Middle Cerebral Artery Aneurysm “Neck Overhang”: Decreased Postclipping Residual Using the Intersecting Clipping Technique

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BACKGROUND: Middle cerebral artery (MCA) aneurysms continue to be viewed by many as primarily surgical entities.

OBJECTIVE: To introduce a new, easily measurable dimension termed “neck overhang,” defined as the amount of the aneurysm that extends proximal to the 2 dimensionally defined “neck” and to evaluate the utility of the intersecting clipping technique (use of straight clip and intersecting fenestrated clip) to adapt to this overhanging segment’s specific dimensions and achieve better obliteration of the MCA aneurysms.

METHODS: We reviewed retrospectively 100 MCA aneurysms treated surgically over the last 10 yr at our institution. We identified the clipping technique that was performed (intersecting vs “standard” technique) and we evaluated the presence of a postoperative remnant. We then correlated these with the aneurysm’s overhanging neck length.

RESULTS: Forty-three aneurysms were treated with the intersecting clipping technique. The overall rate of remnant was 16%. In the standard group, the rate of remnant was 23%, whereas with intersecting clipping that was 7% ($P = .029$). Within the standard clipping group, we found that the optimum threshold for length of the neck overhang was ≥ 1.9 mm in order to predict the occurrence of residual. Applying this threshold to the intersecting clipping technique group resulted in a reduction in remnant from 35% in the standard group to 9%.

CONCLUSION: Neck overhang > 1.9 mm is associated with a higher chance of postclipping residual aneurysm in MCA aneurysms. The intersecting clipping technique is a versatile technique that can conform to various aneurysms’ geometry and can reduce the rate of post clipping residual for aneurysms with high neck overhang.

KEY WORDS: Intersecting clipping, Middle cerebral artery aneurysm, Neck overhang, Remnant

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The middle cerebral artery (MCA) is a very common site for aneurysm formation, representing 18% to 40% of all intracranial aneurysms. They are classically divided into 3 groups: proximal or M1, bifurcation, and distal aneurysms.¹ The MCA bifurcation is the most common site at 63% to 83% of cases.^{1–11} Various further classifications based on morphological variables have been suggested.^{2,11–19}

While endovascular treatment is widely used for many cerebral aneurysms, MCA aneurysms

continue to be viewed by many as primarily surgical entities due to both their anatomical location, which grants relatively straightforward access to the aneurysm, and to their specific morphological characteristics such as a wide neck and asymmetric branches that are incorporated into the aneurysm neck. Such features often require complex endovascular techniques that can increase the incidence of stroke or residual aneurysm. Complete obliteration of MCA aneurysms is achieved in up to 98.3% of surgically treated aneurysms, with remnant rates between 1.7% and 18%. In comparison, endovascular treatment has demonstrated a 26.3% to 67% obliteration rate of MCA aneurysms.^{12–14,20–28} Even though surgical

ABBREVIATIONS: CTA, computed tomography angiogram ; MCA, middle cerebral artery

treatment is generally very successful, the very broad necks often lead to intentionally leaving residual at the base of the aneurysm to preserve outflow vessels (which may or may not be considered “residual” in these studies). The concept of the optimum clipping technique has been studied based on the morphological features of the aneurysm neck, the anatomical variations of the branches in relation with the aneurysm neck, and the ideal closure line for each aneurysm.^{12,29-31}

Study Objectives

One anatomic feature that has not as of yet been carefully evaluated is the amount of aneurysm dome that projects proximal to the 2 dimensionally defined neck of the aneurysm. We term this component “neck overhang,” and sought to define the incidence of significant neck overhang as well as how the degree of this neck overhang affects the likelihood of postoperative residual. In addition, we evaluated the role of the previously described intersecting clipping technique (use of straight clip and intersecting fenestrated clip)^{16,29} to conform to this anatomy and improve residual rates.

METHODS

Patient Selection and Operative Technique

The Human Research Review Committee reviewed and approved the study and institutional review board approval was obtained prior to the initiation of the study while patient consent was not required since it is a retrospective study (Study ID: 17–118).

We identified and reviewed retrospectively 100 consecutive MCA bifurcation aneurysms, ruptured and unruptured, treated surgically (Yasargil Clips, Aesculap Inc, Center Valley, Pennsylvania) over the last 12 yr (January 2005–January 2017) at our institution. Patients were selected based on the following criteria: (1) age $\geq$ 18 yr, (2) diagnosis of MCA aneurysm, (3) underwent craniotomy for clipping, while all aneurysms treated with nonclipping techniques such as wrapping or bypass were excluded from the study, (4) had preoperative and postoperative computed tomography angiograms (CTAs). Pterional craniotomy, under general anesthesia, and clipping of the MCA aneurysm were performed on all patients. Data on the surgical technique that were used on each patient come from the surgical records of 3 different surgeons of our institution.

Neuroradiological Evaluation

We quantified the preoperative “neck overhang” for each of these, defined as the amount of the aneurysm that extends proximal to the 2 dimensionally defined “neck”—being the distance between the 2 M2 junctions with the dome (Figure 1). Using the reconstructions obtained by preoperative CTAs and the Aquarius iNtuition software v4.4.12 (TeraRecon Inc, Foster City, California), we measured the aneurysm volume, the linear neck overhang distance, and volume of the neck overhang. We then reviewed the postoperative CTA to determine the clipping technique that was performed (intersecting vs “standard” technique). For intersecting clips, the clipping angle was calculated. See Figures 2 and 3 for images of these measurements. We also evaluated the presence of a postoperative remnant (incompletely treated aneurysm),

FIGURE 1. Illustration of an MCA aneurysm. The shaded region represents the “neck overhang.” This may be diseased, aneurysmal tissue but extends proximal to the 2 dimensionally defined neck and “closure line.” ©2017 Department of Neurosurgery, University of New Mexico School of Medicine.

as defined by post-op neuroradiologic evaluation, and the presence of outflow vessel occlusion or stenosis.

Statistical Methods and Analysis

For statistical analysis, we tested the association between the aneurysm volume and the neck overhang dimensions with the presence of residual or stenosis using the Chi-squared test. For the cohort of patients with the standard clip technique, we then defined the optimal thresholds of aneurysm volume, neck overhang distance, and neck overhang volume for predicting residual by minimizing the Euclidean distance of sensitivity and specificity from the unitary point (1, 1).³² Patients with measurements above these thresholds are defined as high-risk groups for residual aneurysm postclipping. We then applied these high-risk thresholds to the intersecting clip cohort to determine if the rate of residual aneurysm stayed unchanged or was significantly reduced. We determined significance based on the 95% confidence intervals of the rate of residual in each group. Statistical analysis was performed using SAS 9.4 (SAS Institute Inc, Cary, North Carolina).

RESULTS

Patient Demographics

We identified 100 patients with 100 MCA aneurysms, who had a total of 142 aneurysms. All of these were cases where the MCA aneurysm was treated surgically, either as the primary or secondary aneurysm if there was another ipsilateral ruptured aneurysm. The mean age of the patients at time of diagnosis was 54.7 ± 10.4 yr (range, 25–82 yr). There was a clear female predominance (75 vs 25). All aneurysms were located in MCA bifurcation and they were more common on the right side (60) than on the left (40). There were 59 ruptured, 28 of whom had significant intraparenchymal hemorrhage, and 41 were unruptured (Table 1).

FIGURE 2. CTA scan reconstruction of an MCA aneurysm in **A**, superior and **B**, lateral projections. The red line represents “neck overhang” distance. The horizontal blue line is placed at the level of the M2 junction with the dome of the aneurysm. Note the significant irregular diseased aneurysm extending proximal to this line (arrows). **C**, After the aneurysm dome is segmented out along the dome, the linear and volumetric dimensions of the neck overhang are measured (red line). **D**, Intraoperative view of the aneurysm deforming the MCA bifurcation (M2 vessels red arrows).

FIGURE 3. **A**, Postoperative CTA reconstruction of intersecting clipping technique. Measurement of the angle of the tips of the clips (red curve). **B**, Intraoperative view of clipped aneurysm with simultaneous reconstruction of MCA bifurcation. M2 vessels in red arrows, the M1 can now be clearly seen proximally (blue arrow).

TABLE 1. Demographics

Number of patients and MCA aneurysms	100 patients, 142 aneurysms
Aneurysm site	100 MCA bifurcation aneurysms
Mean age (range), years	54.7 ± 10.4 yr (range, 25–82 yr)
Sex	
Female	73
Male	25
Aneurysm status	
Ruptured	59
Unruptured	41
Ruptured MCA aneurysms with IPH	28
Aneurysm side	
Right	60
Left	40

MCA: middle cerebral artery, IPH: intraparenchymal hemorrhage.

TABLE 2. Results

Number of MCA aneurysms	100 aneurysms
Clipping methods	
Intersecting	43
Nonintersecting	57
Mean angles of the clips (range)	67.4° ± 27.2°, (range, 11°–115°)
Remnant (overall)	
Intersecting (43)	3 (7%)
Nonintersecting (57)	13 (23%)
M2 occlusion/stenosis (overall)	
Intersecting (43)	2 (5%)
Nonintersecting (57)	5 (9%)

MCA: middle cerebral artery.

Measurements

We divided the MCA aneurysms in 2 groups, intersecting clipping group and standard group, based on the clipping technique. Among the 100 MCA aneurysms, 43 were treated with intersecting clipping technique. The angles of the intersecting clips ranged from 11° to 115° with a mean value of 67.4° ± 27.2° (Figure 3). Overall, postoperative remnant was present in 16 patients (16%). Three patients belong to the intersecting group (7%), while 13 of them belong in the standard clipping group (23%; *P* = .029). Vessel occlusion was also evaluated, with 7 (7%) patients presenting M2 occlusion or stenosis, as seen in postoperative CTA. Two of these were in the intersecting group (5%), and 5 were in the standard group (9%; *P* = .424). All of these patients with stenosis or occlusion were patients with subarachnoid hemorrhage and significant intraparenchymal hemorrhage (Table 2).

Optimal Thresholds

Using only the standard clipping group, high-risk thresholds for residual were defined. These thresholds were done for

aneurysm volume, neck overhang distance, and neck overhang volume, and all were calculated using receiver operating characteristic discriminant analysis.^{32,33} These optimal thresholds we arrived at for high risk of residual were 0.3 cm³ for aneurysm

volume, 1.9 mm for neck overhang distance, and 0.08 cm³ for neck overhang volume. These thresholds, obtained from the standard clipping group, provided reference points to distinguish high vs low risk of residual aneurysm. For aneurysm volume >0.3 cm³, the rate of residual was 53% vs 12% if the volume was <0.3 cm³. For neck overhang distance >1.9 mm, the rate of residual was 35% vs 9% if the distance was <1.9 mm. For neck overhang volume >0.08 cm³, the rate of residual was 35% vs 13% if the volume was <0.08 cm³.

Testing these reference points (optimal cut-offs) in the intersecting group yielded a significant reduction in the rates of residual in the high-risk categories. For aneurysm volume >0.3 cm³, the rate of residual was 11%; for neck overhang distance >1.9 mm, the rate of residual was 9%; and for volume of neck overhang >0.08 cm³, the rate of residual was 13% and a reduction of 42%, 26%, and 22%, respectively. All of these differences trended toward improvement in residual rate applying the intersecting clipping technique; significance was noted in both the neck overhang linear distance and aneurysm volume measurements compared to the standard clipping group (see Figure 4). We interpreted these data as confirmation that the intersecting clipping technique is more efficacious

in aneurysm obliteration in the high-risk group with larger neck overhang.

DISCUSSION

The MCA is the most common site for aneurysm formation, comprising 18% to 40% of all intracerebral aneurysms.¹⁻¹¹ Various classifications for MCA aneurysms were suggested based on their neck anatomy, progression of the pathological thin wall into the surrounding vessels, parent vessel geometry, or direction of the dome projection.^{2,11,12,16-19} Outflow vessel size and orientation and neck anatomy can be variable and complex and thus lead to several standardized approaches to clipping based on morphological characteristics.^{2,12,16,17,29-31} Our data suggest that another feature that leads to significant complexity of safe treatment is the amount of aneurysm that extends proximal to the 2 dimensionally defined neck. In aneurysms with large neck overhang, any clipping strategy that places a clip parallel to the outflow vessels further widens the splayed bifurcation and risks kinking or stenosis of these vessels (see Figure 5). One strategy to address this is to intentionally leave a “pouch” at the base of the aneurysm to allow unobstructed outflow.^{12,30,34-37} We propose that the intersecting clipping technique, which has been a surgical option throughout the period of our study, is a versatile clipping strategy that can conform to the specific aneurysm geometry. Since the direction of clipping is perpendicular to the outflow vessels, it actually better reconstructs the bifurcation compared to parallel clipping. In this study, we demonstrated not only the variable angle that can be required, but also that the rate of residual is lower in high-risk aneurysms based on neck overhang compared to standard clipping approaches. The variability of clipping angle argues that a “shank clip”³¹ may work in some situations, but does not allow for the specific tailored repair required. Though the rupture risk of a neck “pouch” is not well known, it is intuitive that an approach that allows for a more anatomic and complete reconstruction is preferable. Furthermore, any residual aneurysm is undesirable from a follow-up perspective

because it will always have to be carefully compared to the immediate postoperative study to rule out growth. If that study is not available, consideration of possibly unnecessary retreatment might be entertained.

Interpretation of the Key Results

Our remnant rates and vessel occlusion or stenosis rates overall are within the range of previous reports between 1.7% and 18% residual and 3% and 9% outflow occlusion.^{13,14,20-25,27,28,34,38-40} Our rates in the intersecting clipping group compare favorably, and this may even represent a higher risk group given that a more complex clipping strategy was used. We introduce a new, easily measurable anatomical dimension termed “neck overhang,” defined as the amount of the aneurysm that extends proximal to the 2 dimensionally defined “neck.” We found that a neck overhang of >1.9 mm results in a significantly increased chance of postoperative residual if a standard clipping technique is used (35%), whereas this amount of residual is significantly reduced if the intersecting clipping technique is used (9%).

Clipping Technique

The intersecting clipping technique treats the aneurysm in 2 separate “bites.” Once the aneurysm and 2 outflow vessels are widely exposed, the first clip is a straight clip placed parallel to the M1, closing perpendicular to the plane of the M2s. We prefer to place the first clip on the “blind” side of the aneurysm, or the side of the M1 that is more challenging to access. The relationship to the M2s can then be carefully inspected for any kinking. In the case of a large aneurysm, a fenestrated clip can be used so that the closing pressure is transmitted to the tips of the clip. The second clip is typically a straight or angled fenestrated clip placed around the tynes of the first clip. The fenestration must be abutted directly to the tynes of the first clip to avoid dome filling between the clips, and the clip is closed on the aneurysm between the 2 M2s. The M2s then both exit through the “V” shaped opening between the 2 clips, making the possibility of kinking less likely than with straight parallel clipping (see Figure 5 for further details).

Such a standard approach to clipping is valuable given that, in the era of endovascular treatment, surgical treatment of aneurysms has significantly declined, leading to a decrease of surgical exposure of young neurosurgeons.^{17,41-43} As a result, less experienced neurosurgeons face difficulties with mastering disparate, complex clipping techniques for anatomically different aneurysms. The intersecting clipping technique is straightforward and versatile as a first-line clipping strategy for most MCA aneurysms and almost all aneurysms with neck overhang >1.9 mm. While it is more complex than straight clipping, it can replace most of the other clipping strategies for a variety of wide neck MCA aneurysms, regardless of other measurements such as outflow vessel angle and size of the outflow vessels. We propose that this may allow for a faster learning curve for younger neurosurgeons with less exposure to myriad aneurysm configu-

rations. Furthermore, we think that this technique better reconstructs the MCA bifurcation compared to techniques that splay the outflow vessels further apart. There are, of course, limits to such an approach in the rarer giant, fusiform, heavily calcified, or dissecting aneurysms, which still will require an individually tailored approach.

Endovascular Techniques

One final point is the potential relevance of this measurement to newer endosaccular flow disrupters.⁴⁴⁻⁴⁷ These devices are designed to sit in the dome of a wide-necked aneurysm above the outflow vessels. It is however possible, with significant neck overhang, that the device may tend to either fall into the outflow vessel or may leave a significant “pouch” at the base. Whether neck overhang is a relevant finding in terms of vessel occlusion, residual, long-term recurrence, or rehemorrhage will remain to be seen with future studies, but we think that this may be a relevant measurement to consider.

Limitations

There are, of course, several limitations to our study. These data are all retrospective and the choice of clipping technique was based only on the judgment of the surgeon. The standard comparison group may be a heterogeneous group, but most of these were simple straight or bayonnetted clipping. Even though 3-dimensional digital subtraction angiography remains the first choice on neurovascular studying, such imaging was not universally available on our patients. With modern CTA technique and software, we feel that such imaging is often adequate, particularly for MCA aneurysms where surgical treatment is heavily favored. No direct intraoperative measurement of residual such as indocyanine green angiography or intraoperative angiography was used because these were variably performed and difficult to quantify. Though certainly surgeon-specific technical issues may also explain some of the variable residual, this technique of intersecting clipping was used throughout the study period rather than being introduced at any particular point. Another advantage is that the concept of the “neck overhang” was not introduced during this study period, so no clipping technique was directed specifically by this measurement. The outcome of residual we used relied only on the postoperative neuroradiologist read, but we used this measurement specifically so we would not be influenced in the measurements by the clipping strategy. Finally, it is unknown if these technical nuances and secondary outcomes such as residual translate to a measurable improvement in patient outcome, but we think that it is reasonable to strive for the safest, most complete treatment.

CONCLUSION

Neck overhang > 1.9 mm is associated with a higher chance of postclipping residual aneurysm in MCA aneurysms. The intersecting clipping technique is a versatile technique that can conform to various aneurysms’ geometry and can reduce the rate

of post clipping residual for aneurysms with high neck overhang. Given the versatility of this technique, we suggest that this is a reasonable “first-line” approach for most MCA aneurysms, especially for less experienced surgeons.

Disclosures

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REFERENCES

- Elsharkawy A, Lehecka M, Niemela M, et al. A new, more accurate classification of middle cerebral artery aneurysms. *Neurosurgery*. 2013;73(1):94-102; discussion 102.
- Dashti R, Hernesniemi J, Niemela M, et al. Microneurosurgical management of middle cerebral artery bifurcation aneurysms. *Surg Neurol*. 2007;67(5):441-456.
- Fox J. *Intracranial Aneurysms*. New York: Springer-Verlag. Vol. 2; 1983: 1012-1023.
- Heros R. Aneurysms in the middle cerebral artery. In: Symon L, Thomas D, Clarke K, eds. *Rob & Smith's Operative Surgery*. New York: Chapman & Hall; 1994:171-179.
- Heros R, Fritsch M. Surgical management of middle cerebral artery aneurysms. *Neurosurgery*. 2001;48(4):780-785.
- Pasztor E, Vajda J, Juhasz J, Tóth S, Orosz E, Horváth M. The surgery of middle cerebral artery aneurysms. *Acta Neurochir (Wien)*. 1986;82(3-4):92-101.
- Peerless S. The surgical approach to middle cerebral and posterior communicating aneurysms. *Clin Neurosurg*. 1974;21(CN_suppl_1):151-165.
- Rasmussen P, Busch H, Haase J, et al. Intracranial saccular aneurysms results of treatment in 851 patients. *Acta Neurochir (Wien)*. 1980;53(1-2):1-17.
- Rinne J, Hernesniemi J, Niskanen M, Vapalahti M. Analysis of 561 patients with 690 middle cerebral artery aneurysms: anatomic and clinical features as correlated to management outcome. *Neurosurgery*. 1996;38(1):2-9.
- Suzuki J, Yoshimoto T, Kayama T. Surgical treatment of middle cerebral artery aneurysms. *J Neurosurg*. 1984;61(1):17-23.
- Yasargil M. *Microneurosurgery*. Stuttgart: Georg Thieme Verlag; 1987.
- Jeon HJ, Kim SY, Park KY, Lee JW, Huh SK. Ideal clipping methods for unruptured middle cerebral artery bifurcation aneurysms based on aneurysmal neck classification. *Neurosurg Rev*. 2016;39(2):215-224; discussion 223-214.
- van Dijk JM, Groen RJ, Ter Laan M, Jeltima JR, Mooij JJ, Metzemaekers JD. Surgical clipping as the preferred treatment for aneurysms of the middle cerebral artery. *Acta Neurochir (Wien)*. 2011;153(11):2111-2117.
- Choi JH, Park JE, Kim MJ, Kim BS, Shin YS. Aneurysmal neck clipping as the primary treatment option for both ruptured and unruptured middle cerebral artery aneurysms. *J Korean Neurosurg Soc*. 2016;59(3):269-275.
- Steklacova A, Bradac O, Charvat F, De Lacy P, Benes V. “Clip first” policy in management of intracranial MCA aneurysms: Single-centre experience with a systematic review of literature. *Acta Neurochir (Wien)*. 2016;158(3):533-546; discussion 546.
- Lawton M. Middle cerebral artery aneurysms. In: Connerly K, Wachinger M, Chernow B, Kenneth B, Probst KX, eds. *Seven Aneurysms: Tenets and Techniques for Clipping*. New York: Thieme; 2011:65-93.
- Washington CW, Ju T, Zipfel GJ, Dacey RG Jr. Middle cerebral artery bifurcation aneurysms: an anatomic classification scheme for planning optimal surgical strategies. *Neurosurgery*. 2014;10 (suppl 1):145-153; discussion 153-145.
- Kumar M, Karagiozov K, Chen L, et al. A classification of unruptured middle cerebral artery bifurcation aneurysms that can help in choice of clipping technique. *Minim Invasive Neurosurg*. 2007;50(3):132-139.
- Hassan T, Timofeev E, Saito T, et al. A proposed parent vessel geometry-based categorization of saccular intracranial aneurysms: computational flow dynamics analysis of the risk factors for lesion rupture. *J Neurosurg*. 2005;103(4):662-680.
- Rodriguez-Hernandez A, Sughrue ME, Akhavan S, Habdank-Kolaczowski J, Lawton MT. Current management of middle cerebral artery aneurysms. *Neurosurgery*. 2013;72(3):415-427.
- Pereira BJ, Holanda VM, Giudicissi-Filho M, Borba LA, de Holanda CV, de Oliveira JG. Assessment of cerebral blood flow with micro-doppler vascular reduces the risk of ischemic stroke during the clipping of intracranial aneurysms. *World Neurosurg*. 2015;84(6):1747-1751.
- Jabbarli R, Pierscianek D, Wrede K, et al. Aneurysm remnant after clipping: the risks and consequences. *J Neurosurg*. 2016;125(5):1249-1255.
- Quadros RS, Gallas S, Noudel R, Rousseaux P, Pierot L. Endovascular treatment of middle cerebral artery aneurysms as first option: a single center experience of 92 aneurysms. *Am J Neuroradiol*. 2007;28(8):1567-1572.
- Guglielmi G, Vinuela F, Duckwiler G, Jahan R, Cotroneo E, Gigli R. Endovascular treatment of middle cerebral artery aneurysms. *Interv Neuroradiol*. 2008;14(3):241-245.
- Suzuki S, Tateshima S, Jahan R, et al. Endovascular treatment of middle cerebral artery aneurysms with detachable coils. *Neurosurgery*. 2009;64(5):876-889; discussion 888-879.
- Kim BM, Kim DI, Park SI, Kim DJ, Suh SH, Won YS. Coil embolization of unruptured middle cerebral artery aneurysms. *Neurosurgery*. 2011;68(2):346-354; discussion 353-344.
- Brinjikji W, Lanzino G, Cloft HJ, Rabinstein A, Kallmes DF. Endovascular treatment of middle cerebral artery aneurysms. *Neurosurgery*. 2011;68(2):397-402; discussion 402.
- Guresir E, Schuss P, Berkefeld J, Vatter H, Seifert V. Treatment results for complex middle cerebral artery aneurysms. A prospective single-center series. *Acta Neurochir (Wien)*. 2011;153(6):1247-1252.
- Clatterbuck RE, Galler RM, Tamargo RJ, Chalif DJ. Orthogonal interlocking tandem clipping technique for the reconstruction of complex middle cerebral artery aneurysms. *Neurosurgery*. 2006;59(4 suppl 2):ONS347-ONS351; discussion ONS351-ONS342.
- Ishikawa T, Nakayama N, Moroi J, et al. Concept of ideal closure line for clipping of middle cerebral artery aneurysms. *Neurol Med Chir (Tokyo)*. 2009;49(6):273-278.
- Ishida A, Matsuo S, Asakuno K, et al. Utility of cranks clips for middle cerebral artery aneurysms: a single-center experience of 150 cases. *Surg Neurol Int*. 2016;7(suppl 18):S518-S522.
- Saeed AI, Qeadan F, Sood A, et al. A novel cytokine profile associated with cancer metastasis to mediastinal and hilar lymph nodes identified using fine needle aspiration biopsy—a pilot study. *Cytokine*. 2017;89:98-104.
- Indrayan A. *Medical Biostatistics*. Series: Chapman & Hall/CRC Biostatistics series. Boca Raton, FL: CRC Press; 2012:297.
- Sindou M, Acevedo J, Turjman F. Aneurysmal remnants after microsurgical clipping: classification and results from a prospective angiographic study (in a consecutive series of 305 operated intracranial aneurysms). *Acta Neurochir (Wien)*. 1998;140(11):1153-1159.
- Drake C, Friedman A, Peerless S. Failed aneurysm surgery. *J Neurosurg*. 1984;61(5):848-856.
- Kim BM, Kim DJ, Kim DI, Park SI, Suh SH, Won YS. Clinical presentation and outcomes of coil embolization of remnant or recurrent intracranial aneurysm after clipping. *Neurosurgery*. 2010;66(6):1128-1133; discussion 1133.
- Burkhardt JK, Chua MHJ, Weiss M, Do ASS, Winkler EA, Lawton MT. Risk of aneurysm residual regrowth, recurrence, and de novo aneurysm formation after microsurgical clip occlusion based on follow-up with catheter angiography. *World Neurosurg*. 2017;106:74-84.
- Tang G, Cawley C, Dion J, Barrow D. Intraoperative angiography during aneurysm surgery: a prospective evaluation of efficacy. *J Neurosurg*. 2002;96(6):993-999.
- Kivisaari RP, Porras M, Öhman J, Siironen J, Ishii K, Hernesniemi J. Routine cerebral angiography after surgery for saccular aneurysms: Is it Worth it? *Neurosurgery*. 2004;55(5):1015-1024.
- Friedman JA, Kumar R. Intraoperative angiography should be standard in cerebral aneurysm surgery. *BMC Surg*. 2009;9(1):7.
- Simon S, Koyama T, Cheng J, Mericle R. Incidence of clipping and coiling procedures: aneurysm treatment of Medicare patients, 1996–2006. *AANS Neurosurg*. 2011;20(1):16-19.
- Andaluz N, Zuccarello M. Recent trends in the treatment of cerebral aneurysms: analysis of a nationwide inpatient database. *J Neurosurg*. 2008;108(6):1163-1169.
- Piazza M, Nayak N, Ali Z, et al. Trends in resident operative teaching opportunities for treatment of intracranial aneurysms. *World Neurosurg*. 2017;103:194-200.

44. Turk AS, Turner RD, Chaudry MI. Evaluation of the Nfocus LUNA, a new parent vessel occlusion device: a comparative study in a canine model. *Neurosurgery*. 2011;69(1 suppl operative):ons20-ons26.
45. Kwon SC, Ding YH, Dai D, Kadirvel R, Lewis DA, Kallmes DF. Preliminary results of the luna aneurysm embolization system in a rabbit model: a new intrasaccular aneurysm occlusion device. *Am J Neuroradiol*. 2011;32(3):602-606.
46. Sorenson T, Brinjikji W, Lanzino G. Newer endovascular tools: a review of experimental and clinical aspects. *J Neurosurg Sci*. 2016;60(1):116-125.
47. Rajah G, Narayanan S, Rangel-Castilla L. Update on flow diverters for the endovascular management of cerebral aneurysms. *Neurosurg Focus*. 2017;42(6):E2.

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COMMENTS

The authors describe the use of “intersecting clips” to address the relatively common challenge of “neck overhang” in middle cerebral bifurcation aneurysms. The fact that more than 180° of the parent artery is often aneurysmal in MCA bifurcation lesions contributes to the challenge of adequate clip reconstruction, the frequent finding of a small amount of residual aneurysm left after clipping, and the difficulty achieving adequate results with current endovascular techniques. The authors’ technique nicely addresses this issue, and it is a clip construct we have used with some frequency as an intuitive solution to the aforementioned problem. Vascular neurosurgeons who continue to clip intracranial aneurysms in the endovascular era must be prepared to

use ever increasingly creative options to achieve excellent results in the treatment of more challenging lesions.

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The authors portray a quantitative analysis of MCA aneurysm intersecting clipping technique in comparison to the standard one-clip reconstruction perpendicular to the M1 axis. The concept of neck overhang is introduced and explains the frequent ‘dog ear’ that causes so much trouble in attaining sound anatomical and angiographical outcomes, as well as—intuitively—less probability of recurrence and hemorrhage. Other techniques like clips in tandem may be considered, but whenever possible, is it also our experience that intersecting clips attain a nice vessel reconstruction in wide-neck aneurysms. Quantification of high risk vs low risk of residual aneurysms, also allows for devising a preoperative clipping plan that will most likely attain a better clip reconstruction depending on the anatomic circumstances.

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This is an outstanding description of the authors’ innovative solution using intersecting clips to improve neck obliteration of wide-necked MCA bifurcation aneurysms that harbor significantly diseased distal M1 segments that are proximal to the 2-dimensionally defined neck of the aneurysm. Particularly relevant in the discussion are the considerations of the issues surrounding microsurgical training and endovascular techniques.

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