Determination of filling volumes in HydroCoil-treated aneurysms by using three-dimensional computerized tomography angiography

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Object. Coil embolization of aneurysms has been shown to be as safe and effective as surgical clip ligation, but has a higher recurrence rate. Advances in coil technology aim to reduce aneurysm recurrence by coating the devices with biological substances. An example of this is MicroVention's HydroCoil, which is a platinum coil coated with hydrogel that improves filling volumes by swelling when it contacts blood. The goal of this study was to determine whether this new coil type significantly reduced or prevented recurrences of aneurysms.

Methods. The authors used three-dimensional computerized tomography angiography to determine aneurysm volumes accurately in 12 patients prior to coil embolization. The percentage filling volume was subsequently calculated for each aneurysm after treatment with HydroCoils and the immediate and 6-month follow-up angiographically confirmed occlusions were evaluated. The data demonstrated that both anterior and posterior intracranial aneurysms with diameters of 3 to 25 mm and volumes of 0.03 to 4.8 ml had filling volumes of 0.02 to 1.36 ml, resulting in filling volumes from 23% in a giant ophthalmic artery aneurysm to 80% in a small anterior communicating artery aneurysm. All of the aneurysms except for the giant one demonstrated stable occlusion on angiographic studies obtained at the 6-month follow-up review.

Conclusions. HydroCoil embolization of intracranial aneurysms is safe and effective for small, large, and very large aneurysms. The percentage filling volume is greater than that reported for bare platinum coils in every case except the giant aneurysm. Nevertheless, angiographically confirmed occlusion is not directly related to percentage filling volume, but rather to the ability to occlude the aneurysm neck.

KEY WORDS • aneurysm • embolization • endovascular treatment • aneurysm filling volume • hydrogel-coated coil • computerized tomography angiography

Coil embolization of aneurysms has recently been shown to be as safe and effective as microsurgical clip ligation in a randomized trial.[2] One important criticism of that report is the need for longer follow-up duration. Clearly, coil embolization has a higher rate of aneurysm rests and recurrences compared with microsurgical clip ligation.[7] In efforts to reduce the rate of recurrences, surface modifications have been made to platinum coils to improve the durability of treatment. In recent studies, in aneurysms that were filled beyond 24% of their volume, the coils effectively prevented recurrences.[10] In in vitro studies, aneurysms maximally treated with bare platinum coils can reach filling volumes of 32 to 34%.[5,6]

The HydroCoil is a hydrogel-coated platinum coil that swells when it contacts blood to provide higher filling volumes than bare platinum coils by filling the interstices of the coil mass.[3] The ability to achieve high-percentage filling volumes may translate to reduced recurrence rates. In our early experience with HydroCoils, we wanted to accomplish the following: 1) to test the hypothesis that an improved percentage of filling would result in reduced recurrences; and 2) to identify a potential percentage filling volume threshold that needs to be achieved to prevent recurrences (such as 24% in the series reported by Sluzewski, et al.[10]). Nevertheless, the difficulty in calculating the aneurysm volume to render an accurate percentage of occlusion remains.[14] We report on the novel use of 3D CT angiography to obtain an accurate measurement of preembolization aneurysm volumes. We were able to calculate the filling volume of 12 intracranial aneurysms treated with HydroCoils and compare the results with the reported filling volume of bare platinum coils. In addition, 6- and 12-month follow-up angiography studies were used to assess the stability of the selected treatment.

Abbreviations used in this paper: ACoA = anterior communicating artery; CT = computerized tomography; OphA = ophthalmic artery; PCoA = posterior communicating artery; 3D = three-dimensional.

CLINICAL MATERIAL AND METHODS

Volumetric Analysis of Intracranial Aneurysms With 3D CT Angiography

Twelve consecutive patients with anterior and posterior circulation, ruptured and unruptured, small (< 10 mm), large (10 to < 25 mm), and giant (≥ 25 mm) cerebral aneurysms underwent 3D CT angiography prior to embolization with HydroCoils (MicroVention, Inc., Aliso Viejo, CA). The CT scans were performed with a 16-slice detector CT machine (General Electric Medical Systems, Milwaukee, WI) by using 0.625-mm acquisitions following an injection of 125 ml of iodinated contrast material. Source images were viewed in sagittal, coronal, and axial planes on a Vitrea workstation and subsequently rendered in 3D by using the Vitrea software (Vital Images, Inc., Plymouth, MN). Regions of interest were outlined on each successive 0.625-mm slice of the aneurysm and the volumes (in milliliters) were calculated with the Vitrea software (Fig. 1).

Embolization Techniques

All patients underwent intracranial aneurysm coil embolization performed by the senior author (A.S.B.). Via a transfemoral approach in which a No. 6 French sheath was used, a No. 6 French Simmons II Envoy (Cordis, Johnson and Johnson, Miami Lakes, FL) (anterior circulation) or a No. 6 French Angled Envoy (posterior circulation) catheter was advanced over a 0.035-in glide wire into the parent artery of interest. A 0.014-in wire (Synchro; Boston Scientific, Natick, MA) was used to guide a microcatheter (Excelsior 1019; Boston Scientific, or Prowler Plus; Cordis, Johnson and Johnson) into the aneurysm dome under direct visualization by using biplane reverse road-mapping techniques.

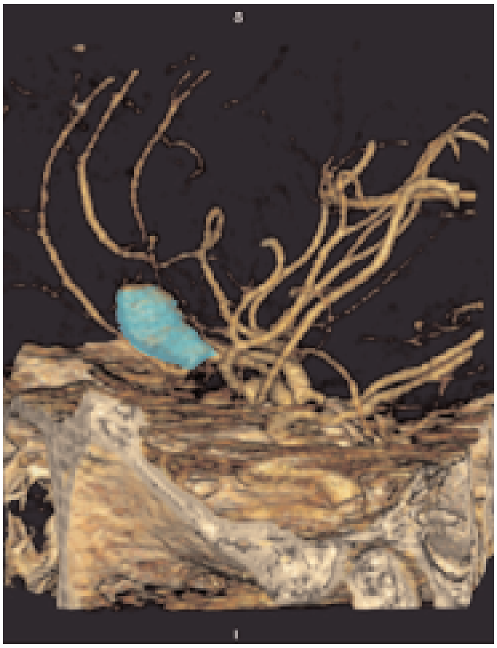

Fig. 1. A CT angiogram demonstrating the reconstructed 3D summation of the points of interest used to measure aneurysm volume (the lesion is highlighted).

The aneurysms were embolized with a combination of framing bare platinum coils and then filled with HydroCoils-14 until one of the following criteria was met: no angiographic evidence of aneurysm dome or neck filling remained (Raymond–Roy Class 1); or coils could no longer be placed into the aneurysm without dislodging the microcatheter. Angiographically confirmed aneurysm occlusion was quantified according to the Raymond–Roy classification system,[8] as follows: Class 1, no filling of the aneurysm neck or dome; Class 2, residual filling of the neck but not the dome; and Class 3, residual filling of the neck and dome. No radiographic evidence of subarachnoid hemorrhage was noted during the embolization procedures.

Calculation of HydroCoil Volume

Analysis of filling volumes was calculated for each aneurysm based on the total length and diameter of the HydroCoils at their ‘swollen diameter’; the framing bare platinum coils used to treat the aneurysm were added as a function of length and radius of the coil.

RESULTS

Twelve patients underwent preembolization volumetric analysis of their intracranial aneurysms with 3D CT angiography (Table 1). There were two ACoA, two OphA segment, two carotid terminus, four PCoA, one basilar apex, and one vertebrobasilar junction aneurysm. The maximal diameters of the lesions ranged from 3 to 25 mm, and the volumes determined using 3D CT angiography ranged from 0.03 to 4.8 ml.

Four small aneurysms were classified as Raymond–Roy Class 1, five lesions consisting of small, large, and a giant aneurysm were Class 2, and two large and one giant aneurysm were Class 3. Aneurysm filling volumes ranged from 23% in the giant OphA aneurysm (Raymond–Roy Class 3) to 80% in a small ACoA aneurysm (Class 2).

The mean filling volume for all aneurysms was 52 $\pm$ 15%. Small aneurysms had volumes less than 0.36 ml, with mean HydroCoil filling volumes of 59 $\pm$ 13%, and three of these were Raymond–Roy Class 1, with filling volumes between 46 and 53%; two were Class 2, with 70 and 80% filling volumes; none of the small aneurysms were Class 3. Of the large aneurysms that had volumes of 0.4 and 0.57 ml, mean HydroCoil filling volumes of 40%, and one each was Raymond–Roy Classes 2 and 3, with mean aneurysm filling volumes of 37 and 43%, respectively. Two other large aneurysms had volumes greater than 1.0 ml, with mean HydroCoil filling volumes of 52%; both were Raymond–Roy Class 2. The giant OphA aneurysm had a volume of 4.8 ml, was Raymond–Roy Class 3, and had a 23% coil filling volume.

Six-month follow-up angiography studies demonstrated that all lesions remained stable, with two exceptions. One was a 12-mm PCoA aneurysm with a 65% HydroCoil filling volume that improved (from Raymond–Roy Class 3 to Class 2 [Fig. 2]). The other was a giant (25-mm) OphA aneurysm that was Raymond–Roy Class 3 and had a 23% HydroCoil filling volume, in which we found more filling of the dome related to coil compaction (Fig. 3). Filling volumes did not correlate with efficacy of occlusion ac-

TABLE 1
*Volumetric analysis of aneurysms and HydroCoil filling volumes in 12 patients**

Case No.	Aneurysm Data			Total HydroCoil Vol (ml)	Occl Class†		% Filling Vol
	Location	Dia (mm)	Vol (ml)		Preop	6-Mo FU	
1	PCoA	3	0.03	0.02	2	2, stable	70
2	ACoA	5	0.05	0.03	1	1, stable	52
3	ACoA	6	0.05	0.04	2	2, stable	80
4	VBJ	6	0.15	0.08	1	1, stable	53
5	BA apex	9	0.21	0.10	1	1, stable	46
6	PCoA	12	0.28	0.81	3	2, better	65
7	PCoA	10	0.36	0.17	1	1, stable	47
8	PCoA	11	0.40	0.11	2	2, stable	37
9	CA terminus	13	0.57	0.24	3	3, stable	43
10	large, ICA terminus	19	1.30	0.56	2	2, stable	43
11	large, OphA	19	2.20	1.36	2	2, stable	62
12	giant, OphA	25	4.80	1.33	3	3, worse	23

* BA = basilar artery; CA = carotid artery; dia = diameter; ICA = internal carotid artery; occl class = occlusion classification; VBJ = vertebrobasilar junction.

† Raymond–Roy classifications: Class 1, no filling of the aneurysm neck or dome; Class 2, residual filling of the neck but not the dome; and Class 3, residual filling of the neck and dome.

cording to angiographic findings or with the Raymond–Roy classification.

DISCUSSION

Bare platinum coils have been shown to provide a maximum of 34% volume filling when there is no longer angiographic evidence of aneurysm filling.[6] The goal in attaining high filling volumes is to prevent aneurysm recurrence. Raymond, et al.,[7] discovered that recurrences occurred in 33% of aneurysms treated at a mean follow-up duration of 12 months. Major recurrences occurred at a mean of 16 months, with a 20% rate. Bare platinum coil embolization fared even worse when considering very large and giant aneurysms. In a single-center study, bare platinum coil embolization was the single definitive treatment in only 12.5% of the giant and 31% of the very large aneurysms.[9] In addition, internal carotid artery aneurysms had a 40% recurrence rate in lesions ranging from 6 to 20 mm in diameter.[4]

Long-term clinical outcomes have demonstrated that coil mesh stability was poor over time, requiring repeated coil placement, surgery, and/or parent-vessel balloon occlusion in 58% of the aneurysms primarily treated with coils.[9] Coil compaction can be a significant problem, and some endovascularly treated patients have subsequently

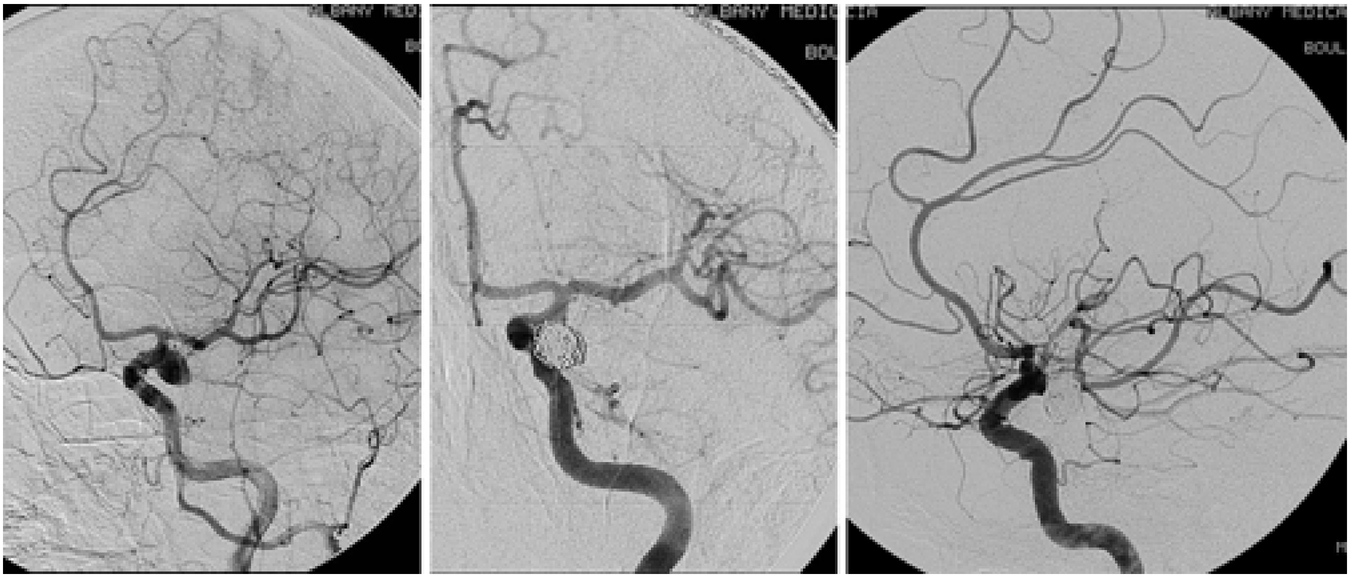

Fig. 2. Digital subtraction angiography studies of a 12-mm PCoA aneurysm. *Left:* Pretreatment study. *Center:* Angiogram obtained after embolization with HydroCoils to obtain 65% filling volume with flow to the apex of the aneurysm dome. *Right:* A 6-month follow-up study demonstrating complete occlusion without filling of the dome (Raymond–Roy categorization improved from Class 3 to 2).

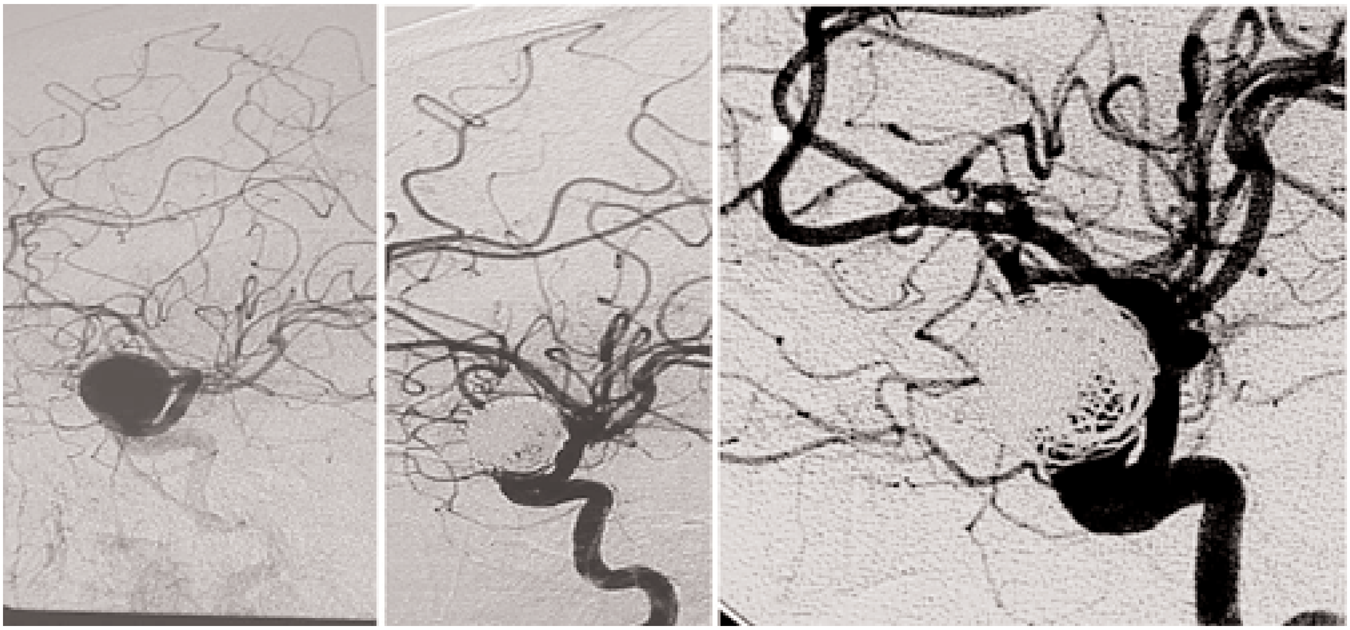

Fig. 3. Digital subtraction angiography studies of a giant 25-mm OphA aneurysm. *Left:* Pretreatment study. *Center:* Angiogram obtained immediately after embolization with HydroCoils to obtain a 23% filling volume. *Right:* A 6-month follow-up study demonstrating increased apical dome filling from coil compaction.

required surgical intervention.[11–13] Therefore, the goal of coil technology is to develop a device that reduces the incidence of coil compaction and aneurysm recurrence. One potential method is to increase the percentage of the aneurysm occluded with the embolic agent.

The accuracy of the reported filling volumes is dependent on the modality used to calculate aneurysm volumes. Traditionally, aneurysm volume is calculated using the maximal linear dimensions on two-dimensional angiography, with the inherent assumption that every aneurysm is a perfect sphere or ellipse.[14] This method does not account for the true aneurysm morphology, resulting in inaccurately calculated aneurysm volumes and incorrect volumetric analyses of the coil filling volumes. Use of 3D CT angiography to determine the aneurysm volume is more precise and allows us to determine more accurately the effectiveness of new coil embolization technology.

HydroCoils are platinum coils coated with a hydrogel that swells when it contacts blood, and this feature reportedly increases filling volumes.[1] In our series, we have demonstrated that HydroCoils provide better aneurysm filling volumes than bare platinum coils in every case except that of a single giant OphA aneurysm (23% filling). The filling volumes in this series were as high as 80% in small, 65% in large, and 23% in giant aneurysms.

Nevertheless, our data do not demonstrate a direct correlation between filling volumes and durability or efficacy of angiographically confirmed occlusion. For example, aneurysms in Raymond–Roy Class 1 had filling volumes between 46 and 53%, whereas those in Class 2 had more angiographically confirmed aneurysm filling despite an 80% filling volume. The absence of a direct correlation implies that other factors are also responsible for attainment of excellent angiographic occlusion.

The interface between parent vessel and aneurysm neck plays a critical role in successful complete embolization of the lesion. The HydroCoil technology does not address this problem, and thus residual necks were left because of the inability to reconstruct the parent vessel adequately. The stability of the closure of aneurysms with residual necks may be improved using the HydroCoil technology. Based on our experience with 70 HydroCoil-treated cases, we determined that to obtain complete angiographically confirmed occlusion of the aneurysm with excellent long-term durability, two requirements must be met: 1) good coil packing to obtain high filling volumes, and 2) occlusion of the aneurysm neck.

In this series, 6-month follow-up angiographic studies demonstrated stable occlusion in every case except two. The first was a large (12-mm) PCoA aneurysm in which the Raymond–Roy category had improved from Class 3 to 2 (Fig. 2). The second was a giant (25-mm) OphA aneurysm that had significant coil compaction and refilling of the dome (Fig. 3). The large aneurysm had residual filling of the dome but good neck occlusion (Raymond–Roy Class 3), with 65% volume filling after the initial treatment. The giant aneurysm demonstrated persistent neck and dome filling, with 23% volume filling after initial treatment, and subsequent worsening.

CONCLUSIONS

Three-dimensional CT angiography is a novel and accurate way of determining aneurysm volume and calculating percentage aneurysm filling volumes. Using this method, we have demonstrated a significantly better aneurysm filling volume in small and large lesions treated with HydroCoils compared with bare platinum coils. Nevertheless, giant aneurysms continue to be a challenge even for HydroCoils, because of coil compaction. Further-more, we did not find a direct correlation between angiographically confirmed occlusion and volume packing; however, preliminary data indicate a possible role in preventing recurrences with higher filling volumes identified in this series. Further evolution of coil technology is required to improve our ability to treat the neck of the aneurysm with endovascular techniques.

Disclaimer

None of the authors has a financial interest in the products reported in this manuscript.

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