

Special Theme Topic: Japanese Surveillance of Neuroendovascular Therapy in JR-NET/JR-NET2—Part I

Endovascular Embolization of Cerebral Arteriovenous Malformations: Results of the Japanese Registry of Neuroendovascular Therapy (JR-NET) 1 and 2

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Abstract

This retrospective study constitutes a part of the Japanese Registry of Neuroendovascular Therapy (JR-NET) 1 and 2. Its purpose is to evaluate the feasibility, safety, and outcome of endovascular embolization for cerebral arteriovenous malformations (AVMs) in Japan. Nine hundred and eighty-seven embolization procedures were registered with JR-NET 1 and 2 (424 procedures in 122 institutions with JRNET 1 and 563 procedures in 150 institutions with JRNET 2). In total, 790 patients (80.1%) had favourable clinical outcomes defined as modified Rankin Scale (mRS) scores 0–2 at 30 days after embolization. Complete AVM obliteration by embolization alone was achieved in 90 procedures (9.1%). The procedural morbidity and mortality rate was 2.5% and 0.3% per procedure, respectively. In the multivariate logistic regression models, deep venous drainage and embolization of four or more feeding pedicles per session were significantly associated with any treatment-related complications ($P = 0.02$ and $P = 0.003$, respectively). About 6 cm or more in maximum nidus diameter had a negative correlation with complications ($P = 0.003$). Our study shows that embolization of cerebral AVMs was performed with a high degree of safety and a low rate of symptomatic complications in Japan.

Key words: cerebral arteriovenous malformation, endovascular embolization, outcome, complication

Introduction

Cerebral arteriovenous malformations (AVMs) are complex vascular lesions with an annual associated haemorrhage risk of 2–4% in symptomatic patients.¹⁾ The primary goal of treatment for cerebral AVMs is to prevent bleeding. For this purpose, complete exclusion of the AVM should be achieved. Treatment methods are highly variable, depending on AVM characteristics and the complete obliteration of cerebral AVMs often requires a multidisciplinary

approach, including endovascular embolization, microsurgical resection, and stereotactic radiosurgery.^{2–6)} Endovascular embolization plays an essential role in the treatment of cerebral AVMs. In multimodal treatments, endovascular embolization is generally the first step of treatment. Furthermore, the role of endovascular embolization as a stand-alone curative treatment has been expanded after the introduction of Onyx embolic system (ev3; Irvine, California, USA).^{7–10)} Although considerable foreign data support its safety and efficacy, the actual outcome of endovascular embolization for cerebral AVMs in Japan has not been investigated.

This retrospective study constitutes a part of the Japanese Registry of Neuroendovascular Therapy (JR-NET) 1 and 2 conducted by the JR-NET Study Group in the Japanese Society for Neuroendovascular Therapy (JSNET). The purpose of this study was to evaluate the outcome, feasibility, and safety of endovascular embolization for cerebral AVMs in Japan.

Materials and Methods

I. Patient selection

JR-NET is a retrospective database collecting data on any type of neuroendovascular therapy at the institutions with which board certified instructors and specialists of neurointervention by JSNET are assigned to work. In total, 11,114 procedures at 122 institutions were registered in JR-NET 1 between January 2005 and December 2006, and 20,854 procedures at 150 institutions were enrolled in JR-NET 2 between January 2007 and December 2009. We performed a retrospective search for cerebral AVM embolizations included in JR-NET 1 and 2. The local Ethics Committees approved the retrospective collection of clinical information from databases and submission of the data to our central office.

It should be added that the registration was based on the number of embolization sessions (procedures). Namely, patients receiving multistage embolization were repeatedly registered depending on the number of sessions (procedures).

II. Outcome measures

The primary endpoint was favourable outcomes as defined by a modified Rankin Scale (mRS) score from 0 to 2 at 30 days after the procedure.

The secondary endpoints were technical success of the procedure and severe complications associated with endovascular embolization within 30 days after the procedure.

Functional neurologic status was evaluated before and after endovascular embolization using mRS. Treatment-related complications with any worsening of the patient's mRS scores at 30 days after procedure were coded as "symptomatic complications," and symptomatic complications resulting in disabling deficits, defined as mRS 3–5, were classified as "disabling complications."

Demographics were recorded for each patient, including age, sex, and presenting symptoms. The angiographic features of AVM were also documented, including maximal size, presence of deep venous drainage, involvement of the eloquent cortex, nidus location, presence of deep arterial feeders, and concurrent aneurysms. AVMs were classified based on morphologic characteristics, according

to the Spetzler-Martin grading system.¹¹⁾ For each embolization session, the number of embolization sessions, the number of feeding pedicles embolized, and the embolic materials used were documented.

III. Statistical analysis

Univariate logistic regression analyses were used to identify risk factors for treatment-related complications by using the following determinants: patient demographics, initial clinical presentations, morphologic characteristics of the AVM, including Spetzler-Martin grade, number of embolization sessions, and number of feeding pedicles embolized per procedure.

All variables with significant association in the univariate analyses ($P < 0.05$) were entered into a multivariate logistic regression model using backward elimination procedures to test their independent association with any treatment-related complications.

Results

I. Patient and AVM characteristics

Nine hundred and eighty-seven embolization procedures were registered with JR-NET 1 and 2 (424 procedures with JR-NET 1, 563 procedures with JR-NET 2). Demographic and clinical data are summarized in Table 1. There were 588 (59.6%) male and 399 (40.4%) female patients with a mean age of 40 years (range 0 to 88). Initial clinical presentations were haemorrhage in 800 (81.1%), neurologic manifestation without haemorrhage (symptomatic without haemorrhage) in 77 (7.7%), incidentally discovered (asymptomatic) AVM in 57 (5.7%), and unknown in 54 (5.5%).

Morphologic characteristics of AVMs are shown in Table 2. There were 92 (9.3%) grade I, 264 (26.7%) grade II, 293 (29.7%) grade III, 198 (20.1%) grade IV, and 40 (4.1%) grade V AVMs, according to Spetzler-Martin grade. Spetzler-Martin grades were not described in 100 AVMs (10.1%).

II. Treatments

The treatments and materials are summarized in Table 3. The treatment strategy for embolization was presurgical in 453 (45.9%), preradiosurgical in 228 (23.1%), palliative in 138 (14.0%), curative in 101 (10.2%), and others in 10 (1.0%) of the procedures. Treatment strategy was not described in 57 (5.8%) procedures. Embolization was performed with *N*-butyl cyanoacrylate (NBCA) alone or with NBCA in conjunction with other materials in 732 (74.2%), detachable coils alone in 117 (11.9%), Onyx alone or Onyx along with other materials in 54 (5.5%), other liquid materials in 15 (1.5%), particle alone in 9 (0.9%), and others in 9 (0.9%)

Table 1 Patients demographics

Age, years, mean (range)	40 (0–88)
Sex, no. (%)	
Male	588 (59.6)
Female	399 (40.4)
Clinical presentation, no. (%)	
Hemorrhagic	800 (81.1)
Symptomatic without hemorrhage	77 (7.7)
Asymptomatic	57 (5.7)
Unknown	54 (5.5)

Table 2 Arteriovenous malformation characteristics in 987 procedures

	No. of procedures (%)
Spetzler-Martin grade	
I	92 (9.3)
II	264 (26.7)
III	293 (29.7)
IV	198 (20.1)
V	40 (4.1)
Unknown	100 (10.1)
AVM size	
< 3 cm	364 (36.9)
3 cm, < 6 cm	449 (45.5)
6 cm ≤	80 (8.1)
Unknown	94 (9.5)
Eloquent location	591 (59.9)
Deep venous drainage	433 (43.9)
AVM location	
Hemispheric	710 (71.9)
Cerebellum	134 (13.6)
Deep*	61 (6.2)
Isolated	35
With hemispheric involvement	24
With cerebellar involvement	2
Others	28 (2.8)
Unknown	54 (5.5)
AVMs with deep arterial feeders**	99 (10.0)
Patients with concurrent aneurysms***	192 (19.5)

*: Refers to involvement of the following: basal ganglia, thalamus, brain stem, **: Defined as penetrating branches of the major intracranial arteries, or of the anterior choroidal arteries, ***: Includes aneurysms on feeding arteries, intranidal, and AVM-unrelated aneurysms. AVM: arteriovenous malformation.

Table 3 Summary of treatments in 987 procedures

	No. of procedures (%)
Treatment strategy	
Presurgical	453 (45.9)
Preradiosurgical	228 (23.1)
Palliative	138 (14.0)
Curative	101 (10.2)
Others	10 (1.0)
Unknown	57 (5.8)
Treatment material	
NBCA	732 (74.2)
Coil alone	117 (11.9)
Onyx	54 (5.5)
Other liquid emolic material	15 (1.5)
Particle alone	4 (0.4)
Others	9 (0.9)
Unknown	56 (5.6)
Number of times of embolization sessions	
1	661 (67.0)
2	152 (15.4)
3	65 (6.6)
≥ 4	54 (5.5)
Unknown	55 (5.5)
Number of pedicles embolization	
0 (trial)	11 (1.1)
1	306 (31.0)
2	336 (34.0)
3	155 (15.7)
≥ 4	113 (11.4)
Unknown	66 (6.8)

NBCA: *N*-butyl cyanoacrylate.

of the procedures. Treatment materials were not described in 56 (5.6%) procedures.

III. Primary and secondary endpoints

The primary and secondary endpoints are summarized in Table 4. For the primary endpoint, a total of 790 patients (80.1%) had mRS scores ranging from 0 to 2 at 30 days after embolization. Pre- and postprocedural mRS scores are given in Table 5. In total, there were 877 patients (88.9%) with mRS scores of 0–2 at pre-embolization. Therefore, the number of patients with non-disabling deficits (mRS ≤ 2) decreased by 87 after embolization.

For the secondary endpoints, technical success was documented in 975 procedures (98.8%). Complete AVM

Table 4 Incidences of primary and secondary endpoints in 987 procedures

	No. of procedures (%)
Primary endpoint	
mRS 0–2 at 30 days after procedure	790 (80.0)
Secondary endpoints	
Technical success	975 (98.8)
Cured by embolization alone	90 (9.1)
Complication	
Any technical complication	91 (9.2)
Symptomatic complication*	25 (2.5)
Disabling complication**	15 (1.5)
Death	3 (0.3)

mRS: modified Rankin Scale. *: Complication resulting in any deterioration of mRS scores at 30 days after embolization compared with those before embolization, **: Complication resulting in disabling deficits defined as mRS 3–5 at 30 days after embolization.

Table 5 mRS scores pre- and postembolization

mRS score	Preembolization		Postembolization	
	No.	%	No.	%
0	664	67.3	462	46.8
1	130	13.2	200	20.3
2	83	8.4	128	13.0
3	27	2.7	72	7.3
4	41	4.2	60	6.1
5	29	2.9	33	3.3
6	0	0.0	14	1.4
Unknown	13	1.3	18	1.8

mRS: modified Rankin Scale.

obliteration by embolization alone was achieved in 90 procedures (9.1%). A total of 91 complications (9.2%) with or without worsening of mRS occurred after embolization: 38 were ischemic, 37 were haemorrhagic, 2 were arterial dissections, 1 was catheter gluing, and 13 were others or unknown. Complications included 25 (2.5%) symptomatic (any worsening of mRS) and 15 (1.5%) disabling (mRS 3–5) complications. Symptomatic complications included 16 intracranial haemorrhages, 7 cerebral ischemia, 1 cholesterol crystal embolization, and 1 other complication. Another 3 patients (0.3%) died from intracranial haemorrhage within 30 days after embolization. Therefore, procedural morbidity and mortality rates were 2.5% and 0.3% per procedure, respectively.

Table 6 Factors predictive for embolization related complications by univariate analysis

Parameter	OR	(95%CI)	P
Patient demographics			
Male gender	0.60	(0.40–0.92)	0.03
Presenting symptoms			
Hemorrhagic	1.50	(0.92–2.44)	0.13
Symptomatic without hemorrhage	0.91	(0.52–1.58)	0.83
Asymptomatic	0.48	(0.22–1.06)	0.09
AVM characteristics			
Spetzler-Martin grade			
I and II	1.05	(0.67–1.63)	0.93
III and IV	1.07	(0.69–1.66)	0.85
V	0.45	(0.11–1.91)	0.40
AVM size			
< 3 cm	1.51	(0.98–2.35)	0.08
3 cm ≤, < 6 cm	0.89	(0.58–1.38)	0.69
6 cm ≤	0.21	(0.05–0.88)	0.03
Eloquent cortex involved	1.22	(0.77–1.94)	0.46
Deep venous drainage	1.59	(1.03–2.46)	0.047
Deep arterial feeders	1.57	(0.85–2.90)	0.20
Concurrent aneurysms	1.67	(1.03–2.71)	0.048
Deep seated location	1.65	(0.75–3.60)	0.31
Treatment			
Number of embolization sessions			
1	0.93	(0.58–1.49)	0.86
2	0.91	(0.50–1.66)	0.88
3	1.74	(0.85–3.54)	0.18
≥ 4	0.72	(0.25–2.04)	0.70
Number of pedicles embolized			
0 (trial)	0.92	(0.12–7.23)	0.67
1	1.12	(0.70–1.75)	0.74
2	0.64	(0.39–1.03)	0.08
3	0.66	(0.34–1.27)	0.27
≥ 4	2.60	(1.54–4.41)	0.0005

AVM: arteriovenous malformation, CI: confidence interval, OR: odds ratio.

IV. Predictors of complication after embolization

The results of univariate analyses are shown in Table 6. Deep venous drainage, concurrent aneurysm, and embolization of 4 or more feeding pedicles per session were significantly associated with treatment-related complications ($P = 0.047$, $P = 0.048$, and $P = 0.0005$, respectively). Male sex and ≥ 6 cm in maximum nidus diameter had a negative correlation with complications ($P = 0.03$ for both). In multivariate logistic regression models (Table 7), deep venous drainage and embolization

Table 7 Predictors for embolization related complications by multivariate logistic regression model test

Parameter	OR	(95%CI)	P
Male gender	0.55	(0.30–1.02)	0.06
AVM size 6 cm ≤	0.09	(0.02–0.43)	0.003
Deep venous drainage	2.02	(1.09–3.72)	0.02
Concurrent aneurysms	2.06	(0.99–4.30)	0.053
Number of pedicles embolized ≥ 4	4.14	(1.65–10.40)	0.003

AVM: arteriovenous malformation, CI: confidence interval, OR: odds ratio.

of 4 or more feeding pedicles per session were independently associated with treatment-related complications ($P = 0.02$ and $P = 0.003$, respectively). A maximum nidus diameter of ≥ 6 cm had an independent negative correlation with complications ($P = 0.003$).

Discussion

This study is a retrospective registry investigating the endovascular embolization of cerebral AVMs performed between January 2005 and December 2009. Although it is a non-randomized, retrospective study, it may reflect the current state of embolization for cerebral AVMs in Japan, because the data were gathered from a wide range of institutions employing board certified instructors and neurointervention specialists of JSNET.

I. Treatment strategy

In the treatment of cerebral AVMs, the goals of embolization are classified into four types as follows: presurgical, preradiosurgical, curative, and palliative embolization. The goal of presurgical embolization is to minimize the risk of intraoperative complications. The reported predictors of intraoperative complications are diffuse nidus,¹²⁾ deep-seated nidus,^{13–15)} perforating artery supply,¹²⁾ fistulous feeder,¹⁶⁾ and ruptured intranidal or flow-related aneurysms.¹⁷⁾ Presurgical embolizations should be planned not only for reduction of nidus volume but also for the obliteration of the aforementioned harmful angioarchitecture. Regarding preradiosurgical embolization, although its efficacy has been controversial, a recent study found that preradiosurgical embolization targeting ruptured intranidal or flow-related aneurysms can decrease the rate of rebleeding after stereotactic radiosurgery.¹⁷⁾ Curative

embolization aims to completely occlude the AVM by embolization alone.

In the present study, presurgical and preradiosurgical embolization accounted for 69.0% of all procedures, while curative embolization was undertaken in only 10.2% of procedures (Table 3). This trend is attributable to the predominance of NBCA (74.2%) over Onyx (5.5%) as embolic material during the study period (Table 3). According to previous reports, the success rate of curative embolization is higher in embolizations using Onyx compared with that using NBCA.^{4,7,8,10,18–23)} However, in Japan, Onyx was only approved for use in a limited number of institutions on September 26, 2009, and it is covered by public insurance only for presurgical embolization. This could be the chief reason why curative embolization was used as a treatment strategy only in the minority of cases in this study.

II. Primary endpoint (mRS after Embolization)

Thirty days after embolization, 790 of 987 patients (80.0%) were nondisabled (mRS ≤ 2), compared with 877 of 987 patients (88.6%) at baseline. In other words, in 87 procedures, patients' mRS scores deteriorated from nondisabled (mRS ≤ 2) to disabled or dead (mRS ≥ 3) after treatments.

As mentioned above, 25 symptomatic complications and 3 deaths (28 in total) were recorded in this study. Among the 28 symptomatic or fatal complications, 17 complications exacerbated patients' mRS scores from nondisabled (mRS ≤ 2) to disabled or dead (mRS ≥ 3). In the remaining 70 procedures that resulted in a deterioration of mRS scores, the causes of deterioration were not clarified within the parameters of this study. There are few articles focusing on the change in mRS following treatment, and the results are controversial. Hartmann et al.²⁴⁾ and Weber et al.²⁵⁾ reported changes in mRS scores in patients receiving endovascular embolization subsequent to surgical treatment. According to the former, the population of nondisabled (mRS ≤ 2) patients decreased for each treatment stage (99% at baseline, 97% after embolization, and 91% after surgery).²⁴⁾ Weber et al. reported that the population of nondisabled patients was equal before and after embolization (91%), decreased after surgery (82%), and increased after a mean follow-up of 13 months (93%).²⁵⁾ Jayaraman et al. also described the rate of nondisabled patients before and after embolization as being equal (89% and 90%, respectively).³⁾ Previous reports revealed that surgery affected mRS scores more than embolization. It is likely that surgery subsequent to embolization was associated with a decrease in nondisabled patients in the present study. However, this is only a speculation,

Table 8 Literature reporting on embolization of cerebral AVMs

Author	Year	Design	Dominant embolic material	No. patients	No. procedures	Subsequent treatment (%)			Cured# (%)	Per procedure (%)		Per patient (%)		
						S*	R**	S + R		None***	Morbidity	Mortality	Morbidity	Mortality
Haw et al. ¹⁸⁾	2006	Retro	NBCA	306	513	23.6	55.9	0.0	20.5	9.2	3.5	1.4	5.9	2.3
Kim et al. ¹⁹⁾	2006	Retro	NBCA	153	203	70.6	13.1	3.9	12.4	1.3	8.4	0.5	11.1	0.7
Ledezma et al. ²⁰⁾	2006	Retro	NBCA	168	295	73.8	16.7	0.0	9.5	2.4	3.7	0.7	6.5	1.2
Mounayer et al. ²¹⁾	2007	Retro	Onyx	94	210	7.4	21.3	0.0	71.3	27.7	3.8	1.4	8.5	3.2
van Rooij et al. ²⁶⁾	2007	Retro	Onyx	44	52	22.7	45.5	0.0	31.8	15.9	3.8	1.9	4.6	2.3
Weber et al. ²⁵⁾	2007	Retro	Onyx	47	112	100.0	0.0	0.0	0.0	0.0	3.6	0.0	8.6	0.0
Jayaraman et al. ³⁾	2008	Retro	NBCA / Onyx	192	489	36.5	35.9	17.7	9.9	NA	1.2	0.4	3.1	1.0
Katsaridis et al. ⁷⁾	2008	Retro	Onyx	101	219	1.0	0.0	0.0	99.0	27.7	3.7	1.4	7.9	3.0
Hauck et al. ²⁷⁾	2009	Retro	Onyx	41	82	70.7	14.6	0.0	14.6	10.0	6.1	0.0	12.2	0.0
Panagiotopoulos et al. ²²⁾	2009	Retro	Onyx	82	119	59.8	3.7	0.0	24.4	24.4	13.4	1.7	19.5	2.4
Pierot et al. ⁹⁾	2009	Pro	Onyx	50	149	0.0	74.0	0.0	26.0	8.3	2.7	0.7	8.0	2.0
Loh et al. ²⁸⁾	2010	RCT	NBCA / Onyx	117	216	100.0	0.0	0.0	0.0	0.0	2.3	0.0	4.3	0.0
Maimon et al. ⁸⁾	2010	Retro	Onyx	43	76	7.0	0.0	0.0	93.0	37.2	3.9	0.0	7.0	0.0
Saatci et al. ¹⁰⁾	2011	Retro	Onyx	350	607	6.3	38.9	0.0	54.9	51.1	4.1	0.7	7.1	1.1
Sahlein et al. ⁴⁾	2012	Retro	NBCA	130	168	71.5	15.4	0.0	12.3	8.5	0.6	0.6	0.8	0.8
Present study	2013	Retro	NBCA	NA	987	45.9	23.1	NA	24.2	9.1	2.5	0.3	NA	NA

*: surgery, **: radiosurgery, ***: embolization alone. #: complete occlusion of AVM by embolization alone. AVM: arteriovenous malformation, NBCA: N-butyl cyanoacrylate.

because the timing and the results of surgery were not included in the present survey items.

III. Secondary endpoints (morbidity and mortality after embolization)

To compare the results of the present study with those of previous reports, the published studies of endovascular embolization of cerebral AVMs are summarized in Table 8. Studies in which sufficient data were not provided to analyse complications were not included in this table. Morbidity and mortality in the previous studies ranged from 1.2% to 13.4% and 0.0 to 1.9% per procedure, respectively. A recent meta-analysis of treatments of cerebral AVMs reported a 6.6% (range, 0–28%) morbi-mortality after embolization.²⁹⁾ In the present study, morbidity and mortality were 2.5% and 0.3% per procedure, respectively, which are within the range of morbidity and mortality rates reported in the previous articles. We should note that the present study included data not only from experienced, high-volume centres, but also from relatively inexperienced institutions in Japan, while most of the previous studies were based on data from a single experienced, high-volume centre. Although the results of these different studies are not directly comparable to each other, it appears that the safety of embolization in Japan as a whole is not inferior to that of foreign high-volume centres.

IV. Predictors of embolization-related complications

In multivariate logistic regression models, deep venous drainage and embolization of 4 or more feeding pedicles per session were independent predictors of treatment-related complications, while a maximum nidus diameter of ≥ 6 cm had a negative correlation with treatment-complications.

The reported predictors of complications during surgery are diffuse nidus,¹²⁾ deep-seated nidus,^{11,14,15)} perforating artery supply,¹²⁾ fistulous feeder,¹⁶⁾ and ruptured intranidal or flow-related aneurysms.¹⁷⁾ Regarding embolization, three previous reports investigated the predictors of complications using univariate and multivariate analyses.^{3,20,24)} Among these studies, only the one conducted by Ledezma et al. could identify a Spetzler-Martin grade of III to V and periprocedural haemorrhage as significantly positive predictors of unfavourable embolization outcomes.²⁰⁾ They suggested that the morphologic character of grade III-V AVMs, including large size, deep and eloquent location, deep arterial supply, and deep drainage, makes it difficult to embolize AVMs sufficiently.²⁰⁾ The other two studies failed to detect any significant predictors.^{3,24)}

The results of our analysis regarding the morpho-

logic character of AVMs were as follows: Spetzler-Martin grade was not a predictor of complications, the presence of deep venous drainage, which is a component of the Spetzler-Martin grading system was independently associated with complications (odds ratio 2.02, $P = 0.02$), and large size of nidus (≥ 6 cm) was a negative predictor of complications (odds ratio 0.09, $P = 0.003$). Other morphologic characters of AVMs, including location, deep arterial feeders, and concurrent aneurysms, did not have independent associations with complications.

The predictors of complications were inconsistent not only between embolization and surgery, but also among the studies investigating embolization. Another important result of our study, which may help interpret this inconsistency is that the embolization of more than adequate number of feeding pedicles (≥ 4) in one session is the strongest predictor of complications (odds ratio 4.14, $P = 0.003$). This result suggests that the risk of complications can depend on the aggressiveness of the embolization procedure, in addition to the morphologic character of AVMs. Similarly, Hauck et al. concluded, on the basis of previous articles, that too much reduction of nidus volume was associated with high morbidity.²⁷⁾ Furthermore, it should be taken into consideration that the present study predominantly reflects the results of presurgical or preradiosurgical embolization procedures using NBCA. Therefore, it is likely that the AVMs with risky morphologic characters were embolized by safer, more conservative procedures, such as staged embolization, in the present study.

However, the situation will probably change with the spread of Onyx. The behaviour of the embolic material widely differs between Onyx and NBCA. Because Onyx is not adhesive and can penetrate the drainers and other feeding arteries through the nidus, this material can enable a more aggressive and curative embolization of cerebral AVMs compared to NBCA.^{10,23)} However, further studies are needed to investigate the predictors of complications in AVM embolization procedures using Onyx.

V. Limitations

One of the limitations of the present study is that the efficacy of presurgical and preradiosurgical embolization could not be evaluated, because the final outcomes for patients after surgery or radiosurgery were not available. Additionally, long-term outcomes, including recanalization rate and bleeding rate after “cured” embolization, are also unknown due to a lack of long-term follow-up.

Conclusion

Embolization of cerebral AVMs was performed with a high degree of safety and a low rate of symptomatic complications in Japan.

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Conflicts of Interest Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices discussed in the articles. The first author who is member of The Japanese Society for Neuroendovascular Therapy (JSNET) and other authors who are members of The Japan Neurosurgical Society [JNS] have registered online Self-reported COI Disclosure

Statement Forms through the website for members of each Society.

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