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Significance of Volume Embolization Ratio as a Predictor of Recanalization on Endovascular Treatment of Cerebral Aneurysms with Guglielmi Detachable Coils

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Key words: cerebral aneurysm, Guglielmi detachable coil, volume embolization ratio, recanalization

Summary

The purposes of this study are, firstly, to define the relationship between volume embolization ratio (VER) and degree of angiographical occlusion in endovascular treatment with Guglielmi detachable coils, and secondly, to examine influences of neck and dome sizes of aneurysms on the VER and the angiographical treatment result, and thirdly, to determine the relationship between the VER and the recanalization of coiled aneurysms.

Fifty-two aneurysms in 46 patients were examined. VER ranged 8.1-31.9% (mean 18.5%). The mean VERs of each categories based on angiographical treatment results were 23.1% in complete occlusion, 16.1% in neck remnant and 12.2% in incomplete occlusion, respectively. The VER correlated significantly with both neck and dome size, while the angiographical treatment result was only affected by neck size. Five aneurysms showed aneurysmal recanalization among followed-up 41 aneurysms. All recanalized aneurysms were large, and their VERs were in range of 10.4-17.6%.

Measurement of VER is useful to estimate the degree of occlusion objectively and to predict the aneurysmal recanalization. A small aneurysms with a small neck is relatively easy to achieve high VER and angiographical complete occlusion, with the consequence of less recanalization. On the other hand, a large aneurysm is liable to recanalize due to low VER, even if there was little filling of contrast medium in the aneurysmal cavity.

Introduction

Endovascular embolization using Guglielmi detachable coils (GDCs) has been accepted as a treatment for patients with intracranial aneurysms. Although the results of these treatments are very encouraging in the prevention of early rebleedings, the literature also reports a 2.2% subsequent hemorrhage rate among ruptured aneurysms that are incompletely occluded with coils [1]. Therefore, recent published data [2,3,4] stress the need to establish "100% or complete occlusion" to avoid aneurysm recurrence and rebleeding. However, because the percentage occlusion rate such as "100% or complete occlusion" is very subjective, we calculated volume embolization ratio (VER) as an objective marker of packing density following endosaccular aneurysm embolization.

The purpose of this study is to define the re-

lationship between the VER and the degree of angiographical occlusion, and to examine the influences of neck and dome sizes of aneurysms on the VER. We also evaluate the relationship between the VER and recanalization of coiled aneurysms.

Patients and Methods

Patient Population

From March 1997 to June 1999, 46 patients with 52 cerebral aneurysms underwent endovascular therapy with GDCs at Kanazawa University Hospital. Twenty-eight patients (61%) were female and 18 (39%) were males, and their ages ranged from 29 to 89 years with an average age of 60 years. Of the 46 patients, 41 had a single aneurysm, 4 had two aneurysms, and one had three aneurysms. At the time of initial clinical presentation, 24 (52%) patients had subarachnoid hemorrhage (SAH) due to a ruptured aneurysm, and 22 (48%) had unruptured aneurysm and no SAH. Thirty-nine aneurysms were located in the anterior circulation (75%) and 13 in the posterior circulation (25%).

Description of Aneurysms

Neck size. Thirty-two (62%) aneurysms had a small neck (4 mm or less), and 20 (48%) had a wide neck (more than 4 mm).

Dome size. Thirty-five (67%) aneurysms were small (10 mm or less in the largest diameter), and 17 (33%) were large (11-25 mm). In the present series, there was no giant (more than 25 mm) aneurysm.

Aneurysm volume. This characteristic that was necessary to obtain VER, was determined by the product of three diameters in the orthogonal plane. The volume were calculated either as prolate spheroids ($V = 4/3\ \pi \times a \times b \times c$, where a, b, and c are half the greatest diameter of the aneurysm in three perpendicular directions) or as cylinders ($V = r^2 \times \pi \times 1$, where r is the radius and l is the height of cylinder), depending on the aneurysm's geometry.

Angiographical treatment result and VER. Degree of angiographical occlusion in all aneurysms was evaluated by immediate postembolization angiography in multiple projection. These angiographical treatment results were classified as "complete occlusion", which was defined as no contrast medium filling of the dome, body, and neck; "neck remnant", which was defined as residual filling of part of the neck of the aneurysm; "incomplete occlusion", which was defined as some contrast medium filling of the dome. VER of all coiled aneurysms was calculated as the ratio of the volume of the packed coils to the aneurysm volume (VER (%) = Vcoil / Vaneurysm x 100). The coils were considered cylinders for volumetric calculations. The coil volume of GDC-18 standard, GDC-18 soft, GDC-10 standard, and GDC-10 soft were calculated at 11.0, 9.1, 4.9, and 4.5 mm^3/10 cm, respectively.

Follow -up Study

Each patient was scheduled for angiographical follow-up approximately 3, and 12 months after initial embolization. If the aneurysm had been completely or nearly completely occluded 12 months postembolization, subsequent follow-up study was performed by magnetic resonance angiography.

Statistical analyses

The mean VERs of each group divided by the angiographical treatment results were compared by one-way analysis of variance (ANOVA). After the one-way ANOVA comparisons, between-group comparisons were made using the Sheffe's method. Fisher's exact probability tests and χ^2 tests were used to compare the complete occlusion rates and the recanalization rates in the subgroups divided by neck size and dome size. Mann-Whitney U tests were used to compare the VER in the subgroups divided by neck size and dome size. A probability of less than P = .05 was considered statistically significant.

Result

Angiographical treatment result and VER

Of all aneurysms undergoing GDC treatment, 24 (46%) were in angiographical complete occlusion, 17 (33%) in neck remnant and 11 (21%) in incomplete occlusion. VER was in range of 8.1-31.9% (mean 18.5%). The mean VER of each category divided by angiographical treatment result were 23.1% in complete occlusion, 16.1% in neck remnant and 12.2% in

Table 1 **Angiographical treatment result and volume embolization ratio**

Angiographical treatment result	N	(%)	Volume embolization ratio (%) mean ± SE	min	max
Complete occlusion	24	(46)	23.1 ± 1.1	18.0	31.9
Neck remnant	17	(33)	16.1 ± 1.3[a]	8.8	26.1
Incomplete occlusion	11	(21)	12.2 ± 0.9[b]	8.1	16.9
Total	52	(100)	18.5 ± 0.9	8.1	31.9

[a] P = .0001 in comparison with complete occlusion; [b] P < .0001 in comparison with complete occlusion

incomplete occlusion. There was a positive correlation between the angiographical treatment result and the VER (table 1).

Influences of neck and dome sizes on the angiographical result and the VER (table 2)

Neck size. Of 32 aneurysms with small necks, 19 (59%) demonstrated angiographical complete occlusion. On the other hand, of 20 aneurysms with wide necks, only five (25%) were occluded completely. The mean VER of small neck group (20.3%) was significantly higher than that of wide neck group (15.7%).

Dome size. Complete occlusion rate was 49% in small aneurysms and 41% in large aneurysms. The angiographical treatment result was not affected by the dome size. However, the mean VER of large aneurysm group (15.6%) was significantly lower than that of small aneurysm group (19.9%).

Follow-up result

Ten patients with 11 aneurysms withdrew from the follow-up study; five patients of these underwent subsequent aneurysm clipping within 3 weeks after the initial embolization because of incomplete occlusion. Five patients died of severe SAH, pneumonia and renal failure. Follow-up cerebral angiogram was obtained in 36 patients with 41 aneurysms. The median clinical follow-up was 14.5 months.

In the present series, 5 aneurysms showed aneurysmal recanalization (table 3). No aneurysm recanalization was seen in the 22 completely occluded aneurysms. Of the 12 aneurysms with neck remnant, four showed aneurysmal recanalization due to aneurysm regrowth and coil compaction, six remained anatomically unchanged, and two showed further aneurysmal thrombosis. Of the seven incompletely treated aneurysms, one showed aneurysmal recanalization, four remained anatomically unchanged, and two showed further aneurysm thrombosis. All recanalized aneurysms were large, and their VERs were in range of 10.4-17.6%. Four of these patients underwent re-embolization, and one was retreated surgically. Factors affecting the recanalization were angiographical treatment result, VER, and aneurysmal size (table 4).

Discussion

VER as an evaluation of the aneurysmal occlusion

It is very difficult to assess the degree of aneurysmal occlusion after endosaccular pack-

Table 2 **Influence of neck and dome sizes on the angiographical treatment result and the volume embolization ratio**

factor	N	Angiographical treatment result: Complete occlusion (n)	(%)	Volume embolization ratio: mean ± SE (%)
Neck				
small	32	19	59[a]	20.3 ± 1.1[c]
wide	20	5	25	15.7 ± 1.4
Dome				
small	35	17	49[b]	19.9 ± 1.1[d]
large	17	7	41	15.6 ± 1.3

[a] P = .0226 (Fisher's exact probability test); [b] P = not significant (Fisher's exact probability test); [c] P = .0068 (Mann-Whitney U test); [d] P = .0335 (Mann-Whitney U test)

Table 3 **Summary of recanalized cases**

Case	Age	Sex	Site	Dome (mm)	Neck (mm)	Angiographical treatment result	VER (%)	Duration (months)	Additional treatment	Outcome (GOS)
1	72	F	ICPC	11	5	NR	17.6	3	coiling	GR
2	54	M	ACoA	20	8	NR	10.4	10	coiling	GR
3	69	M	ACoA	12	6	NR	10.9	3	clipping	MD
4	47	F	MCA	13	3	NR	14.5	3	coiling	MD
5	52	F	BA tip	12	6	I	14.9	6	coiling	GR

ACoA = anterior communicating artery; BA = basilar artery; GOS = Glasgow outcome scale (GR = good recovery; MD = moderately disabled); I = incomplete occlusion; IC = internal carotid artery; MCA = middle cerebral artery; NR = neck remnant; PC = posterior communicating artery; VER = volume embolization ratio

ing with GDCs. Because angiographical evaluation is very subjective, nobody knows exactly how much part of the aneurysmal cavity can be placed with coils.

Thus, we introduced VER in all aneurysms that were embolized with GDCs as an objective packing density. Recently, Piotin et Al reported that VER of maximally dense packing was approximately 30% to 36% using *in vitro* aneurysm models[5]. In our *in vivo* study, the VER of even angiographically completely coiled aneurysms was in range of 18.0-31.9%, that was lower than the value presented by Piotin et Al. In-vivo observation of coiled aneurysms showed that thrombosis could occur during the procedure and the aneurysm lumen was filled with not only coils but also thrombus[6], so less VER may be required clinically than experimentally to achieve aneurysmal obliteration.

Table 4 **Factors influencing the recanalization**

factor	N	recanalization (n)	(%)
Angiographical initial treatment result			
complete	22	0	0
not complete	19	5	26[a]
Volume embolization ratio			
low (<15%)	12	4	33[b]
medium (15-20%)	12	1	8
high (>20%)	17	0	0
Neck			
small	25	1	4
wide	16	4	25[c]
Dome			
small	21	0	0
large	20	5	25[d]
Total	41	5	12

[a] P = .0155 (Fisher's exact probability test); [b] P = .0231 (χ^2 test) [c] P = not significant; [d] P = .0207 (Fisher's exact probability test)

Influences of neck and dome size on the angiographical treatment result and the VER

Our results, as well as those presented in other reports[7,8,9], suggest that an aneurysm with a small neck of 4 mm or less has a greater chance of complete occlusion by GDCs than that in an aneurysm with a wide neck more than 4 mm. Furthermore, our study revealed that the smaller the neck, the higher the VER.

In an aneurysm with a small neck, GDCs are kept inside the aneurysmal sac, allowing dense packing with low risk of coil migration or impingement into the parent artery. On the other hand, a wide-necked aneurysm can hardly be densely packed because of the risk of depositing coils in the parent arteries or herniating into the parent arteries.

Moret et Al[10] developed a remodeling tech-

nique for coiling wide-necked aneurysms by means of temporary inflation of a nondetachable balloon across the neck during deployment of coils.

Although we did not use this technique in the present series, it may increase not only the complete occlusion rate but also the VER in wide-necked aneurysms.

It is well known that large aneurysms treated with GDC techniques are liable to recanalize [1,9,11,12]. Complete occlusion rates of large aneurysms and small ones were not statistically different.

However, the mean VER of large aneurysms was significantly lower than the value of small ones in the present series. These results suggest that, even if there was little contrast medium filling in the aneurysmal cavity, large aneurysms could possess a residual compartment enough to cause recanalization. Thus, when endovascular embolization is applied to large aneurysms, VER should be calculated in order to recognize the actual possibility of recanalization.

Factors influencing the recanalization

In the present series, 5 aneurysms showed aneurysmal recanalization. All of them could not achieve angiographical complete occlusion and their VERs were less than 20% at initial treatment. On the other hand, the aneurysms with the VER of more than 20% had not show the recanalization, even if their angiographical results were "neck remnant". Thus, measurement of VER is useful to estimate the degree of occlusion objectively and to predict the aneurysmal recanalization.

Our results showed that aneurysm size was another factor influencing the rate of recanalization. As mentioned above, large aneurysms could hardly get high VER more than 20%. A large aneurysm with low VER may has larger residual cavity than that in a small aneurysm with equal VER, where coil compaction can occur more easily as a consequence of the constant force of pulsating arterial blood flow.

Conclusions

Measurement of VER is useful to estimate the degree of occlusion objectively and to predict the aneurysm recanalization. A small aneurysms with a small neck is relatively easy to achieve the angiographical complete occlusion and high VER, with the consequence of less recanalization. On the other hand, a large aneurysm is liable to recanalize due to low VER.

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