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The Volume Embolization Ratio of Intraaneurysmal Embolization Using Guglielmi Detachable Coils

Guglielmi Ayrılabilir Sarmalları Kullanarak İntraanevrizmal Embolizasyonun Hacim Embolizasyon Oranı

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ABSTRACT

AIM: To analyse the relationship between the Volume Embolization Ratio (VER), aneurysmal morphological characteristics, and intracranial aneurysm embolization results.

MATERIAL and METHODS: Using the clinical and radiological data of 57 cerebral aneurysms treated with detachable coils, VERs were calculated. The relationship between the VER and aneurysm embolization was analysed.

RESULTS: We observed that the mean VERs of the small, medium, large, and giant aneurysms were 40.8±26.5%, 18.6±16.1%, 2.3±2.1% and 0.4±0.1%, respectively and the differences were statistically significant (F=7.091, P=0.000). The mean VERs of the wide- and small-necked aneurysms were 27.5±23.1% and 29.4±26.6%, respectively. There was no significant difference between these values. The mean VERs of aneurysms causing complete occlusion, neck residual and partial embolization were 41.8±29.3%, 31.4±21.2%, 12.3±15.1%, respectively, and the differences were statistically significant (F=7.97, p=0.001).

CONCLUSION: The VER is an objective index with which to evaluate aneurysm embolization and is a significant predictor of the efficacy of intracranial aneurysm embolization.

KEYWORDS: Intracranial aneurysm, Embolization, Angiography Volume Embolization Ratio

ÖZ

AMAÇ: Hacim Embolizasyon Oranı (VER), anevrizmal morfolojik özellikler ve intrakraniyal anevrizma embolizasyonu sonuçları arasındaki ilişkiyi analiz etmek.

YÖNTEM ve GEREÇLER: Ayrılabilir sarmallarla tedavi edilen 57 serebral anevrizmanın klinik ve radyolojik verileri kullanılarak VER'ler hesaplandı. VER ile anevrizma embolizyonu arasındaki ilişki analiz edildi.

BULGULAR: Küçük, orta, büyük ve dev anevrizmalar için ortalama VER'lerin sırasıyla %40,8±26,5, %18,6±16,1, %2,3±2,1 ve %0,4±0,1 olduğunu ve farkların istatistiksel olarak önemli olduğunu (F=7,091, P=0.000) bulduk. Geniş ve küçük boyunlu anevrizmaların ortalama VER'leri sırasıyla %27,5±23,1 ve %29,4±26,6 bulundu. Bu iki değer arasında önemli bir fark yoktu. Tam oklüzyon, boyun rezidüel ve parsiyel embolizasyona neden olan anevrizmaların ortalama VER'leri sırasıyla %41,8±29,3, %31,4±21,2 ve %12,3±15,1 bulundu ve farklar istatistiksel olarak önemliydi (F=7,97, p=0,001).

SONUÇ: VER, anevrizma embolizasyonunu değerlendirmek için objektif bir indekstir ve intrakraniyal anerizma embolizasyonunun etkinliğinin öngörülmesinde önemli bir faktördür.

ANAHTAR SÖZCÜKLER: İntrakraniyal anevrizma, Embolizasyon, Anjiyografi, Hacim Embolizasyon Oranı

INTRODUCTION

Coil embolization for intracranial aneurysms has been widely used since the introduction of Guglielmi detachable coils (4, 5). The advantage of an endovascular approach is that the coils promote the formation of thrombi in the aneurysm cavity and prevent blood flow into the sac. The aneurysmal orifice becomes endothelialized following thrombus organization, which makes it possible for clinicians to treat multiple aneurysms simultaneously. However, controversy exists regarding how to evaluate the results such procedures. Generally, aneurysm embolization results have been classified using the following modified scheme: class I, complete obliteration, 100% occlusion; class II, near-complete obliteration with a small neck remnant, greater than 95% occlusion; and class III, incomplete obliteration with evidence of residual filling or a large aneurysm remnant or lobule, less than 95% occlusion;

this classification scheme was developed by experts in this field (Figure 1) (7, 28, 29). The disadvantage of this method is that it is too subjective. Therefore, an objective method of evaluating aneurysm embolization is needed. The volume embolization ratio (VER) may be used to quantitatively evaluate the results of intracranial aneurysm coil embolization (2, 6, 7, 11, 18, 25, 27-29). Previous clinical studies have demonstrated that high VERs are difficult to obtain in both large- and wide-necked aneurysms and that a VER >25% is believed necessary in order to achieve stability in aneurysms treated via endovascular embolization (29). The VER may be a significant predictor of aneurysm retreatment, reopening, recanalization, recurrence and neck remnants (7, 28, 29).

The present study aimed to investigate the relationships between the VER and aneurysmal morphological characteristics, as well as the results of intracranial aneurysm embolization.

MATERIAL and METHODS

Patient Population

From January 2009 to September 2010, 53 patients (40 women and 13 men) with 57 ruptured intracranial aneurysms were treated with Guglielmi detachable coils. The patients ranged from 34-75 years of age (a mean of 57.23 years and a median of 49 years). All patients had previously suffered a sub-arachnoid haemorrhage (SAH) secondary to the ruptured aneurysm. The aneurysm presentations included all clinical grades of acute sub-arachnoid haemorrhage, remote rupture, and symptoms of mass effect, including headache and cranial neuropathy.

Aneurysm Location

Aneurysm location was assigned using standard conventions. Fifty-two (91.3%) aneurysms were located in the anterior circulation, and five (8.7%) aneurysms were located in the posterior circulation (Table I).

Table I: Location of Aneurysms

Aneurysm location	No. Of aneurysm
Anterior circulation	52 (91.2)
ICA	4
MCA	5
ACA	1
PcoA	26
AcoA	15
OA	1
Posterior circulation	5 (8.8)
VA	2
PCA	3
Total	57

Dates in parentheses are rounded percentages. ***ICA:*** *internal artery,* ***PcoA:*** *posterior communicating artery,* ***AcoA:*** *anterior communicating aneurysms,* ***ACA:*** *anterior cerebral artery,* ***MCA:*** *middle cerebral artery,* ***OA:*** *ophthalmic artery,* ***PCA:*** *posterior cerebral artery,* ***VA:*** *vertebral artery.*

Aneurysm Measurements

The aneurysm dimensions were determined using standard angiography software in order to determine maximum lengths, widths, and heights in perpendicular planes. Accurate angiographic aneurysmal sac and neck measurements were performed via 3D digital subtraction angiography after a consensus regarding the measurements was reached between the operators, and the 3D-DSA software was calibrated. The maximum length of the aneurysmal sac ranged from 1.82 mm to 21.27 mm. The maximum width of the aneurysmal sac ranged from 1.25 mm to 17.85 mm. The maximum height of the aneurysmal sac ranged from 1.15 mm to 21.45 mm. The neck size ranged from 2.5 mm to 15 mm and was ≤ 4 mm in 39 (68.4%) patients and > 4 mm in 18 (31.6%) patients. Thirty (52.6%) of the aneurysms were small aneurysms (<5 mm); 22 (38.6%) of the aneurysms were medium-sized aneurysms (5 mm-10 mm); 3 (5.3%) of the aneurysms were large aneurysms (11 mm-25 mm) and 2 (3.5%) of the aneurysms were giant aneurysms (>25 mm).

Angiographic Evaluation

The degree of aneurysmal occlusion observed following the procedure was evaluated based on the degree of angiographic occlusion and the occlusion volume. The degree of angiographic occlusion as measured via angiography was classified into three classes as follows: class I, complete obliteration, 100% occlusion; class II, near-complete obliteration with a small neck remnant, greater than 95% occlusion; and class III, incomplete obliteration with evidence of residual filling or a large aneurysm remnant or lobule, less than 95% occlusion (Figure 1) (10, 15, 16). The occlusion volume was the percentage of the coil volume occupying the aneurysmal volume, or the volume embolization ratio (VER) (2, 6, 7, 11, 18, 25, 27-29). The VER was calculated using the following algebraic equation: VER = (volume of the embolized coil) / (volume of the aneurysm) * 100% (2, 6, 7, 11, 18, 25, 27-29). The aneurysm volume was calculated before embolization as follows assuming that the aneurysm was ellipsoid: aneurysm volume (AV) = $(4\pi/3) * (A/2) * (B/2) * (C/2)$, where A, B and C are the aneurysm length, width and height, respectively (2, 7, 27,29). Assuming that the coil was a cylinder the following equation was used: coil volume = $\pi * (\text{coil diameter}/2)^2 * \text{coil length}$ (2, 7, 27,29).

Procedure

All patients received information about the procedure prior to treatment, which took place after each patient provided informed consent to participate in the study. Accurate angiographic aneurysmal sac and neck measurements were performed via 3D digital subtraction angiography before the procedures. All procedures were performed in the angiography suite, with the patients under local anaesthesia after receiving systemic heparin sodium therapy, which was administered as an intravenous bolus of 3000 IU. Additionally, aspirin was administered orally beginning 3 days prior to the procedure. All aneurysms were embolized with 1-13 GDC coils (a mean of 6) with a total length ranging from 15-340 mm (a mean of 34.5 mm), packed as densely as possible. The end points of embolization included complete angiographic occlusion and the inability to insert the last coil into the sac. All wide-neck aneurysms were treated via stenting. Postoperatively, the patients received heparin for 24 hours, followed by oral aspirin at a dose of 100 mg/day for 6 months.

Statistical Analysis

The quantitative data are presented as the means ± S.D. and were compared among the groups via a one-way analysis of variance, followed by Tukey's multiple comparison test. A P value <0.05 was considered statistically significant.

RESULTS

Angiographic Occlusion Results

At the end of the procedure, the percentage of aneurysmal occlusion was determined for all 57 aneurysms. Angiographic occlusion (Figure 2) was classified into three classes as follows: complete in 19 (33.3%) aneurysms, near complete in 20 (35.1%) aneurysms, and incomplete in 18 (31.6%) aneurysms.

The VERs of the Aneurysms

The VER of each aneurysm was calculated and ranged from 0.3% to 79.6% (mean 32.6%). The mean VERs of the small, medium, large, and giant aneurysms were 40.8±26.5%, 18.6±16.1%, 2.3±2.1%, 0.4±0.1%, respectively, differences that were statistically significant (F=7.091, P=0.000) (Figure 3). The mean VERs of the wide- and narrow-necked aneurysms were 27.5±23.1% and 29.4±26.6%. There was no significant difference between these values (P>0.05) (Figure 4). The mean VERs of the complete, near complete and incomplete aneurysms were 41.8±29.3%, 31.4±21.2%, 12.3±15.1%, respectively, differences that were statistically significant (F=7.97, P=0.001) (Figure 5).

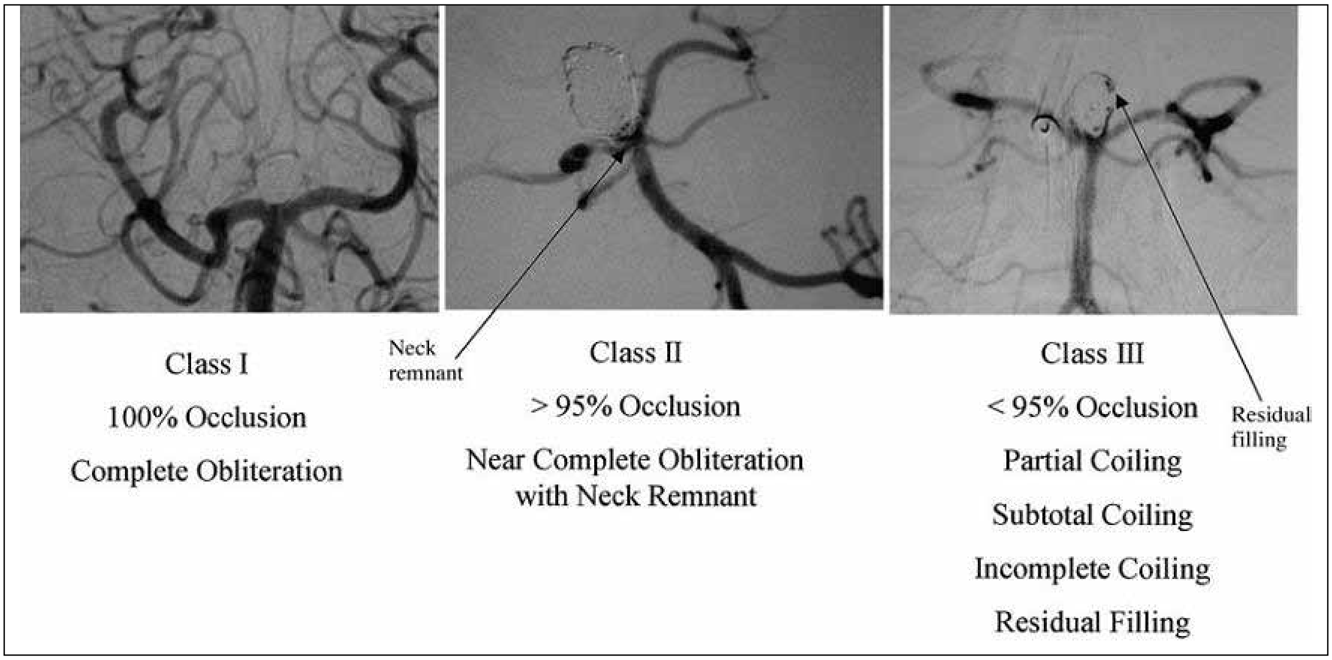

Figure 1: The degree of angiographic occlusion was classified into three classes.

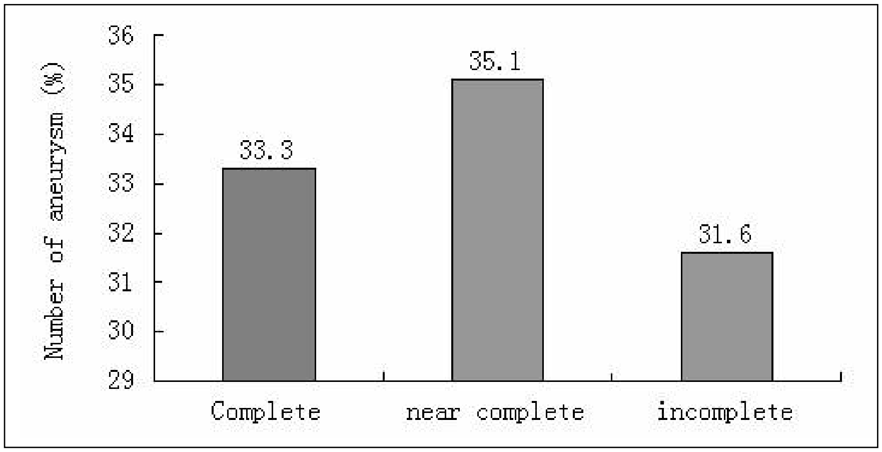

Figure 2: Degree of angiographic occlusion in all aneurysms.

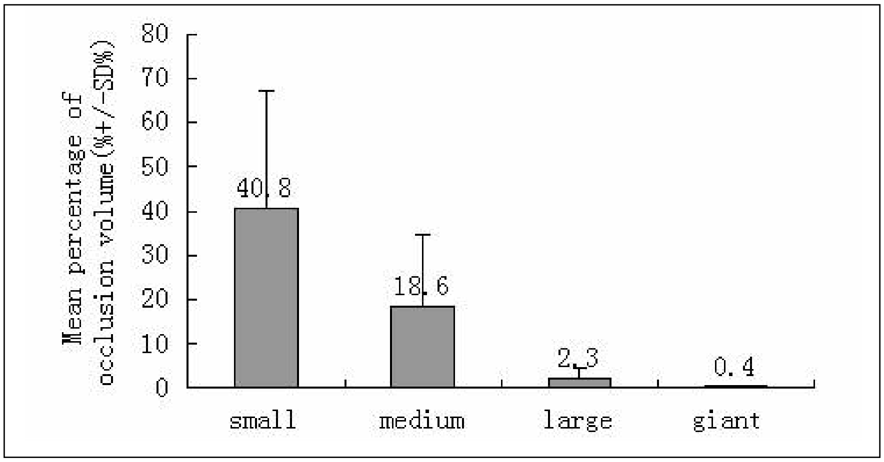

Figure 3: Mean percentage of occlusion volume according to aneurysmal feature (p<0.05).

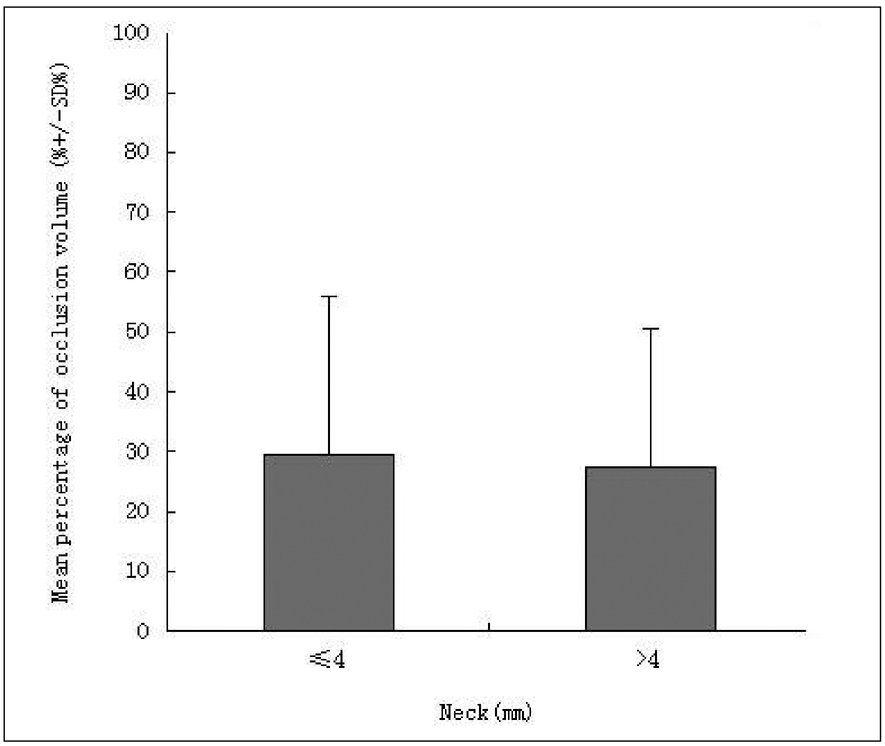

Figure 4: Mean percentage of occlusion volume according to aneurysmal feature (p>0.05).

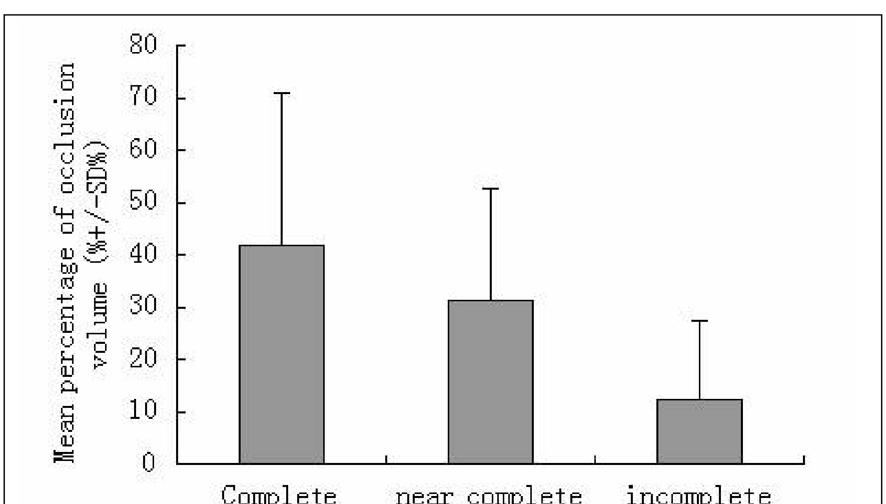

Figure 5: Mean percentage of occlusion volume according to degree of angiographic occlusion (p<0.05).

DISCUSSION

Endovascular coil embolization for intracranial aneurysms has been widely used since the introduction of Guglielmi detachable coils (4, 5). This method is effective at preventing re-bleeding following aneurysmal rupture (1, 26) and protecting against sub-arachnoid haemorrhage, and has been proven to result in better clinical outcomes compared with surgical clipping (9). However, the degree of aneurysm occlusion is influenced by many factors, including aneurysm morphology (aneurysm dome size, neck size, and dome/neck ratio) and the proximity of major neighbouring arteries. Additionally, there are several shortcomings of endovascular coil embolization, including retreatment (3, 7), reopening (3), recanalization (29), recurrence (6, 7) and neck remnants (28).

The volume embolization ratio (VER) has been used to evaluate the results of endovascular coil embolization in the setting of intracranial aneurysms (2, 6, 7, 11, 18, 25, 27-29). The VER is calculated using the following algebraic equation: VER = (volume of the embolized coil) / (volume of aneurysm) * 100%, which quantifies the amount of coil material occupying the aneurysm, providing an objective measurement of aneurysm obliteration. In combination with subjective angiographic assessments, angiographic occlusion results may be classified into three classes (10, 15, 16); this percentage of embolized volume may allow for a more accurate prediction of the immediate results and the long-term effects of endovascular coil embolization. Many studies have demonstrated that the shortcomings of endovascular coil embolization in are influenced by the VER. The higher the VER, the lower the rates of re-rupture (29), recanalization (24, 29), recurrence (29) and neck remnants (28) following treatment. However, a high VER may result in bleeding due to the fragility of aneurysm wall, whereas a low VER carries the risk of recanalization. Therefore, the optimal VER for coil embolization should range between 20% and 33%, as demonstrated by previous studies (6, 12, 19, 20, 23, 24, 29). High VERs are difficult to obtain in both large- and wide-necked aneurysms; a VER >25% is believed necessary to achieve stability in aneurysms treated via endovascular embolization (12, 21, 23). Therefore, a VER of 25% or greater should be the goal of endovascular embolization (12, 21, 23).

The factors influencing the success of angiographic occlusion include aneurysm dome size, neck size, and dome/neck ratio (25). Aneurysm dome size and neck size are the most important factors (25). In this study, we observed that the mean VERs of the small, medium, large, and giant aneurysms were 40.8±26.5%, 18.6±16.1%, 2.3 ±2.1%, and 0.4 ±0.1%, respectively, differences that were statistically significant (Figure 3). This result was consistent with those of previous studies that demonstrated that there was a negative correlation between aneurysm size and the VER (3, 25, 29). Vallee et al. (25) determined that the larger the volume of the aneurysm, the greater the length of coil required and the larger the amount of coil intertwining, resulting in additional dead space that may not be filled by coils. These results suggest that complete thrombosis is easier to achieve with small aneurysms compared with large aneurysms.

Wide-necked aneurysms are defined as aneurysms with a neck diameter greater than 4 mm. Many studies have reported that aneurysmal neck size is the most important factor affecting aneurysm treatment. Yagi et al. (29) reported that small (< 4 mm) aneurysms (22/40) exhibited higher VERs (>25%) compared with wide-necked (> 4 mm) aneurysms (4/22), a difference that was statistically significant. The VERs of the narrow- and wide-necked aneurysms were (24±8%) and (20±9%), respectively, a difference that was statistically significant (P=0.001) (29). When aneurysms have a small neck, the coils are held inside the aneurysmal sac, allowing for both complete occlusion and dense packing, with a low risk of either coil migration or bulging into the parent artery. However, wide-necked aneurysms may not be densely packed with coils because their necks are too wide to keep the coils within the aneurysmal lumen, which carries a risk of coil deposition in the parent vessel, as well as protrusion into the vessel (25). However, Vallee et al. (25) demonstrated that there was no significant difference between the small- and wide-necked aneurysms treated with 3D coils. In our study, we observed that the mean VERs of the wide- and narrow-necked aneurysms were 27.5±23.1% and 29.4±26.6%, respectively, a difference that was not statistically significant (P>0.05) (Figure 4), when the wide-necked aneurysms were treated with intracranial vascular stents. Our results were consistent with those of previous studies (8, 13, 14, 22, 25), which determined that remodelling (14), intracranial vascular stenting (8, 22), TriSpan neck–bridge devices (17) and three-dimensional coils (25) improve both the coil packing within and the occlusion of wide-necked aneurysms. These results suggest that stent-assisted embolization increases both the density and the packing of wide-necked aneurysms, as well as the VERs of wide-necked aneurysms.

In our study, aneurysm embolization was evaluated based on both the degree of angiographic occlusion and VERs. We observed complete obliteration in 19 (33.3%) aneurysms, near complete obliteration in 20 (35.1%) aneurysms, and incomplete obliteration in 18 (31.6%) aneurysms (Figure 2), the mean VERs of which were (41.8±29.3%), (31.4±21.2%) and (12.3±15.1%), differences that were statistically significant (Figure 5). Vallee et al. (13, 23,25, 29) observed that there were significant differences in VER between the completely occluded aneurysms and the nearly completely occluded aneurysms. Recent studies have determined that VER appears to be a more objective and useful index than the percentage of angiographic occlusion with respect to the prediction of the long-term anatomical stability of embolized aneurysms and successful aneurysm embolization (23,25).

Our study was limited in that it was a retrospective clinical study with a small sample size. Additionally, the lack of a uniform follow-up for all patients and the relationship between VER and the long-time outcomes of intracranial aneurysm embolization warrant the undertaking of additional studies.

CONCLUSION

This study demonstrated that there was a negative correlation between aneurysm size and the VERs of aneurysm. Stent-assisted embolization increases both the density and the packing of wide-necked aneurysms. The combination of a subjective angiographic assessment and the VER (objective measurement) is a good predictor of successful aneurysm embolization.

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