

Original Article

Angiographic and epidemiological characteristics associated with aneurysm remnants after microsurgical clipping

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Abstract

Background: Despite new techniques for the treatment of cerebral aneurysms, the percentage of aneurysm remnants after surgical intervention seems to be relatively constant. The objective of this study was to assess angiographic and epidemiological features associated with aneurysm remnants after microsurgical clipping.

Methods: This study was conducted from February 2009 to August 2012 on a series of 90 patients with 105 aneurysms referred to the Santa Casa of Belo Horizonte who were surgically treated and angiographically controlled.

Results: Surgical clipping was considered incomplete in 13.3% of the aneurysms. The mean age of cases with an aneurysm remnant was 57.5 years, whereas the mean age without aneurysm remnant was 49.7 years ($P = 0.02$). Aneurysm remnants were detected more frequently on the internal carotid artery, nevertheless, no statistically significant differences were verified when comparing the locations. Aneurysm size in the preoperative angiography verified that the mean size of aneurysms operated was 6.56 mm, such that in cases showing a postoperative remnant, the mean size was 9.7 mm and in cases with complete clipping it was 6.08 mm ($P = 0.02$). Postoperative angiography showed that, in cases with residual aneurysm, the number of clips used was higher – a mean of 1.8 for complete clipping and 3.1 for incomplete clipping ($P < 0.001$).

Conclusions: Aneurysm size and patient age showed significant correlations with residual intracranial aneurysm. The mean number of clips used was higher in cases with incomplete occlusion.

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Key Words: Aneurysm remnants, angiographic features, epidemiological characteristics, microsurgical clipping

INTRODUCTION

Despite new techniques for the treatment of cerebral aneurysms, such as intraoperative indocyanine green videoangiography and intraoperative micro-Doppler examination, the percentage of aneurysm remnants after surgical intervention seems to be relatively constant. Residual aneurysms are identified in 4–19% of surgical procedures.^[5,6,8,12,16] In a recent study using intraoperative indocyanine green videoangiography, Roesler *et al.*^[15] identified unexpected aneurysm remnants in 11 of 121 (9.1%) patients for whom postoperative angiography studies were available. In 10 of these patients, the remnants were small (<2 mm), though in 1 patient the remnant was 6 mm.

Thus, identifying factors that can predict the presence of aneurysm remnants could contribute toward treatment planning of these patients. The purpose of this study was to assess angiographic and epidemiological features associated with aneurysm remnants after microsurgical clipping.

MATERIALS AND METHODS

Patients

This study was conducted from February 2009 to August 2012 on a series of 90 patients referred to the Santa Casa de Belo Horizonte who were surgically treated and angiographically controlled. Because several patients had multiple aneurysms, 105 aneurysms were clipped and angiographically controlled. The clips applied were mainly Vicca clips (Vicca, Porto Alegre, Rio Grande do Sul, Brazil) made of a titanium alloy.

During the study period, 31 additional patients were operated, but did not undergo angiographic follow-up. The reasons for not performing the control examination were death in the postoperative period secondary to severe vasospasm in 23 cases (9.3% of the total series) and patient refusal in 8 cases [Figure 1]. These patients were excluded from the series studied due to the nonavailability of this data.

Angiographic study

In the pre- and postoperative periods, patients were submitted to rotational angiography performed using the transfemoral arterial approach in the Neuroradiology Department of our institution followed by three-dimensional (3D) reconstruction of the imaging data.

Angiographic examinations were performed using a biplanar angiographic (unit Axiom Artis dBA, Siemens

AG Medical Solutions, Vacuum Technology Division, Henkestr. 127 91052 Erlangen Germany with an image intensifier matrix of 1024 × 1024). In performing digital subtraction angiography (DSA), we tried to optimize the angle to define the clip/aneurysm relationships as well as possible. Usually, we referenced the angle from rotational angiography.

During rotational angiography, the C arm rotated over a 240° range at a speed of 55° per second for about 4.4 seconds. Contrast medium (Iomeron, 300 mg of iodine per mL) was injected at a flow rate of 4–5 mL per second, resulting in total injected volumes of 16–20 mL for each rotational angiographic session in the internal carotid artery (ICA). A flow rate of 2.5–3.5 mL per second resulted in total injected volumes of 10–14 mL into the vertebral artery. Sometimes, a 1-second exposure delay was applied to allow an aneurysm to be fully filled. The image data were transferred to a workstation (Syngo Workplace VA72B, X-Leonardo, Siemens) to reconstruct the 3D images (volume VB35E version software). We analyzed snapshots which consisted of six basic views (anterior, posterior, both lateral, superior, and inferior views) and views from arbitrary angles, as well as cutting views to visualize the clip aneurysm configurations well.

Analysis of residual aneurysms

Radiologically, a residual aneurysm, aneurysm remnant, or incomplete clipping was defined as a small segment at the base of the aneurysm proximal to a clip that was still filled with contrast material in the postoperative angiography.

Aneurysm remnants were classified into 5 grades – grade I, less than 50% of neck size; grade II, more than 50% of neck size; grade III, residual lobe of a multilobulated sac; grade IV, residual portion of the sac less than 75% of aneurysm size; and grade V, residual portion of the sac more than 75% of aneurysm size.^[18]

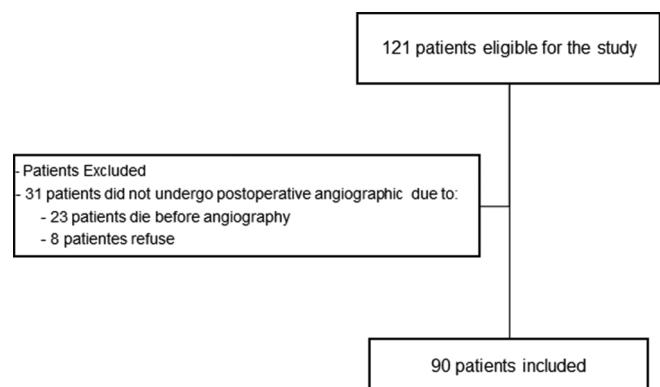


Figure 1: Flow diagram for selecting eligible patients

The groups used for analysis were divided according to grades, as follows: cases only involving residual neck (grades I and II) and cases involving residual sac lobes or portions (grades III, IV, and V).

Data analysis

The variables studied were aneurysm size, neck size, and location, determined by preoperative angiography; number of clips, determined by postoperative angiography; and patient age. The endpoint was the presence of residual aneurysm after microsurgical clipping identified by postoperative angiography.

Medcalc software was used for data analysis. For variables in which the mean was evaluated, such as patient age, aneurysm size, neck size, and number of clips, analysis of variance (ANOVA) test was used. The Chi-square test and Chi-square trend test were used when evaluating categorical variables, such as aneurysm location, and aneurysm size, classified as small (less than 7 mm), medium (7–15 mm), large or giant (larger than 15 mm). In cases in which the value of one of the variables was lower than 5, the Fisher test was used. *P* values were considered statistically significant when less than 0.05.

RESULTS

Of the 90 patients treated and submitted to both pre- and postoperative angiography examinations, 66 were females and 24 were males. Patient age ranged from 26 to 80 years, with a mean of 50.7 years.

Surgical clipping was considered incomplete in 14 aneurysms (13.3%). All were cases with remnants less than 50% of the neck size (grade I), none of the patients were submitted to reoperation [Figures 2 and 3].

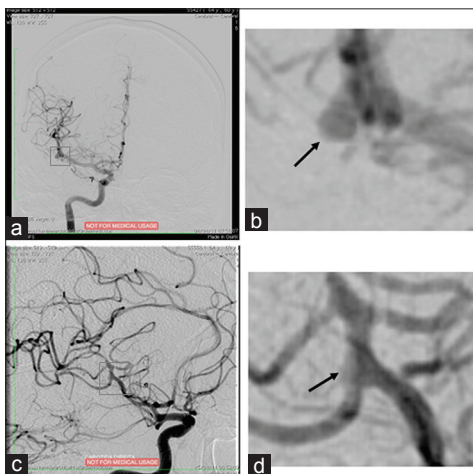


Figure 2: Arteriography of a 60-year-old man with headaches and meningism. (a) Right middle cerebral artery saccular aneurysm, measuring 7.1 × 3.2 mm; (b) The black arrow indicates the aneurysm; (c) Aneurysm clipping performed with 2 clips. Identified an aneurysm remnant, which was treated conservatively; (d) The black arrow indicates the remnant aneurysm

The mean patient age of cases with an aneurysm remnant was 57.5 years, whereas the mean patient age without aneurysm remnant was 49.7 years; this difference was statistically significant (*P* = 0.02) [Table 1].

Aneurysm location

Regarding the location of the 105 operated aneurysms, 100 (95.2%) were located in the anterior circulation and 5 (4.8%) in the posterior circulation. All the aneurysms that showed remnants were in the anterior circulation, 14.0% of these cases. Eight of the 14 aneurysm remnants were located on the ICA, 3 on the ophthalmic segment, 4 on the posterior communicating artery (PCoA), and 1 on the anterior choroidal artery (AChoA); 2 were on the middle cerebral artery (MCA) and 4 were on the anterior communicating artery (ACoA). Although aneurysm remnants were detected more frequently on the ICA, no statistically significant differences were noted regarding location [Table 2].

Aneurysm size

Regarding the size of the aneurysms, 72 were small (<7 mm), and of these 7 (9.7%) showed an aneurysm remnant in the postoperative arteriography. Twenty-eight aneurysms were medium (7–15 mm) of these 5 (17.8%) showed an aneurysm remnant.

Table 1: Basic characteristics comparing patients with and without remnant

Characteristic	Aneurysms without a remnant	Aneurysms with a remnant	<i>P</i>
Age (mean/years)	49.7	57.5	0.02
Sex			0.06
F	59	7	
M	17	7	

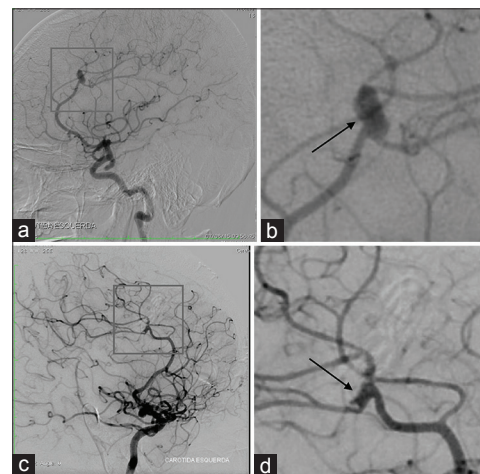


Figure 3: Arteriography of a 52-year-old woman with an incidental aneurysm. (a) Left pericallosal artery saccular aneurysm, measuring 6.0 × 2.5 mm; (b) The black arrow indicates the aneurysm; (c) Aneurysm clipping performed with 3 clips. An aneurysm remnant measuring 1.1 mm was identified and treated conservatively; (d) The black arrow indicates the remnant aneurysm

Only 5 aneurysms were large or giant (>15 mm), and of these 2 (40.0%) showed an aneurysm remnant in the postoperative arteriography [Table 2]. Thus, the frequency of aneurysm remnants in the postoperative period increased with aneurysm size ($P = 0.04$, Chi-square test for trend).

Evaluation of aneurysm size in the preoperative angiography verified that the mean size of aneurysms operated was 6.56 mm, such that in cases showing a postoperative remnant, the mean size was 9.7 mm, and in cases with complete clipping it was 6.08 mm; this difference was statistically significant ($P = 0.02$). Similarly, regarding aneurysm neck size, for aneurysms showing a remnant, the mean size was 3.3 mm, and for aneurysms without a remnant the mean was 2.9 mm. Despite the larger neck size in aneurysms showing a postoperative remnant, this difference was not statistically significant ($P = 0.373$) [Table 2].

Number of clips required

Postoperative angiography also showed that, in cases with residual aneurysm, the number of clips used was higher: a mean of 1.8 for complete clipping and 3.1 for incomplete clipping ($P < 0.001$) [Table 3].

Table 2: Characteristics of aneurysms with and without remnants

Characteristic	Aneurysms without a remnant	Aneurysms with a remnant	P
Location			
Internal carotid artery	35	8	0.3
Other	56	6	
Size of the aneurysm (mm)			0.04*
Small (<7 mm)	65	7	
Medium (7-15 mm)	23	5	
Large or giant (>15 mm)	3	2	
Size of the aneurysm (mean/mm)	6.08	9.7	0.02
Neck size (mean/mm)	2.9	3.3	0.373

*Chi-square test for trend

Table 3: Number of required clips

Characteristics	Mean clips required	With remnant	Without remnant	P
Residual aneurysm				<0.001
Presence	3.1			
Absence	1.8			
Age				
<60 years	1.9			
≥60 years	1.9			
Size of the aneurysm				
Small	1.7	2.4	1.6	0.013
Medium	2.4	4	2.13	0.003
Large or giant	4.5	3.5	5	0.106

Comparison of the number of clips used with patient age showed that the mean number of clips used for an aneurysm in patients less than 60 years and patients 60 years of age or older was 1.9 clips in both groups [Table 3].

Comparison of the number of clips required with aneurysm size showed that a mean of 1.7 clips were used for small aneurysms, whereas for small aneurysms showing a remnant, the mean was 2.4 clips, and for small aneurysms without a remnant it was 1.6 clips ($P = 0.013$). For medium-sized aneurysms, the mean number of clips used for each aneurysm was 2.4, whereas for medium-sized aneurysms without a remnant, the mean was 2.13, and in medium-sized aneurysms showing a remnant it was 4 clips ($P = 0.003$). For large or giant aneurysms, the mean number of clips used for each aneurysm was 4.5, whereas for large or giant aneurysms without a remnant, the mean was 5 clips, and in large or giant aneurysms showing a remnant it was 3.5 clips ($P = 0.106$) [Table 3].

DISCUSSION

The importance of identifying residual aneurysms is due to the risk of hemorrhage from these remnants.^[2,11,12,17] In this study, postoperative angiography detected aneurysm remnants in 13.3% of cases; these results are similar to the reported literature.^[5,6,8,12,16]

In a retrospective study involving postoperative arteriography, Le Roux *et al.*^[10] identified residual aneurysm in 36 (5.7%) of the 637 aneurysms treated with surgery. Atherosclerosis identified in preoperative angiograms is associated with residual aneurysm. A higher incidence of aneurysms showing a remnant was observed in older patients than in younger patients, such that the mean ages were 57.5 and 49.7 years, respectively. This result could be associated with higher incidence of atherosclerosis in older patients, which increases the difficulty of clipping aneurysms. Atherosclerotic lesions cause stiffness of the vessel wall and a reduction in its diameter, which can result in vascular occlusion or embolic phenomena during clipping of cerebral aneurysms. We considered this to be an important factor in the increased rate of aneurysm remnants in older patients. Park *et al.*^[13] observed atherosclerotic aneurysms in 25.6% of all patients submitted to cerebral aneurysm clipping treatment. Patients' mean age among those with atherosclerotic aneurysms was 60 years (range: 38-74) and without atherosclerotic aneurysms was 54.2 years (range: 21-79). These data reach statistical significance in their study ($P = 0.001$).

Although some authors have reported no relationship between aneurysm size and the presence of remnants,^[10,12,19] Sindou *et al.*^[18] showed that the only

significant factor in 305 aneurysms operated was aneurysm size. Their study verified 18 cases of residual aneurysm; 18% of giant aneurysms showed a remnant compared with 5% for large and small aneurysms. In a prospective study involving intraoperative arteriography on 100 consecutive craniotomies to clip 107 aneurysms in 92 patients, Alexander *et al.*^[1] reported that giant aneurysm was a significant predictor of unexpected residual aneurysm. In a recent study involving 616 primarily clipped aneurysms, Jabbarli *et al.*^[7] verified that an aneurysm larger than 12 mm was a risk factor for aneurysm remnants.

Aneurysm size and mean aneurysm size were also predictors of residual aneurysm in this study. The rate of residual aneurysm was 9.7% for small aneurysms and 40.0% for large or giant aneurysms. Furthermore, the mean size of aneurysms measured in the preoperative arteriography was 9.7 mm in cases that showed a remnant and 6.6 mm in cases with no remnant. Some aneurysm remnants were left intentionally due to the complexity of the operation during clipping and the risk of vessel stenosis induced by a complete clipping. This decision was based on the current understanding that grade 1 remnants present low rates of rebleeding.

In this study, even though aneurysm remnants were observed more frequently in the ICA, no statistically significant differences were observed compared with other locations. Regarding these findings, the literature is controversial. In a study involving intraoperative arteriography, Derdeyn *et al.*^[3] reported incomplete clipping in about 17% of cases. They reported high frequencies of unexpected residual aneurysms that required clip manipulation in the superior hypophyseal artery at the bifurcation of the internal carotid artery and in the superior cerebellar artery. Alexander *et al.*^[1] showed that location in the posterior communicating artery was a significant predictor of unexpected residual aneurysm when using intraoperative arteriography.

The number of clips required for aneurysm exclusion was shown to be another predisposing factor for the presence of residual aneurysm. Moreover, the number of clips used in small and medium-sized aneurysms in cases where a remnant was observed was significantly higher than in cases without a remnant. Although the literature has not established an association between this variable and any increase in residual aneurysm, multiple clip applications during surgery was identified as a predictor of residual aneurysm by Le Roux *et al.*^[10] Multiple clips or multiple clip applications is relatively common, particularly when simple clipping may not be possible due to the complex anatomy of the aneurysm, regardless of size. These aneurysms require multiple clips that close an aneurysm neck in sequential steps, progressing from deep neck to near neck and tackling the most difficult aspects first.

Another possibility is the use of multiple clips in small or large aneurysms, broad necks, and complex aneurysms.^[9] Even if the aneurysms are small, they may have a complex anatomy and require a multiple clips. They may present clipping difficulties due to atheromatous plaques and require multiple sequential and/or overlapping clips.

Jabbarli *et al.*^[7] affirmed that aneurysm location (ACA > ICA > PC > MCA) and aneurysm size (>12 mm) were the most important risk factors for remnants after clipping that would require retreatment. Sindou *et al.*^[18] related the fact that giant aneurysms presented higher rates of remnants with the characteristic of frequently having broad necks and atheromatous plaques.

Finally, even though the risk of hemorrhage was present, in this study, none of the patients with aneurysm remnants were submitted to reoperation. This approach is similar to other authors, such as Sindou *et al.*,^[18] who did not indicate surgery in cases with a remnant less than 50% of the neck size. Rossler *et al.*^[15] also observed that all their patients showed small remnants. Feuerberg *et al.*^[6] reported 28 aneurysm remnants in 27 patients. Follow-up angiography revealed that 5 remnants had disappeared, 2 had decreased in size, 1 had increased in size, and 13 had remained unchanged. Among their cases, recurrent hemorrhages were observed in only 1 patient during a total observation time of 266 years. Thus, the risk of rebleeding from an aneurysm remnant was 0.38–0.79% per year during the observation period. Drake *et al.*^[4] reported an operative morbidity rate of 7% and a mortality rate of 5%. Thus, the risk of rupture of an incompletely clipped aneurysm seems lower than operative morbidity, making reoperation hard to justify, especially in patients that only present residual neck.

However, a risk of rupture per year makes the cumulative risk one of importance, particularly in young patients.^[6] Lin *et al.*^[11] studied 19 patients with aneurysm regrowth in which 14 patients were less than 40 years old. They suggest that young patients have a higher risk of developing larger aneurysms from the tiny remnant at an incompletely clipped neck. Similar results were reported by Jabbarli *et al.*^[7] According to these authors, age less than 45 years was the only independent risk factor for remnant growth. Thus, we recommend that these patients undergo long-term (>5 years) vascular follow-up.

Intraoperative indocyanine green videoangiography and intraoperative angiography are methods used to avoid aneurysm remnants. Intraoperative indocyanine green videoangiography has the advantage of easy-to-perform intraoperative method for evaluating the occluded dome or neck of a cerebral aneurysm during surgery to avoid residual aneurysms. Thus, the very low complication rate, low costs of the technique, and described benefit rate of nearly 15% of the procedures argue for routine application during clipping of cerebral aneurysms. In contrast, in

up to 10% of patients, small aneurysm sac remnants can be overlooked intraoperatively by indocyanine green videoangiography.^[15] Intraoperative angiography led to repositioning of the aneurysm clip in 27% cases. Postoperative angiography demonstrates a lower incidence of unexpected residual aneurysm (3.2%) than that by indocyanine green videoangiography.^[14] Thus, the combination of indocyanine green videoangiography and intraoperative angiography may ultimately prove most effective for maximizing the efficacy of aneurysm surgery, especially in patients with a complex aneurysm.^[20]

Despite the limitations of this study, including its retrospective view and the lack of an evaluation of morphological features that can be associated with aneurysm remnants, the findings and suggestions proposed can contribute to improving presurgical planning. Our analysis demonstrates that an incomplete occlusion is more likely in older patients, and/or in patients with larger or giant aneurysms.

CONCLUSIONS

Aneurysm size and patient's age showed significant correlations with residual intracranial aneurysm. The mean number of clips used was higher in cases with incomplete obstruction probably due to the complex anatomy of these aneurysms.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

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Conflicts of interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or

beliefs) in the subject matter or materials discussed in this manuscript.

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