New Predictor for Intraaneurysmal Embolization Using Guglielmi Detachable Coils

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Abstract

Aneurysm volume/virtual column volume (AV/CV) ratio, calculated from measurements derived from reconstructed images based on rotational three-dimensional digital subtraction angiography (3D-DSA), was investigated as a predictor of the success of intraaneurysmal embolization in 20 unruptured wide-necked internal carotid artery aneurysms treated by Guglielmi detachable coils. AV and neck area were automatically calculated with a workstation. CV was defined as the product of height and neck area of the aneurysm. The percentage of aneurysm occlusion at the end of the procedure was evaluated by volume embolization ratio (VER). Successful intraaneurysmal embolization (VER \( \geq 20\% \)) was achieved in 10 of 11 aneurysms with AV/CV ratios of more than 1.0, whereas failed embolization (VER = 0\%) was observed in 3 of 4 aneurysms with AV/CV ratios of less than 0.8. The AV/CV ratio is a possible predictor of embolization success, which can be easily calculated using 3D-DSA.

Key words: aneurysm, embolization, angiography

Introduction

Aneurysm configuration and neck morphology are essential factors in deciding on the type of treatment, clipping versus coiling for intracranial aneurysm. The neck size and dome-to-neck ratio have gained widespread recognition as general indicators of the technical difficulty and outcomes of coil embolization. Complete aneurysm thrombosis can be achieved in 85% of aneurysms with a neck size of less than 4 mm, but in only 15% of aneurysms with a neck size of 4 mm or greater.\(^3\) The maximum diameter/neck size (A/N) ratio is a predictor of the stability of coils placed within the aneurysm.\(^6\) If the A/N ratio is equal to or less than 2, coils in the aneurysm are unlikely to be stable. The occlusion rate was 77% with an A/N ratio of at least 2.0, but was only 53% if the A/N ratio was less than 2.0.\(^2\)

Nevertheless, recent progress with endovascular techniques such as the neckplasty technique, and the development of new devices such as rotational three-dimensional digital subtraction angiography (3D-DSA) and 3D coils have changed the approach of intraaneurysmal embolization, especially for wide-necked aneurysms which are generally defined as having a neck size of greater than 4 mm and/or dome-to-neck ratio of less than 2.\(^1\) Therefore, a new indicator is needed to reflect such changes.

The present study evaluated a possible new predictor, the aneurysm volume/virtual column volume (AV/CV) ratio, in a series of patients treated for wide-necked intracranial aneurysm.

Methods

Twenty patients aged 43–74 years (mean 57.3 years) were treated for unruptured internal carotid artery aneurysms with wide necks by intraaneurysmal embolization using Guglielmi detachable coils between April 2003 and June 2004. Six aneurysms were located in the carotid cave, 4 at the ophthalmic artery, 8 at the superior hypophyseal artery, and 2 at the posterior communicating artery. Wide-necked aneurysm is defined as an aneurysm with a dome-to-neck ratio less than 2.0.

All procedures were performed in the angiography room, with the patient under local anesthesia after receiving systemic heparin sodium therapy, administered as an intravenous bolus of...
5000 IU. Heparin was infused continuously to maintain activated coagulation time of at least 2 times the normal level throughout the procedure. In addition, aspirin was administered orally beginning 3 days prior to the procedure. 3D-DSA images were obtained with a rotational angiography scanner (Advantage 3D XR 2.0; GE Medical Systems, Milwaukee, Wis., U.S.A.). The C-arm of the machine was rotated through 200 degrees two times. Each rotation produced 44 images within a 5-second time frame. The first rotation obtained the subtraction mask, then contrast medium was automatically injected into the target artery through the catheter using a power injector on the second rotation.

The aneurysm was then embolized with GDC-10 coils, 1–11 (mean 5) with total length 6–110 cm (mean 41.7 cm), packed as densely as possible. Neck plasty technique with a balloon was used in 16 aneurysms. The endpoints of embolization were complete angiographical occlusion or when no further coils could be inserted into the sac. Postoperatively, patients received heparinization for 24 hours followed by oral aspirin of 100 mg/day for 6 months.

The results of embolization were evaluated using the volume embolization ratio (VER) calculated as the percentage of coil volume occupying the AV, given by VER = (volume of embolized coils)/(volume of the aneurysm). Coil volume was calculated approximately, assuming the coil took the shape of a cylinder, given by coil volume = π × (coil diameter/2)^2 × coil length. The primary diameter of the coils was provided by the manufacturer (Boston Scientific, Fremont, Calif., U.S.A.). We defined successful treatment for unruptured intracranial aneurysms as a VER equal to or higher than 20%. The Fisher t-test was used for statistical analysis; probability values of less than 0.05 were considered significant.

The 88 3D-DSA images were transferred to workstation (Advantage Workstation 3.1; GE Medical Systems), to construct 3D digital imaging and communications in medicine (DICOM) images. The 3D DICOM image is based on a 3D reconstruction algorithm based on the algebraic reconstruction technique. From the 3D DICOM images, an angle was selected which allowed the aneurysm to be clearly separated from the parent artery to reconstruct cross-section DICOM images of the aneurysm. AV and neck area were measured. CV was calculated as the product of height and neck area. The slice interval was set to 0.3 mm and the matrix size of the cross-section image was 512 by 512 for an area of 130 mm by 130 mm. Threshold was set to 1100. The AV/CV ratio, defined as the ratio of AV to CV (Fig. 1), was calculated for all aneurysms.

**Results**

The maximum diameter of the aneurysm sac was calculated from the maximum intensity projection image and ranged from 2.7 to 8.3 mm (mean 5.0 mm). Aneurysm neck size measured as the maximum axial diameter at the orifice of the aneurysm ranged from 1.7 to 5.9 mm, and was less than 4 mm in 11 aneurysms and 4 mm or greater in 9. Dome-to-neck ratio was 0.8 to 1.89 (mean 1.32), aneurysm
volume ranged from 13 to 352 mm³ (mean 102.6 mm³), and neck area ranged from 5 to 42.2 mm² (mean 19.2 mm²).

To determine the relationship between AV/CV ratio and VER, the aneurysms were divided into three subgroups according to AV/CV ratio on presentation: very small (<0.8), small (0.8–1.0), and large (>1.0). Satisfactory intraaneurysmal embolization (VER ≥20%) was achieved in 0 of 4 aneurysms in the very small group, 3 of 5 aneurysms in the small group, and 10 of 11 aneurysms in the large group, indicating a significant difference between the very small and large subgroups (p < 0.01, Fisher t-test). Furthermore, failed embolization (VER = 0%) was observed in 3 of 4 aneurysms with AV/CV ratios of less than 0.8. Moreover, successful embolization was achieved in 8 of the 11 aneurysms with a neck size of less than 4 mm, and in 5 of the 9 aneurysms with a neck size of 4 mm or greater, indicating no significant difference between the two subgroups (Fig. 3).

**Discussion**

In the present series, all aneurysms had a dome-to-neck ratio of less than 2.0. Nevertheless, successful embolization (VER ≥20%) was achieved in only 13 of the 20 aneurysms. Moreover, successful embolization was obtained in 8 of the 11 aneurysms with a neck size of less than 4 mm, and in 5 of the 9 aneurysms with a neck size of 4 mm or greater. No significant difference was seen between the two subgroups. In contrast, a large AV/CV ratio allowed coils to be detached inside the aneurysm sac, resulting in dense packing with low risk of coil migration or impingement on the parent artery. On the other hand, a small AV/CV ratio was associated with greater difficulty in dense packing because of the high probability of spilling coils into the parent vessel. These preliminary findings suggest that AV/CV ratio may be a more practical indicator for intraaneurysmal embolization than the absolute neck size and dome-to-neck ratio, especially in wide-necked aneurysms.

Various methods for assessment of treatment choice and measurement of aneurysm have been described, but are generally based only on angiographic tracing. Analysis of a 3D structure, such as an aneurysm and its relationship to the parent artery, cannot be achieved by only referring to two-dimensional images. 3D-DSA provided us with accurate geometric data, which is important for patient management. The difficulty score based on 3D-DSA findings provides useful information for the prediction of successful endovascular treatment. Several aneurysm-related morphological factors, including largest diameter of the sac, size of the neck, dome-to-neck ratio, can be measured by 3D-DSA. However, the volume and neck area of the aneurysm were not considered. This study indicates that area and volume are apparently key factors.

The actual neck area is a convex or concave surface and is not planar. The present study considered the neck area as a planar surface, which was artificially determined when isolating the aneurysm from the parent artery. Therefore, the neck area may vary depending on this action, as well as the effect of the threshold values on the neck area. Such issues remain to be resolved, but the AV/CV ratio makes use of new information acquired from 3D-DSA, and does not rely on conventional measurements such as...
the aneurysm maximum diameter and neck size. Therefore, we suggest that the AV/CV ratio may be a useful measurement for predicting the success of intraaneurysmal embolization, particularly for wide-necked aneurysms, based on whether coils can be placed in a stable position within the aneurysm dome. Confirmation requires further examination by a comprehensive study.

References


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Commentary

The authors present an interesting analysis of a novel aneurysm morphology index as a predictor of the feasibility of endosaccular coil embolization of unruptured broad necked internal carotid artery aneurysms. The aneurysm volume/virtual column volume (AC/CV) ratio seemed to be a good predictor of technical success of endosaccular coil embolization in a small cohort of cases. Of course the number of cases is small and the aneurysm selection quite narrow, mostly smaller lesions, and complete data on the aneurysms was not provided to compare with previously suggested indices in the literature. Positive predictive values and negative predictive values are not analyzed statistically. Hopefully these more rigorous analyses will be done as the authors acquire larger experience in a more diverse aneurysm cohort. Technical success as measured by volume embolization ratio (VER) >20% is an arbitrary criterion, without any proven correlation with clinically successful results, i.e. prevention of growth, coil compaction, retreatment and/or bleeding. Techniques of balloon assisted embolization, and stent enforced coiling are now more commonly used for such broad necked aneurysms especially at the internal carotid artery, and the relevance of the AC/CV ratio in those techniques is not known. We continue to caution against the use of endosaccular coil of unruptured aneurysm cases where clipping is relatively straightforward (ophthalmic, posterior communicating segment, etc.), since any coiling of unruptured aneurysms is associated with prospective bleed rates which approximate or are worse than the natural history (1–2% post coiling hemorrhages in most published series), a rate much higher than reported in any clipping series.

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Matsumoto et al. present a new predictor for dense packing during coil embolization for intracranial aneurysms with the help of 3D angiography. 3D angiography provides a new insight in the diagnosis and treatment of intracranial aneurysms, and aneurysm volume/virtual column volume is one of such benefits provided by this tool. We expect other valuable parameters to be derived from this predictor.

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