脈高度狭窄に対するステントを用いた経皮的血管拡張術
症候性の脳底動脈高度狭窄(a)に対し，ステントを用いて良好な拡張が得られた(b)。末梢の後大脳動脈などの血流が改善している(b:矢印)。

頭蓋内ステント

宮地 茂

ステントは金属でできたメッシュで，持続的に血管を形成し，血流を確保するためのデバイスである．もともと狭窄血管を拡張させるためのデバイスであり，冠動脈領域で最も汎用されている．頭蓋内で用いるステントには，そのような血管拡張用のステントと，脳動脈瘤塞栓術においてコイルの逸脱を防ぐためのステント様血管形成再建デバイス(vascular reconstruction device：VRD)がある．本稿では広義の頭蓋内ステントとして，両者のわが国における現状を述べる．

頭蓋内動脈狭窄病変に対する拡張用ステント

本邦では頭蓋内専用ステントはまだ認可されていない(現在申請中)．従ってこれまでは保険適用外ではあるが，冠動脈ステントを流用していた(図1)．このステントは冠動脈狭窄に対する拡張用のバルーン拡張型ステントで，極めて固く，頭蓋内の屈曲した動脈に留置するには到達そのものが困難な上，血管損傷の危険も伴っていた．従って，挿入不可能な場合にはバルーンカテーテルによる血管形成術(PTA)のみ行われていたが，PTAのみでは周術期合併症率はステント使用時と変わりないものの，recoil等による残存狭窄，血管解離，50%に及ぶ高い再狭窄率など，問題が多いことがわかっている[1,2]．

現在，世界中で最も使われ，多数例の報告があるのはWingspan^{TM}(Boston Scientific Corporation)である(図2)．非常に柔軟性の高い自己拡張型ステントで，狭窄部への到達性も高い．留置方法はまずバルーンカテーテルを用いて狭窄部を少し拡張した後，やや太めのマイクロカテーテルを，狭窄部を超えるように親血管内を進める．細くたたまれた形の本デバイスをカテーテル内に挿入し，マイクロカテーテルを引き戻しながらデバイスをむき出すことにより，先端部からメッシュが開いてくる．狭窄部の遠位正常血管部より展開を開始し，狭窄部を含み近位正常部まで十分な長さのステントを留置する．拡張不十分であればバルーンカテーテルで後拡張を追加する．

2010年に行った臨床治験における治療の適応は，症候性の50%以上の頭蓋内動脈狭窄であったが，ガイドラインでは頭蓋内症候性70%以上の狭窄が推奨されており(Class Ⅱb，level C)，無症候性狭窄は適応外とされる．このステントを用いた血管形成術の安全性と有用性については，前向き登録の予後調査において，30日後の死亡，脳卒中を含めた有害事象(MAE)は4.5%であったと報告されている[3]．市販後調査でも，技術的成功は99%，狭窄率は74.6%

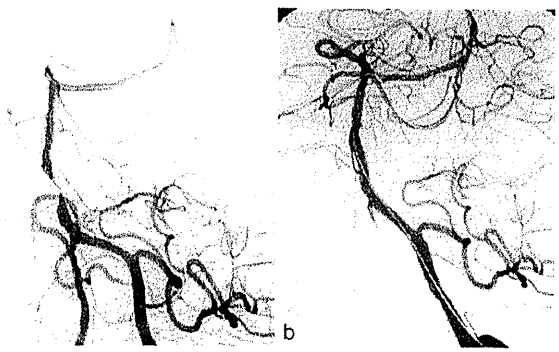

図1 脳底動脈高度狭窄例(a)に対し，冠動脈ステントを用いて良好な拡張と末梢循環改善を認めた(b)．

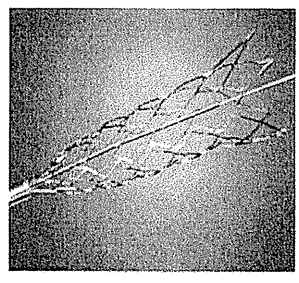

図2 Wingspan^{TM} stent
(Boston Scientific Corporation)

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0289-0585/11/¥500/論文/JCOPY

から27.2%に改善し，周術期合併症は6.1%，30日後のMAEは9.6%であった[4,5]．MAEの中で過灌流を含む出血性合併症は3.5%であるが，一旦おこれば重篤で予後は極めて厳しいとされる．MAE発生の危険因子は，後方循環の狭窄，経験数の少ない施設，脳卒中発症例，症候性イベント直後の実施などとされ，年齢，性別，人種，狭窄率の間には有意差がない[6]．一方，再狭窄については25～30%に認められ[5,7]，このうち8割で再拡張術が行われている[4]．再狭窄はステント内の局所的な狭窄が大部分であり，半数はステント留置前よりも強い狭窄であったとされる[8]．再狭窄のリスクは前方循環(特に鞍上部)，小径，若年者，糖尿病患者等である[9]．

再狭窄については，バルーン拡張型ステントを用いた場合の方が低い傾向があることが報告されている[10～12]．現状ではまだ適用は限られ，スタチンや抗血小板剤などの薬剤による保存的治療に対する優位性について検討が必要であるが，今後，薬剤溶出性ステントなどの応用，ステントデザインや機能性について改良により治療成績の向上が期待される．

頭蓋内ステントは上記のように脳梗塞予防目的として症候発現前に戦略的に留置する場合以外に，急性閉塞を緊急に再開させるレスキューとしての意義がある(図3)．急性閉塞によるstroke患者に用いると，90%以上の高率に再開通を得ることができる[13～15]．また，CCFなどの血管損傷に対する適用も親動脈確保の点でも有用なことがある(図4)．

ステント様血管再建デバイス(VRD)

本デバイスの形状はステントとほぼ同様であるが，用途は広柄の動脈瘤のコイル塞栓術において，コイルの親動脈

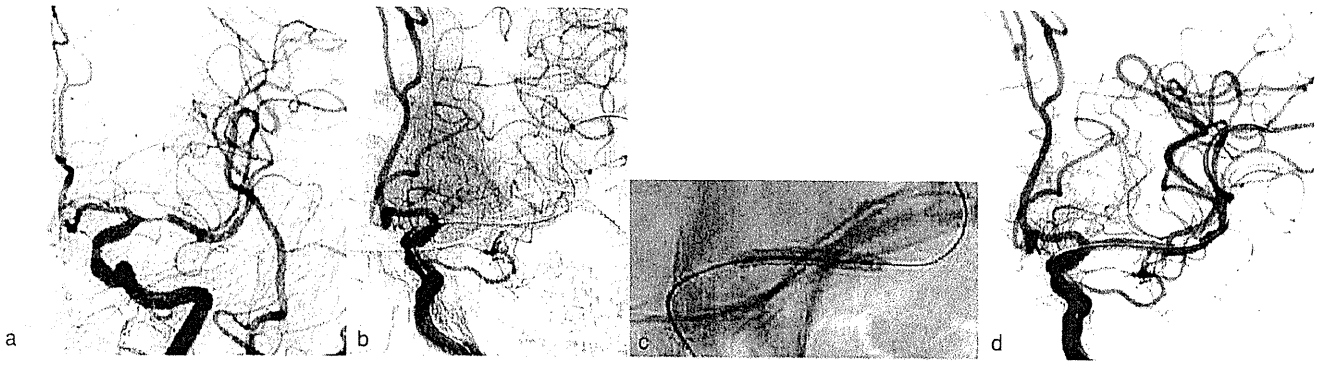

図3　症候性の左中大脳動脈狭窄(a)に対し，バルーンによる拡張を行ったところ解離をきたしほぼ完全閉塞となった(b)．直ちに冠動脈ステントによるレスキュー(c)により，再開通と病変拡張を得た(d)．

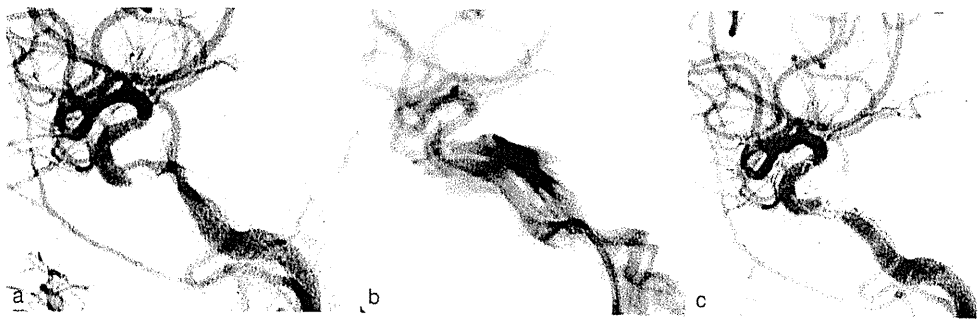

図4　症候性の内頸動脈狭窄(a)に対し，バルーンカテーテルによる拡張を行ったところ内頸動脈が裂けて海綿静脈洞瘻を生じた(b)．冠動脈ステントを5枚重ねた上に経静脈的にコイルによる静脈洞のパッキングを行い，病変の拡張と動静脈瘻の閉鎖に成功した(c)．

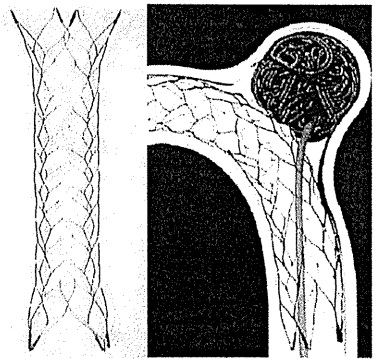

図 5 Enterprise™
(Johnson & Johnson Company)

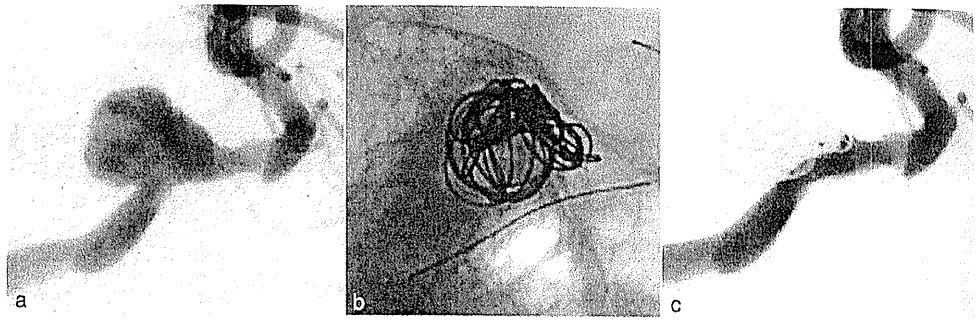

図 6 内頸動脈海綿静脈洞部の大型瘤(a)に対し，Enterprise™を留置した上(b)，コイル塞栓術を行い完全閉塞を得た(c)．

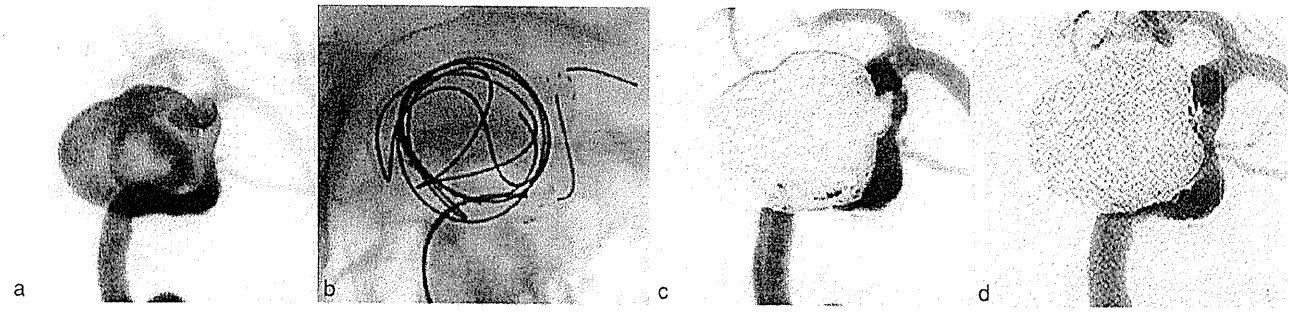

図 7 内頸動脈傍鞍部巨大動脈瘤(a)に対し，Enterprise™を留置した上，jail method を用いてコイル塞栓術を行った(b)．終盤でステント内に血栓が突出し，増大したため(c)，血栓溶解と抗血小板療法の強化を行った．2週間後の血管撮影では血栓の消失と瘤の閉塞を認めた(d)．

への逸脱を防ぎ，安全かつ密なコイルパッキングを可能にする補助デバイスである．ニチノール性の自己拡張型のメッシュであるが，欧米ではクローズドセルデザインの Enterprise™(Johnson & Johnson Company)と，オープンセルデザインの Neuroform™(Boston Scientific Corporation)の2種類が使用されている．現在，本邦では後者は申請中で，前者のみが認可されている(図5)．

Enterprise™のわが国での適応は，外科的手術(クリッピングなど)またはコイル単独の塞栓術では治療困難な未破裂脳動脈瘤で，最大径が7 mm 以上のワイドネック(ネック部が4 mm 以上またはドーム/ネック比が2未満)の瘤となっている(図5)．また，留置する親血管径は2.5〜4 mm が適用範囲とされている．VRD 本体の留置方法は，バルーンによる前拡張は不要であること以外は，ほぼ前出の Wingspan™と同様である．ただし，瘤口部での支えがないため，瘤口部の前後に5 mm 以上の長さで Enterprise™が正常血管に密着している必要がある．コイル挿入用のカテーテルを Enterprise™挿入前に瘤内に留置しておく方法(jail method)とステント留置後その網目の間から挿入する方法(trans-cell method)があるが，前者の方が簡便で普及している．本邦における臨床治験の結果では，安全性，有効性ともに極めて優れ，広柄瘤に対する治療適応が広がり，フレームコイルの安定，親動脈の確実な温存の点で有用なデバイスであることが証明された．また，メッシュによるコイル突出の予防により密なコイルパッキングが可能となったこと，多少の flow diverting 効果で瘤内の血栓形成性が高まることにより再発予防にも寄与している．一方，前述の jail method を用いている場合は，カテーテルの微調整がききにくいことが問題であり，血栓形成性についても simple な塞栓術よりも高まる危険性が指摘されている(図6，7)．

これまでの報告では，Enterprise™を用いた多施設共同研究の結果，手技的成功は97%に得られ，周術期の morbid-mortality は破裂瘤例も含めて4.8%であったとされる[16]．また，VRD アシストによる塞栓術では，塞栓率の上昇と柄部の遺残の減少が有意に優れているとされる[17]．一