

RESEARCH

Open Access



# Intracranial wide neck aneurysms: clinical and angiographic outcomes of endovascular management

Abdalla Morsy<sup>1\*</sup>, Mohamed Mahmoud<sup>1</sup>, Ahmad Elsayed Abokresha<sup>1</sup>, Ahmad A. Moussa<sup>1</sup>,  
Mohamed Abdel-Tawab<sup>2</sup>, Moustafa Othman<sup>2</sup> and Mahmoud A. Moubark<sup>2</sup>

## Abstract

**Background:** The treatment of intracranial wide neck aneurysms (WNAs) is usually difficult, hence several endovascular techniques were developed. This study aims to assess the clinical and angiographic imaging outcome of endovascular management of intracranial wide neck aneurysm. Forty patients were referred to the neuro-endovascular unit, at our hospital, each with a wide neck aneurysm. They were assessed regarding clinical presentation, aneurysm size, the character of the aneurysm, and the age and sex of the patient. Post-procedural, clinical, and angiographic outcomes of the patients who underwent endovascular intervention were reviewed.

**Results:** In this study, the mean aneurysmal neck was  $5.4 \pm 1.6$  mm (mm). Endovascular intervention was carried out in all 40 patients in the form of simple coiling in 3 patients, double-catheter technique in 5 patients, balloon-assisted coiling (BAC) in 16 patients, stent-assisted coiling (SAC) in 13 patients, and flow diverter (FD) in 3 patients. Regarding clinical outcome, 4 patients had unfavorable outcome (the modified Rankin Scale, mRS > 2) at presentation and 3 patients at discharge. There was no unfavorable clinical outcome at 6- and 12-month follow-ups. Overall angiographic outcome at 1-year follow-up, 37/40 aneurysms (92.5%) had complete occlusion while two aneurysms had neck recurrence and one aneurysm had neck recanalization.

**Conclusion:** The current endovascular techniques in the treatment of WNAs are considered effective, feasible, and safe.

**Keywords:** Cerebral aneurysm, Wide neck, Endovascular treatment, Clinical outcome, Angiographic outcome

## Background

A wide neck aneurysm (WNA) is defined as an aneurysm that has a neck of > 4 mm or a dome-to-neck ratio of < 2 [1, 2]. WNAs were considered to be challenging or difficult to treat by endovascular therapy as the possibility of coil protrusion into the parent vessel is high [3].

Endovascular management of WNAs is associated with low rates of morbidity and mortality compared to

microsurgical clipping. Endovascular treatment is proven to be effective in preventing re-bleeding after aneurysmal subarachnoid hemorrhage (SAH) [4–6]. The treatment of these types of aneurysms is considered difficult despite these advantages [7]. Various endovascular devices, such as balloons and stents were developed in response to this situation [8–10]. However, some treatment outcomes for these aneurysms showed a low initial angiographic occlusion rate and high recurrence rates [3, 5, 8, 11, 12]. Device innovations have ushered in new treatment concepts, such as FD, to overcome these issues [6].

Since instability of coil in WNAs leads to herniation into the parent artery, and herniated coils may lead to

\*Correspondence: [abdallaragab990@aun.edu.eg](mailto:abdallaragab990@aun.edu.eg)

<sup>1</sup> Department of Neurosurgery, Faculty of Medicine, Assiut University, Assiut, Egypt  
Full list of author information is available at the end of the article

migration or cause thrombo-embolic complications, complete coil embolization using a single microcatheter without a supporting device in cases of wide-necked intracranial aneurysm is technically very difficult. Total occlusion rates have increased recently as a result of the advancement of supporting devices such as balloons and stents [13].

The aim of this study is to evaluate the efficacy and safety of different available endovascular modalities used in WNAs.

## Methods

This is a retrospective analysis of treatment for WNAs. We reviewed the medical records of patients who underwent endovascular intervention at the neuro-endovascular unit within the last 5 years. The study was approved by, the Faculty of Medicine, Ethical Committee at our university. Informed written consent to participate in the study was obtained from all patients.

We retrospectively analyzed the medical and surgical records of 40 patients who had endovascular treatment for ruptured and unruptured WNAs. This was carried out during the period from 2016–2020.

All patients had computed tomography angiography (CTA), or digital subtraction angiography (DSA). Computed tomography (CT) and CTA imaging were carried out on a 64-channel Multidetector CT scanner (Aquilion; Toshiba Medical Systems, Tokyo, Japan). DSA was carried out on three-dimensional (3D) digital subtraction angiography (DSA) machine (Siemens Healthineers, Forchheim, Germany). Magnetic resonance imaging (MRI) was carried out on a 1.5-Tesla MRI system (Achieva, Philips Medical Systems, Best, The Netherlands).

The size, height, width, and length of the aneurysm's neck were carefully assessed. The specific technique for endovascular aneurysm treatment was dependent on the angiographic findings. The therapeutic procedures were carried out through a percutaneous femoral artery puncture. Six French femoral sheaths were placed and the guiding catheter was inserted into the parent vessel. A microcatheter suit for aneurysm coiling, Echelon (ev3 Endovascular Inc/Covidien, Plymouth, Minn). A Marksman microcatheter (ev3, Irvine, CA, USA) suit for FD insertion, we used Pipeline Embolization Device (ev3 Endovascular Inc/Covidien, Plymouth, Minn) and Axiom coils; 3D and Helix (ev3 Endovascular Inc/Covidien, Plymouth, Minn). Target coils (Stryker Neurovascular, Fremont, CA, USA).

The microcatheter was advanced over the microguidewire into the site of the aneurysmal sac. A bolus of 3000 international unit (IU) heparin was infused at the beginning of the procedure (with the targeted activated

clotting time of 250 s) and 1000 IU heparin was infused per hour during the procedure.

Patients with a stent or FD received antiplatelet medications before the procedure in the form of 300 mg of each clopidogrel and aspirin, 30 min before the procedure. In addition, they were given a 24-h heparin infusion (intravenous 25,000 IU for 24 h). Following the treatments these patients were given clopidogrel 75 mg once daily for at least 6 months and aspirin 100 mg once daily for the rest of their lives.

The clinical outcome was assessed by mRS [14] after 1 month of the procedure, at 6 months and at once a year follow-ups. Favorable outcome was defined as mRS from 0 to 2 and unfavorable outcome more than 2.

CT scan or MRI was carried out to detect any post-operative ischemia. Procedural-related ischemia was defined as new ischemic symptoms or new imaging infarctions after the procedures.

Angiographic outcomes by DSA follow-up were performed at 6 months and 1 year after intervention which were assessed by Raymond–Roy score [15] for coiling embolization and O'Kelly–Marotta grade (OKM) [16] for FD. Raymond-I and OKM D consider favorable occlusion.

Statistical Package for the Social Sciences (SPSS) version 25 launched on 2017 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Categorical variables were expressed as numbers and percentages, statistical significance was calculated using Fisher's exact test. Continuous data were expressed in mean  $\pm$  standard deviation. Depending on the type of variables, the Student's *T* and Chi-square tests will be used. Friedman test was used to test the differences between the repeated mRS measurements. Statistical significance was described as  $p$ -value  $< 0.05$ .

## Results

In this study, 40 patients had WNAs, 22 patients were male (55%) and 18 patients were female (45%). Out of these 40 patients, 23 presented with clinical manifestations of a ruptured aneurysm, 17 patients with unruptured aneurysms (16 patients had headache, and one patient presented with third nerve palsy).

The modified Fisher grade [17] was used to assess the SAH in CT brain of all patients at presentation, as it was grade 1 in 10, grade 2 in 5 patients, and grade 3 in 8 patients.

Diagnostic angiography showed 35 aneurysms were in the anterior circulation (87.5%), and (12.5%) were located in the posterior circulation. The mean aneurysmal height was  $6.9 \pm 2.1$  mm, the dome was  $6.6 \pm 6.2$  mm and the neck was  $5.4 \pm 2.1$  mm.

**Table 1** Summary of study results

Variable	n (%)
Immediate post-procedure angiography follow-up	40 (100%)
Complete occlusion	39 (97.5%)
Aneurysm neck residual	1 (2.5%)
One-year follow-up angiography	40 (100%)
Complete occlusion	37 (92.5%)
Neck recurrence	2 (5%)
Aneurysm recurrence	1 (2.5%)

**Table 2** Summary of peri-procedural complications

Variable	n (%)
Peri-procedural complications	8 (20%)
Mechanical vasospasm	3 (7.5%)
Groin hematoma	2 (5%)
Coil migration	1 (2.5%)
Herniated coil	1 (2.5%)
Thrombus formation	1 (2.5%)
Death	0 (0%)

All patients underwent endovascular intervention in the form of simple coiling in 3 cases, double-catheter technique in 5 cases, BAC in 16 cases, SAC in 13 cases, and FD in 3 cases.

A summary of the treatment results and follow-up data is presented in Table 1. In addition, a summary of the peri-procedural complications is presented in Table 2.

Ventriculomegaly complicated SAH in four patients, which resolved spontaneously with follow-up without any intervention. Post-SAH vasospasm occurred in 6 patients; 4 patients cured, and 2 patient complicated with stroke which partially improved with physiotherapy.

Unfavorable clinical outcome (mRS > 2) was found in 4 patients at presentation and 3 patients at discharge. There was no unfavorable clinical outcome at 6- and 12 month follow-ups.

Immediate angiographic follow-up showed 36 patients (90%) with Raymond-I and one patient (2.5%) with Raymond-II necessitating further management with stent-assisted technique (Figs. 1, 2).

One year of angiographic follow-up showed 34 patients (85%) with Raymond-I, two patients (5%) with Raymond-II, and one patient (2.5%) with Raymond-III (Table 3).

Three aneurysms (7.5%) which had been treated with FD were angiographically assessed and revealed complete occlusion (OKM Grade D) at immediate post-procedural imaging and after 1-year follow-up.

## Discussion

Wide neck cerebral aneurysms are difficult aneurysms to be treated either by surgical or endovascular approach [18]. Endovascular treatment of this type of aneurysm has been challenging for many reasons. Apart from coil protrusion and thrombo-embolic complications due to neck width, several branches arise from the neck, and may cause branch occlusion during coiling. In addition, a wide neck has a higher risk of aneurysm recanalization [19]. To overcome these concerns, various techniques have been developed: BAC, SAC, FD, and intrasaccular flow disruption [19].

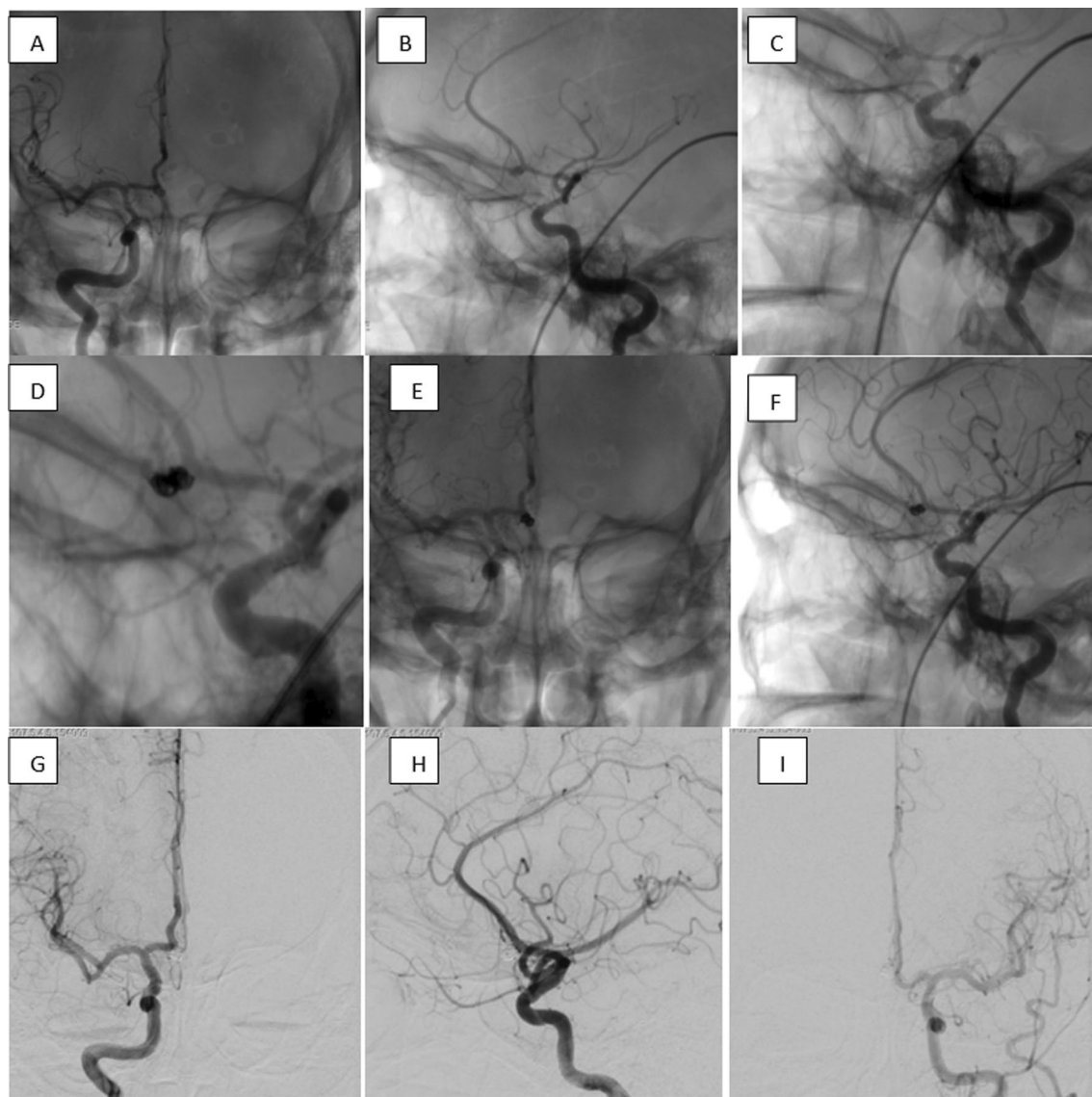
We retrospectively reported a series of 40 WNAs to evaluate the safety and efficacy of endovascular treatment. Different techniques were reported in the treatment of cerebral WNAs-like simple coiling, double-microcatheter technique, BAC, SAC, and FD. The clinical and radiological outcomes of these cases were assessed at a 1-year follow-up. We found that the initial angiographic occlusion was significantly related to the type of intervention. The only aneurysm that had residual neck was reported with simple coiling treatment, otherwise complete occlusion was reported in other treatment modalities.

Our results are relatively different from the large study conducted by Chung and colleagues [13] who reported immediate complete occlusion rates of SAC, double-catheter coiling, and BAC embolization were 63.8%, 46.7%, and 63.2%, respectively. The differences could be attributed to our small sample size.

Over the past two decades, the initial results in the literature review showed relatively lower rates of complete occlusion, however, the improvements in neurovascular stent techniques improve the treatment of complex intracranial aneurysms [20, 21]. The Matrix and Platinum Science Trial conducted by Hettis and colleagues [22] reported complete occlusion and subtotal occlusion of SAC and coiling alone, in the treatment of unruptured cerebral aneurysms, of 45.7% and 62.8%, respectively.

King and colleagues [23] also compared two types of SAC and the initial and final complete occlusion were reported in 53% and 69%, respectively. In addition, the Enterprise type showed a higher rate of complete occlusion at follow-up. In a recent multicenter study [24] of SAC including 162 aneurysms (97.5% were wide-necked), the reported initial and long-term complete occlusion rates of 72.8% and 81.5%, respectively. These results are relatively similar to our study as the complete occlusion rate was found in 92.5% of aneurysms.

Our results also agreed with other studies; as in the USA trial [25], using the stent technique, complete and adequate occlusions were obtainable in 12 months 88.2% and 96.1%, respectively. Cagnazzo and colleagues [26]



**Fig. 1** Anterior communicating artery aneurysm with 4.1-mm fundus and 3.8-mm neck (dome-to-neck ratio of  $\leq 2$ ). Simple coiling (A–F). One-year follow-up shows complete occlusion of the aneurysm (G–I)

also reported in their study the long-term complete or near-complete aneurysm occlusion of 95.4% [26].

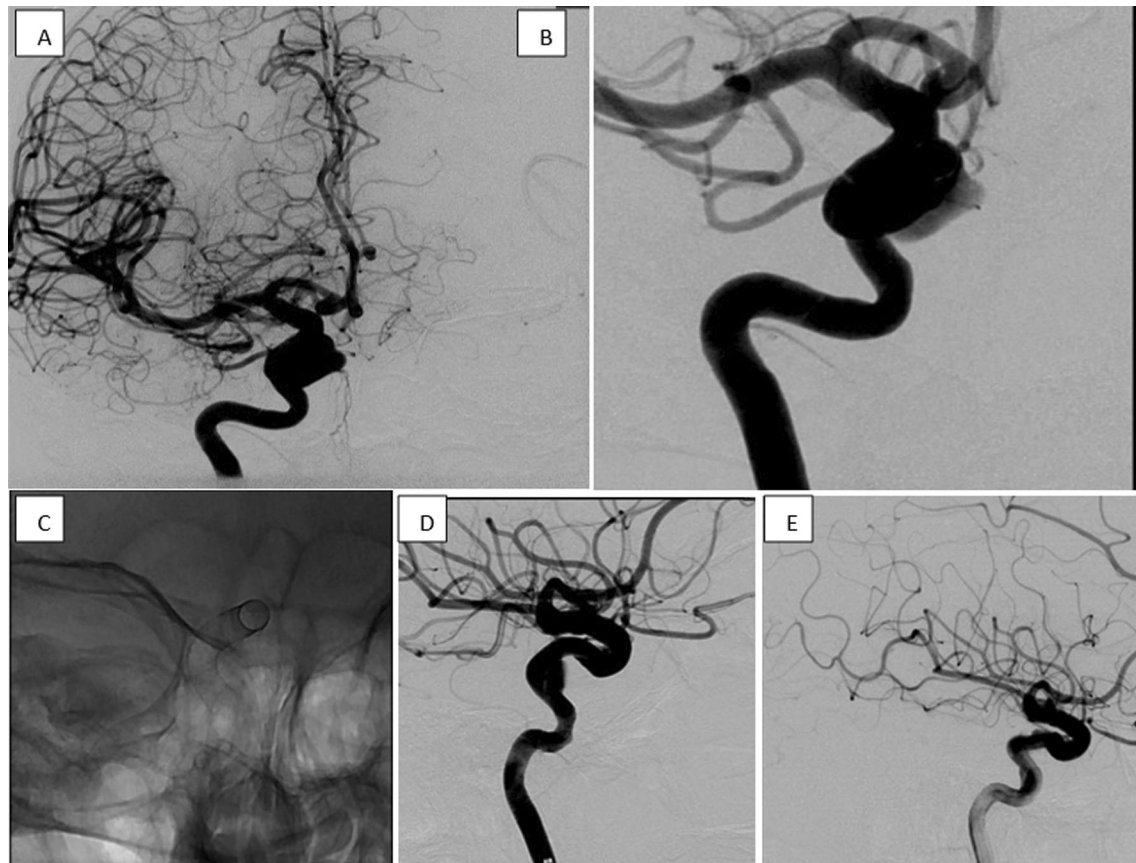
Regarding FD, a recent meta-analysis conducted by Abdel-Tawab and colleagues [27] concluded a complete occlusion rate of 82.4% in posterior circulation aneurysms and 77.5% in the anterior circulation aneurysm. The rate of complete aneurysm occlusion was 82.1% at 12 months, which is relative to what we reported in our results.

We had no mortality in our patients and the peri-procedural complications rate was relatively low (20%). These findings are similar to Gory [9], who reported a

low rate of overall peri-procedural complications as they used the Solitaire device and found a complication rate of 12.7%. Another meta-analysis showed the same rate of peri-operative complications as they reported 20.2% and 13.1% in patients treated with SAC and coiling, respectively [28].

In our study, thrombus formation occurred in one patient treated with SAC and was managed with balloon dilatation and stenting. King and colleagues [23] reported near-similar rates of thrombo-embolic events of 6.4%. Thrombo-embolic events are considered the major complications of SAC.





**Fig. 2** Right carotid cavernous aneurysm with 16-mm fundus and 5.4-mm neck. **A, B** DSA anteroposterior and lateral views, right internal carotid artery. **C** Pipeline flow diverter 4.25 × 18 mm. **D** Immediate postcontrast DSA shows stagnation of dye within the sac. **E** 1-year follow-up shows complete occlusion of the aneurysm

**Table 3** Immediate radiological outcome and 1-year follow-up in 37 patients (excluding 3 patients treated by flow diverters)

Raymond-Roy classification	Immediate outcome	One-year follow-up	Details
Raymond-I	36	34	Two patients became Raymond-II
Raymond-II	1	2	One patient became Raymond-III
Raymond-III	0	1	Need further management

Vasospasm was the main complication encountered in our study during and after endovascular intervention. Delayed cerebral ischemia is considered the worst complication after SAH occurred due to vasospasm [27].

We encountered mechanical vasospasm in three patients treated with SAC during the procedure which required nimodipine infusion and there were no related post-procedure clinical complications. SAH-related vasospasm was reported in six patients pre-intervention

and caused contralateral weakness: four of the patients improved with medical treatment, however the other two patients were complicated with stroke which partially improved with physiotherapy. These findings are similar to that in the Matrix and Platinum Science trial [22] that revealed the rate of peri-procedural adverse events of patients with WNAs was similar in the SAC (6.6%) and coiling (4.5%), while at 1-year follow-up, the rate of stroke was higher in the SAC (8.8%) than in the coiling group (2.2%).

In accordance with the present results, a previous systematic review [29] has demonstrated that the overall procedure-related complication rate is 6.5%. Only two patients had intracranial hemorrhage in this study and there were six cases of groin hematomas that did not require any surgical intervention, so the rate of hemorrhagic complications was quite low. However, the risk of thrombo-embolic complications was relatively higher which was 4.9% [29]. There were no hemorrhagic complications in our study.

Several limitations should be considered in the current study. Firstly, the small size of our study sample has WNAs. Secondly, the retrospective nature of the study and the potential patient selection bias for endovascular treatment. Thirdly, the rarity of using some high-cost endovascular modalities in the treatment of WNAs, such as flow diverters.

## Conclusion

WNAs are difficult to treat and are permanently occluded. Despite some difficulties during treatment, endovascular treatment of intracranial aneurysms has proven safe, effective, and feasible. Due to the introduction of new flow modification devices, further studies with longer follow-ups are required to approve their effectiveness in the treatment of WNAs.

## Abbreviations

BAC: Balloon-assisted coiling; CT: Computed tomography; CTA: Computed tomography angiography; DSA: Digital subtraction angiography; FD: Flow diverter; IU: International unit; mm: Millimeter; MRI: Magnetic resonance imaging; mRS: Modified Rankin Scale; OKM: O'Kelly–Marotta grade; SAC: Stent-assisted coiling; SAH: Subarachnoid hemorrhage; SPSS: Statistical Package for the Social Sciences; WNAs: Intracranial wide neck aneurysm.

## Acknowledgements

We thank Prof. Abdel-Hai Mousa Abdel-Latif Ismail for his support and helpful comments on the manuscript.

## Author contributions

AM is a corresponding author and participated in all steps of the research. MM, AEA, AAM, MO, MAM participated in the design of the work, interpretation of data and have drafted the work or substantively revised it. MA participated in the acquisition, analysis, interpretation of data and have drafted the work or substantively revised it; All authors read and approved the final manuscript version (and any substantially modified version that involves the author's contribution to the study); have agreed both to be personally accountable for the author's own contributions and ensured that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

## Funding

Not applicable.

## Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

The study was approved by Assiut University, Faculty of Medicine, Ethical Committee on 24-3-2019, IRB Number 17200298.

### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

## Author details

<sup>1</sup>Department of Neurosurgery, Faculty of Medicine, Assiut University, Assiut, Egypt. <sup>2</sup>Department of Diagnostic and Interventional Radiology, Assiut University, Assiut, Egypt.

Received: 26 April 2022 Accepted: 4 September 2022

Published online: 10 September 2022

## References

- Lazareska M, Aliji V, Stojovska-Jovanovska E, Businovska J, Mircevski V, Kostov M, et al. Endovascular treatment of wide neck aneurysms. *Open Access Maced J Med Sci*. 2018;6(12):2316–22.
- Hendricks BK, Yoon JS, Yaeger K, Kellner CP, Mocco J, De Leacy RA, et al. Wide-neck aneurysms: systematic review of the neurosurgical literature with a focus on definition and clinical implications. *J Neurosurg*. 2019;133:159–65.
- Gory B, Turjman F. Endovascular treatment of 404 intracranial aneurysms treated with nexus detachable coils: short-term and mid-term results from a prospective, consecutive, European multicenter study. *Acta Neurochir (Wien)*. 2014;156(5):831–7.
- Abdel-Tawab M, Abdeltawab AK, Abdelmonem M, Moubark MA, Taha MA, Morsy A, et al. Efficacy and safety of flow diverters in posterior circulation aneurysms and comparison with their efficacy in anterior circulation aneurysms: a systematic review and meta-analysis. *Interv Neuroradiol*. 2021;27(5):609–21.
- Raymond J, Guilbert F, Weill A, Georganos SA, Juravsky L, Lambert A, et al. Long-term angiographic recurrences after selective endovascular treatment of aneurysms with detachable coils. *Stroke*. 2003;34(6):1398–403.
- Zhao B, Yin R, Lanzino G, Kallmes DF, Cloft HJ, Brinjikji W. Endovascular coiling of wide-neck and wide-neck bifurcation aneurysms: a systematic review and meta-analysis. *Am J Neuroradiol*. 2016;37(9):1700–5.
- Horowitz M, Levy EI. Endovascular management of wide-necked aneurysms. *Contemp Neurosurg*. 2001;23(7):1–7.
- Gory B, Kessler I, Seizem Nakiri G, Riva R, Al-Khawaldeh M, Mounayer C. Initial experience of intracranial aneurysm embolization using the balloon remodeling technique with Scepter C, a new double-lumen balloon. *Interv Neuroradiol*. 2012;18(3):284–7.
- Gory B, Klisch J, Bonafé A, Mounayer C, Beaujeux R, Moret J, et al. Solitaire AB stent-assisted coiling of wide-necked intracranial aneurysms: short-term results from a prospective, consecutive, European multicentric study. *Neuroradiology*. 2013;55(11):1373–8.
- Gory B, Klisch J, Bonafé A, Mounayer C, Beaujeux R, Moret J, et al. Solitaire AB stent-assisted coiling of wide-necked intracranial aneurysms: mid-term results from the SOLARE Study. *Neurosurgery*. 2014;75(3):215–9.
- Linfante I, DeLeo MJ 3rd, Gounis MJ, Brooks CS, Wakhloo AK. Cerecyl versus platinum coils in the treatment of intracranial aneurysms: packing attenuation and clinical and angiographic midterm results. *Am J Neuroradiol*. 2009;30(8):1496–501.
- Shapiro M, Becske T, Sahlein D, Babb J, Nelson PK. Stent-supported aneurysm coiling: a literature survey of treatment and follow-up. *Am J Neuroradiol*. 2012;33(1):159–63.
- Chung EJ, Shin YS, Lee CH, Song JH, Park JE. Comparison of clinical and radiologic outcomes among stent-assisted, double-catheter, and balloon-assisted coil embolization of wide neck aneurysms. *Acta Neurochir (Wien)*. 2014;156(7):1289–95.
- van Swieten JC, Koudstaal PJ, Visser MC, Schouten HJ, van Gijn J. Inter-observer agreement for the assessment of handicap in stroke patients. *Stroke*. 1988;19(5):604–7.
- Roy D, Milot G, Raymond J. Endovascular treatment of unruptured aneurysms. *Stroke*. 2001;32(9):1998–2004.
- O'Kelly CJ, Krings T, Fiorella D, Marotta TR. A novel grading scale for the angiographic assessment of intracranial aneurysms treated using flow diverting stents. *Interv Neuroradiol*. 2010;16(2):133–7.
- Fisher CM, Kistler JP, Davis JM. Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomographic scanning. *Neurosurgery*. 1980;6(1):1–9.
- Pierot L, Biondi A. Endovascular techniques for the management of wide-neck intracranial bifurcation aneurysms: a critical review of the literature. *J Neuroradiol*. 2016;43(3):167–75.

19. Pierot L, Cognard C, Anxionnat R, Ricolfi F. Endovascular treatment of ruptured intracranial aneurysms: factors affecting midterm quality anatomic results: analysis in a prospective, multicenter series of patients (CLARITY). *Am J Neuroradiol*. 2012;33(8):1475–80.
20. McLaughlin N, McArthur DL, Martin NA. Use of stent-assisted coil embolization for the treatment of wide-necked aneurysms: a systematic review. *Surg Neurol Int*. 2013;4:43.
21. McDonald JS, Norgan AP, McDonald RJ, Lanzino G, Kallmes DF, Cloft HJ. In-hospital outcomes associated with stent-assisted endovascular treatment of unruptured cerebral aneurysms in the USA. *J Neurointerv Surg*. 2013;5(4):317–20.
22. Hetts SW, Turk A, English JD, Dowd CF, Mocco J, Prestigiacomo C, et al. Stent-assisted coiling versus coiling alone in unruptured intracranial aneurysms in the matrix and platinum science trial: safety, efficacy, and mid-term outcomes. *Am J Neuroradiol*. 2014;35(4):698–705.
23. King B, Vaziri S, Singla A, Fargen KM, Mocco J. Clinical and angiographic outcomes after stent-assisted coiling of cerebral aneurysms with Enterprise and Neuroform stents: a comparative analysis of the literature. *J Neurointerv Surg*. 2015;7(12):905–9.
24. Poncyłjusz W, Zwarzany Ł, Limanówka B, Zbrozczyk M, Banach M, Bereza S, et al. Stent-assisted coiling of unruptured MCA aneurysms using the LVIS Jr. device: a multicenter registry. *J Clin Med*. 2020;9(10):3168.
25. Zaidat OO, Hanel RA, Sauvageau EA, Aghaebrahim A, Lin E, Jadhav AP, et al. Pivotal trial of the neuroform atlas stent for treatment of anterior circulation aneurysms: one-year outcomes. *Stroke*. 2020;51(7):2087–94.
26. Cagnazzo F, Limbucci N, Nappini S, Renieri L, Rosi A, Laiso A, et al. Y-stent-assisted coiling of wide-neck bifurcation intracranial aneurysms: a meta-analysis. *Am J Neuroradiol*. 2019;40(1):122–8.
27. Abdel-Tawab M, Hasan AA, Ahmed MA, Seif HMA, Yousif HA. Prognostic factors of delayed cerebral ischemia after subarachnoid hemorrhage including CT perfusion: a prospective cohort study. *Egypt J Radiol Nucl Med*. 2020;51(1):1–10.
28. Zhang X, Zuo Q, Tang H, Xue G, Yang P, Zhao R, et al. Stent assisted coiling versus non-stent assisted coiling for the management of ruptured intracranial aneurysms: a meta-analysis and systematic review. *J Neurointerv Surg*. 2019;11(5):489–96.
29. Zhang X, Zhong J, Gao H, Xu F, Bambakidis NC. Endovascular treatment of intracranial aneurysms with the LVIS device: a systematic review. *J Neurointerv Surg*. 2017;9(6):553–7.

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Submit your manuscript to a SpringerOpen<sup>®</sup> journal and benefit from:**

- Convenient online submission
- Rigorous peer review
- Open access: articles freely available online
- High visibility within the field
- Retaining the copyright to your article

---

Submit your next manuscript at ► [springeropen.com](https://www.springeropen.com)