Evaluation of the Stability of Intracranial Aneurysms Occluded with Guglielmi Detachable Coils

S. TAMATANI, Y. ITO, T. KOIKE*, H. ABE, T. KUMAGAI, S. TAKEUCHI, R. TANAKA

Department of Neurosurgery, Brain Research Institute; Niigata University;

*Department of Neurosurgery, Niigata City General Hospital; Niigata, Japan

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Summary

The purpose of this study is to evaluate the long-term stability of embolized aneurysms using the volume embolization rate (VER).

One hundred and six aneurysms in 96 patients who were treated with Guglielmi detachable coils were selected for this study. Follow-up angiography was performed at six or more months after initial treatment.

Every aneurysm was packed as densely as possible, however, the percentage of stability varied according to the size of the aneurysm or the size of the aneurysm neck. The percentage of stable aneurysm was 82% (56/68) in small aneurysms with small necks, 68% (13/19) in small aneurysms with wide necks and 42% (8/19) in large aneurysms. The mean VER of embolized aneurysms in each size was 30%, 22% and 17%, respectively. There was a correlation between the percentage of stable aneurysms and the mean VER. On the other hand, there seemed to be a difference of VER for the stability of embolized aneurysms between ruptured aneurysms and unruptured ones. In small aneurysms with small necks, the stability of em-

bolized aneurysms in ruptured ones was obtained only when the VER was greater than 30%, whereas it was found in unruptured ones even though the VER was less than 20%.

In conclusion, the long-term stability of embolized aneurysms was obtained in small-sized aneurysms, especially small neck aneurysms, and unruptured ones. The VER is a good, objective index to predict the long-term stability of embolized aneurysms.

Introduction

In the last decade, endovascular coil embolization with Guglielmi detachable coil system¹ has accepted as an effective method for the treatment of intracranial aneurysm and it has been widespread. However, coil embolization for the intracranial aneurysm is a relatively new treatment modality and two main questions are remained comparing the result of surgical clipping.

One of the big questions is the ability of protection against rebleeding for ruptured aneurysms. The other question is concerned

Table 1 Location of the embolized aneurysms

Aneurysm location	No. of aneurysms	
	Ruptured	Unruptured
Anterior circulation	19	64
ICA	10	48
paraclinoid	2	30
PcoA	7	16
AchA	0	2
ACA	8	9
MCA	1	7
Posterior circulation	17	6
BA tip	5	2
SCA	6	1
PICA	4	1
PCA	2	1
BA trunk	0	1
Total	36	70

ICA: internal carotid artery, PcoA: posterior communicating artery, AchA: anterior choroidal artery, ACA: anterior cerebral artery, MCA: middle cerebral artery, BA: basilar artery, SCA: superior cerebellar artery, PICA: posterior inferior cerebellar artery, PCA: posterior cerebral artery

about the stability of the occluded aneurysms with detachable coils and the efficacy in providing protection against growth or regrowth of the embolized aneurysm and consequent bleeding.

In this study, we aimed to evaluate the long-term angiographic stability of embolized aneurysm using volume embolization rate², which is the objective index to show the per-

centage of coil volume occupying aneurysm lumen. The difference of stability between ruptured aneurysms and unruptured ones is also demonstrated.

Material and Methods

Patient population

Two hundred fifty-seven aneurysms in 239 patients were treated with Guglielmi detachable coils (GDCs) between March 1997 and August 2000 at Niigata University Medical Center and affiliated hospitals. Each patient was scheduled for follow-up cerebral angiography at six months and two years after initial treatment.

Ninety-six patients with 106 aneurysms underwent follow-up angiography. One hundred thirty-seven patients were not included in this study. Follow-up angiography in 36 patients could not be performed due to poor medical condition or death; 23 patients have moved to another place and we cannot contact with them; 27 patients refused to have angiographic examination; 51 patients are awaiting scheduled follow-up angiography. The study population was composed of 69 women and 27 men. The mean age of the patients was 58 years old (range 22 to 83 years).

Thirty-six aneurysms in 32 patients were ruptured and 70 aneurysms in 64 patients were unruptured. Three of 33 patients with subarachnoid hemorrhage (SAH) had multiple aneurysms (two aneurysms in two patients, three in one). These aneurysms were included in ruptured ones, because we could not decide which aneurysm caused SAH.

Table 2 Angiographic findings on follow-up angiogram (ruptured aneurysm)

Angiographic findings	Size of aneurysm		
	Small (n=28)		Large (n=8)
	Small neck (n=24)	Wide neck (n=15)	
Unchanged	12	1	3
Improved	2		
Recanalized	10	3	5

Table 3 Angiographic findings on follow-up angiogram (unruptured aneurysm)

Angiographic findings	Size of aneurysm		
	Small (n=59)		Large (n=11)
	Small neck (n=44)	Wide neck (n=15)	
Unchanged	29	3	3
Improved	13	9	2
Recanalized	2	3	6

Description of aneurysm

Locations of 106 aneurysms are shown on table 1. Of the 36 ruptured aneurysms, 19 (53%) were in the anterior circulation and 17 (47%) were in the posterior circulation. Out of the 70 unruptured aneurysms, 64 (91%) were located in the anterior circulation.

The size of the aneurysms in three planes (height, length and width) was measured by DSA system of ruler. Eighty-seven aneurysms (28 ruptured aneurysms, 59 unruptured ones) were small (less than 10 mm in the largest diameter); and 19 (eight ruptured aneurysms, 11 unruptured) were large (10-24 mm). No giant aneurysm (more than 25 mm) was included in this study.

The neck diameter less than 4 mm is defined as "small neck". Sixty-eight aneurysms (24 ruptured aneurysms, 44 unruptured ones) had

small neck. The neck size greater than 4 mm is defined as "wide neck". Thirty-eight aneurysms (12 ruptured, 26 unruptured) had wide necks. All large aneurysms had necks wider than 4 mm in diameter.

Embolization of aneurysm

GDC system was used for aneurysmal embolization. The embolization procedure was performed under general anesthesia. Systemic heparinization (5000 units bolus followed by 1000 units per hour) were used throughout the procedure. In all patients with unruptured aneurysms, systemic heparinization was continued for 24 hours after embolization. Aneurysms were embolized using detachable coils to pack as densely as possible. The embolization was stopped when complete obliteration was performed, or when the last coil

Table 4 The mean VER of embolized aneurysms

	VER (%)		
	Small aneurysm		Large aneurysm
	Small neck	Wide neck	
Ruptured	31.0±13.0	22.1±16.5	15.0±11.0
Unruptured aneurysm	29.2±10.8	21.6±10.8	18.6±5.7

VER: Volume embolization rate

Table 5 Relationship between VER and stability of aneurysm (ruptured aneurysm)

VER	Size of aneurysm		
	Small (n=28)		Large (n=8)
	Small neck (n=24)	Wide neck (n=4)	
30 <	86% (12/14)	50% (1/2)	100% (1/1)
25 - 30	0%(0/3)		
20 - 25	33%(1/3)		100%
< 20	25° (1/4)	0% (0/2)	17% (1/6)

VER/: Volume embolization rate

could not be introduced inside the sac, or when the chance of occlusion for the normal branch beside aneurysm was occluded. The percentage occlusion rate at the end of the procedure was evaluated by volume embolization rate (VER)². The VER was calculated by following algebraic equation: $VER = (\text{Volume of the embolized coil}) / (\text{Volume of the aneurysm})$. The volume of the coil is calculated approximately on the supposition that the coil is a cylinder. The algebraic equation to calculate the volume of the coil (CV) is as follows:

$CV = \pi \bullet (\text{diameter of coil} / 2)^2 \bullet (\text{length of coil})$. Primary diameter of each type of coil is

published by Boston Scientific, Target (Fremont, CA). The volume of the aneurysm (AV) is also calculated approximately on the supposition that the aneurysm is ellipsoid; $AV = 4\pi/3 \bullet (\text{width} / 2)^2 \bullet (\text{length} / 2)^2 \bullet (\text{height} / 2)^2$.

The rate of occlusion by angiography was classified as follows: total occlusion when the sac and neck were densely packed in any projection, subtotal occlusion when the sac was occluded but there was a suspicion of a neck remnant or an obvious tiny neck remnant, partial occlusion when there was loose packing and / or persistent opacification of the sac or neck remnant.

Table 6 Relationship between VER and stability of aneurysm (unruptured aneurysm)

VER	Size of aneurysm		
	Small (n=59)		Large (n=11)
	Small neck (n=44)	Wide neck (n=15)	
30 <	100% (19/19)	100% (2/2)	
25 - 30	100%(7/7)	67%(2/3)	
20 - 25	91%(10/11)	75%(3/4)	67%(4/6)
< 20	86° (6/7)	50% (3/6)	20% (1/5)

VER/: Volume embolization rate

Angiographic follow-up studies

Each patient was scheduled for follow up angiography at six months and two years interval after treatment.

Recurrence was defined as an increase in the amount of contrast filling the aneurysm compared to angiographic appearance of the aneurysm at the end-of-treatment, which was classified as unstable aneurysm. An aneurysm was classified as stable at follow-up review if the degree of occlusion was unchanged or had improved compared to the end-of-treatment study.

Statistical analysis

All value is expressed as the mean $\pm$ standard deviation of the mean. Student's t-test was used for statistical analysis.

Probabilities less than 0.05 were considered significant.

Results*Relationship between the stability of aneurysm and the size of aneurysm*

Follow-up angiographic findings of aneurysms in each size are summarized on table 2 and 3. The percentage of stability in small aneurysms with small necks was 82% (56/68). That in small aneurysms with wide necks and in large aneurysms were 68% (13/19) and 42% (8/19). There is a significant difference of the stability between small aneurysms with small necks and large aneurysms ($p=0.0008$). Comparing the stability of embolized aneurysms between ruptured group and unruptured ones, unstable aneurysms were found more frequently in ruptured group (table 2,3).

Relationship between VER and Size of Aneurysm

Relationship between VER and size of aneurysm is shown on table 4. The mean VER was highest in small aneurysms with small necks (VER = 30%) and lowest in large aneurysm (VER = 17%), although every aneurysm was packed as densely as possible. There was no significant difference of mean VER between ruptured aneurysms and unruptured ones.

Relationship between the stability of embolized aneurysm and VER

Relationship between the long-term stability of embolized aneurysm and the VER are shown on table 5,6. Although the number of ruptured aneurysms is relatively small, enough stability of embolized aneurysm was obtained only when the VER was greater than 30% in the ruptured small aneurysms with small necks. On the other hand, adequate stability was found in unruptured small aneurysms with small necks even though the VER was less than 20%. In the small aneurysms with wide necks and large aneurysms, no significant difference of stability was found between ruptured aneurysms and unruptured ones.

Discussion*Correlation among the stability of embolized aneurysm, size of aneurysm and size of aneurysm neck*

Size of aneurysm and size of the aneurysm neck influenced the stability of embolized aneurysm. In our study, 82% of small aneurysms with small necks was stable on follow-up angiogram. However, the rate of the stability of embolized aneurysms on follow-up angiogram decreased to 68% in small aneurysms with wide necks and it was only 42% in large aneurysms. Several authors demonstrated similar results that coil embolization for large-sized aneurysms obtained less favorable results than for small aneurysms^{3,4,5}. These results might be correlated with occlusion rate of aneurysm. In this study, we used the VER as an index to evaluate the occlusion rate of embolized aneurysm. Our study demonstrated that the mean VER of stable small aneurysms with small necks was 29-31%. On the other hand, that of small aneurysms with wide necks was 21-22%, and that of large aneurysms was 15-18%. Although intraaneurysmal coil packing was performed as densely as possible, these results mean that possible embolization rate was decreased according to the increase of the size of aneurysm or the neck. It might be thought that this phenomenon means the limitation of intraaneurysmal coil embolization.

Several techniques or devices are considered to make up this limitation. The balloon-assisted

technique described by Moret, et al⁶, "remodeling technique", has made it possible to pack wide-neck aneurysm densely. The GDC embolization in conjunction with intravascular stent is another treatment modality to treat wide neck aneurysms⁷. Three-dimensional GDC and/or soft coil, stretch-resistant coil are also useful to achieve tight packing of aneurysms.

The difference of stability between ruptured aneurysms and unruptured aneurysms

There was a significant difference of the long-term stability between ruptured aneurysms and unruptured ones. In the ruptured aneurysms, the long-term stability was obtained only when the VER of embolized aneurysms was greater than 30%. On the other hand, the small aneurysms with small necks were stable even though the VER was less than 20%. Several reasons are considered for this result. Intraaneurysmal thrombus may be existed in the ruptured aneurysm, which leads to underestimation of the true volume of aneurysm. If there is some thrombus in the

aneurysm, spontaneous lysis of the clot may be occur in the days after rupture and the space where is not embolized with coils is appeared. Then coil compaction may be easily occurred in such aneurysm. Cognard et al³ demonstrated similar result that recurrences were more frequent after treatment of ruptured aneurysms than in unruptured aneurysms. Considering these results, strict follow-up is mandatory for the ruptured aneurysms.

Conclusion

In conclusion, the long-term stability of embolized aneurysms is correlated with the size of aneurysm, size of the neck and the state of aneurysm.

The embolization rate was decreased in the large-sized aneurysms, which may be the reason why the long-term stability could not be obtained. Ruptured aneurysms were unstable than unruptured ones even though the VER of ruptured and unruptured aneurysm was same. It is important for the ruptured aneurysm to pack as dense as possible, and to have strict follow-up.

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Shinichi Tamatani, M.D., PhD
Department of Neurosurgery, Brain Research Institute,
Niigata University,
1-757, Asahimachi, Niigata, 951-8585
Japan
E-mail: stamatani@pop16.odn.ne.jp