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Endovascular Treatment of Multiple Intracranial Aneurysms: A Multicenter Study from Türkiye on Morphology-Based Strategies and Clinical Outcomes

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ABSTRACT

AIM: To evaluate the role of recent endovascular techniques as less invasive alternatives in the management of multiple intracranial aneurysms, particularly in the context of heterogeneous aneurysm morphology and anatomical complexity.

MATERIAL and METHODS: This retrospective analysis included 65 patients with a total of 151 MIAs that were treated using endovascular approaches. Morphological parameters, anatomical location, and clinical features were evaluated. Treatment strategies included primary coiling, stent-assisted coiling, Y/X-stent coiling, flow diversion (with or without coiling), use of Woven EndoBridge devices, and parent artery occlusion. Patient outcomes were assessed radiologically (Raymond–Roy Occlusion Classification) and clinically (Modified Rankin Scale, Glasgow Outcome Scale).

RESULTS: Morphometric parameters significantly differed by aneurysm location. Flow diversion was preferred for wide-necked ınternal carotid artery aneurysms, while coiling was more commonly used for aneurysms at bifurcation sites. Complete occlusion (Class I) was achieved in 70.2% of the cases, while residual neck/sac (Classes II–IIIa) were observed in 29.8% of the cases. Incomplete occlusion was associated with higher aspect ratios and was more frequent in aneurysms in the anterior and posterior communicating arteries and at the middle cerebral artery bifurcation. The clinical outcomes were favorable, with median Modified Rankin Scale and Glasgow Outcome Scale scores of 0.5 and 5, respectively. The mortality rate was 12%, with a median follow-up of 8.5 months.

CONCLUSION: Endovascular therapy provides a safe and effective approach to treat MIAs. Aneurysm morphology, especially location and aspect ratio, significantly influences angiographic outcomes, supporting the need for individualized treatment plans.

KEYWORDS: Multiple intracranial aneurysm, Endovascular treatment, Aneurysm, Multicenter study

ABBREVIATIONS: Acom: Anterior communicating artery, **CT:** Computed tomography, **GCS:** Glasgow Coma Scale, **ICA:** Internal carotid artery, **MCA:** Middle cerebral artery, **MIA:** Multiple ıntracranial aneurysm, **Pcom:** Posterior communicating artery, **WFNS:** World Federation of Neurosurgical Societies

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INTRODUCTION

The management of multiple intracranial aneurysms (MIAs) is clinically complicated by heterogeneity in aneurysm size and location and the complexity of three-dimensional vasculature (12,19,26). Achieving precise anatomical orientation becomes particularly difficult in cases involving ruptured aneurysms. The disruption of natural arachnoid dissection planes further increases the complexity of microsurgical exposure and manipulation. When aneurysms are located in different vascular territories, simultaneous access through a single craniotomy may be unfeasible, often necessitating multiple surgical approaches and patient repositioning (10,19,21). While microsurgical clipping has traditionally been the standard treatment, it is often limited by anatomical constraints and increased perioperative morbidity in complex MIA cases.

Advances in endovascular techniques, such as stent-assisted coiling, flow-diverter stents, and intrasaccular devices, have significantly expanded the treatment horizons for MIAs. These minimally invasive approaches allow for single-session treatment of multiple lesions, reducing overall procedural burden and improving safety (7,22).

In this multicenter retrospective study, we analyzed patients with MIAs who underwent endovascular treatment over a 1-year period. We aimed to evaluate the contemporary role of endovascular management in MIAs, focusing on morphological predictors, treatment strategies, and clinical outcomes within an integrated neurovascular care framework.

MATERIAL and METHODS

Patients and Data Collection

This retrospective observational study included 65 patients diagnosed with a cumulative total of 151 MIAs. As an inclusion criterion, all patients underwent endovascular treatment, and the clinical, morphological, procedural, and outcome-related data were systematically analyzed to evaluate associations among aneurysm characteristics, treatment modalities, and clinical outcomes. Comorbidities included hypertension, diabetes mellitus, smoking, and other vascular risk factors.

Symptoms included headache, visual problems, seizure, vertigo, and paresthesia. Neurological grading was performed using the World Federation of Neurosurgical Societies (WFNS) scale and Glasgow Coma Scale (GCS). Pre-treatment cranial computed tomography (CT) findings were evaluated using the Fisher scale. Additionally, hemorrhage distribution in cranial cisterns was categorized into four groups: lamina terminalis, sylvian cistern, quadrigeminal cistern, and prepontine cistern. The presence of hydrocephalus was also assessed on initial CT scans.

For each treated cerebral aneurysm, the following information was documented: morphology (categorized as saccular, fusiform, dissecting, thrombosed); location (categorized as internal carotid artery [ICA] cervical, cavernous, clinoid, ophthalmic, communicating segment, posterior communicating artery [Pcom], ICA bifurcation, A1 segment, anterior communicating artery [Acom], A2 segment, M1 segment, middle cerebral artery [MCA] bifurcation, M2 segment, P1 segment, basilar tip, basilar trunk, superior cerebellar artery, anterior inferior cerebellar artery, posterior inferior cerebellar artery, and vertebral artery); neck width; dome-to-neck ratio; aspect ratio; and maximum diameter.

Endovascular treatment strategies included primary coiling, stent-assisted coiling, Y/X-stent coiling, flow-diverter stent (alone or combined with coiling), Woven EndoBridge devices, and parent artery occlusion. Procedural efficacy was radiologically stratified using Raymond–Roy Occlusion Classification and O′Kelly–Marotta grading. Clinical outcomes were evaluated using the Modified Rankin Scale and Glasgow Outcome Scale. Digital subtraction angiography was the primary modality for follow-up imaging at 3–6 months after treatment.

The study received approval from the ethics committee of Ankara Etlik City Hospital (Ethical ID: AEŞH BADEK1-2025-048).

Statistical Analysis

Statistical analyses were performed using parametric and non-parametric methods depending on the data distribution. Morphometric parameters across anatomical locations were compared using one-way analysis of variance. Categorical and ordinal data were compared using chi-square and Kruskal–Wallis tests, respectively. Relationships between parameters were quantified using Spearman's rho correlation. Longitudinal differences between parameters were analyzed using the Wilcoxon signed-rank test. All statistical analyses were performed using SPSS software for Windows, version 25.0, with the threshold of significance set at 0.05.

RESULTS

The mean patient age was 55.5 ± 15.3 years. Of the 65 enrolled patients, 37 were women and 28 men. Comorbidities included hypertension (45.3%), diabetes mellitus (15.6%), smoking (20.3%), and other vascular risk factors. At admission, 39.1% of the patients presented with subarachnoid hemorrhage, most frequently involving the distal Sylvian fissure (50.0%) and lamina terminalis (45.3%). Neurological grading was performed using the WFNS scale and GCS score. A majority of the patients (51.6%) were assessed to be in good clinical condition, with a WFNS grade of 1 and a GCS score of 15. Radiologic evaluation was conducted using the Fisher grading system. Grade 4 hemorrhage was identified in 42.2% of the cases (Table I).

The average neck width was 3.6 ± 1.1 mm, aspect ratio was 1.5 ± 0.9, dome-to-neck ratio was 1.3 ± 0.4, and maximum diameter was 6.4 ± 2.5 mm. Three morphometric parameters, namely neck width (analysis of variance, p=0.0012), aspect ratio (p=0.0471), and maximum diameter (p=0.0113), differed significantly across anatomical regions. Aneurysms in the proximal ICA tended to be larger in dimension, while those at bifurcation sites (e.g., Acom, middle cerebral artery bifurcation) demonstrated higher aspect ratios (Figures 1, 2).

Flow-diverter stents were preferentially used to manage wide-necked aneurysms of the ICA, whereas coiling approaches were applied to bifurcation or distal branch aneurysms.

Table I: Demographics and Clinical Characteristics of the Patients

Category	Subcategory / Label	n	% of Patients
Demographics	Mean Age ± SD (years)		55.5 ± 15.3
	Gender (Female : Male)	(n)	37 : 28
Comorbidities	Hypertension (HT)	29	45.3
	Diabetes Mellitus (DM)	10	15.6
	Smoking	13	20.3
	Chronic Lung Disease	5	7.8
	Hyperlipidemia	8	12.5
Symptoms	Headache	14	21.9
	Visual Problems	5	7.8
	Seizures	2	3.1
	Incidental Finding	8	12.5
	Dizziness	3	4.7
	Hemiparesis / Stroke Signs	5	7.8
Subarachnoid Hemorrhage		25	39.1
Clinical Admission	Antiaggregant Therapy	27	42.2
	Hydrocephalus	8	12.5
Glasgow Coma Scale (GCS) at Admission	4-8	12	18.7
	9	1	1.6
	10	4	6.2
	11	1	1.6
	12	3	4.7
	13	4	6.2
	14	6	9.4
	15	33	51.6
Patient Classification	Fisher Grade (4) (1/2/3/4)		25/5/7/27
	WFNS Grade (18) (1/2/3/4/5)		33/9/3/10/9
Cisternal Blood	Lamina terminalis (AComA region)	29	45.3
	Distal Sylvian fissure (MCA bifurcation)	32	50.0
	Quadrigeminal cistern	22	34.4
	Prepontine cistern	10	15.6
	Unknown / No detectable blood	25	39.1

***WFNS:** World Federation of Neurological Surgeons, **AcomA:** Anterior communicating artery, **MCA:** Middle cerebral artery.*

Primary angiographic outcome was assessed using the Raymond–Roy classification: Class I (complete occlusion) was achieved in 70.2% of the cases, while Classes II and IIIa (residual neck or sac) were achieved in 27.2% and 2.6% of the cases, respectively (Figure 3). Aneurysm location significantly influenced occlusion rates (chi-square test, p=0.0002), with higher incomplete occlusion in Acom, Pcom, and MCA bifurcation aneurysms (Figures 4, 5). Aspect ratio was also a significant predictor of incomplete occlusion (Kruskal–Wallis test, p=0.0202), whereas dome-to-neck ratio and neck width did not exhibit significant associations (p=0.06). The mean Modified Rankin Scale and Glasgow Outcome Scale scores were 1.44 (median: 0.5) and 4.19 (median: 5.0), respectively, indicating that most of the patients recovered favorably. The overall mortality rate was 12% and the mean hospital stay was 12.2 days (range: 2–147 days). The median follow-up period was 8.5 months.

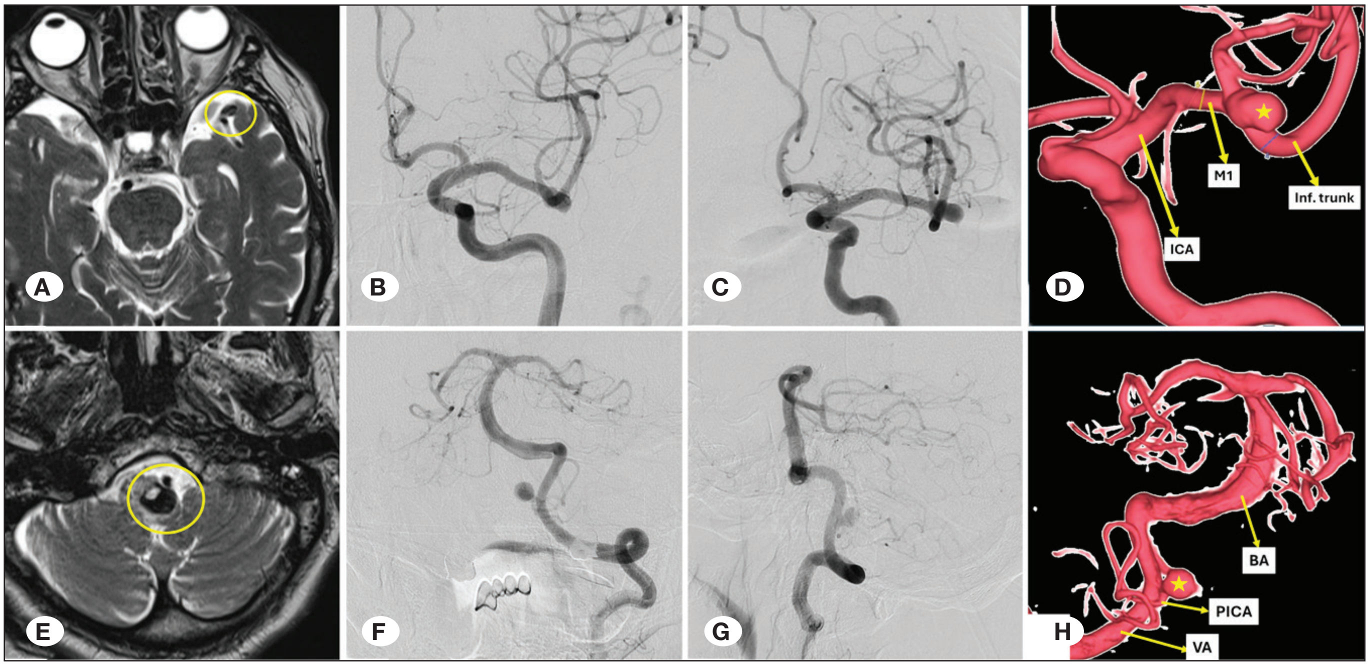

Figure 1: Pre-treatment imaging of a patient with non-ruptured left MCA bifurcation aneurysm and left PICA aneurysm. **A)** Axial T2-weighted MRI showing the left MCA bifurcation aneurysm. **B)** Anteroposterior (AP) view and **C)** oblique view DSA images demonstrating aneurysm location. **D)** 3D reconstructive DSA image showing a 7.3 × 4.2 mm saccular, wide-necked aneurysm. **E)** Axial T2-weighted MRI showing the left PICA aneurysm with a thrombosed component. **F)** AP view and **G)** lateral view DSA images demonstrating aneurysm location. **H)** 3D reconstructive DSA image showing a 12.4 × 8.3 mm saccular, wide-necked aneurysm.

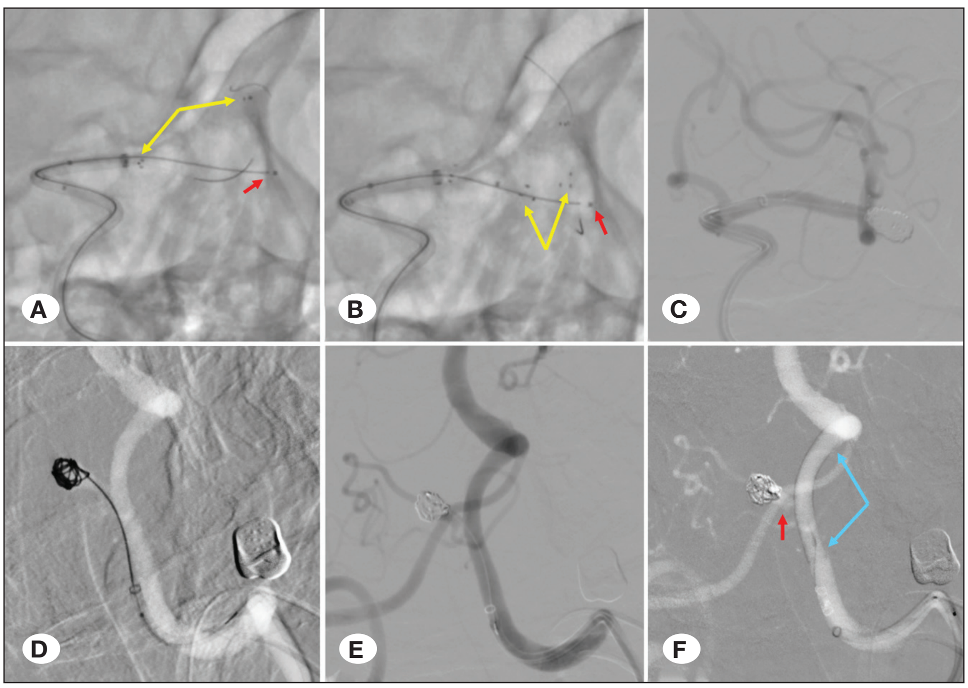

Figure 2: Treatment imaging of a patient with a left MCA bifurcation aneurysm and a left PICA aneurysm. **A)** In the Y-stent-assisted coil embolization procedure for the left MCA aneurysm, distal and proximal markers of the first stent (Acclino 3.5x25 mm) placed into the superior trunk (yellow arrows) and the coil microcatheter within the aneurysm dome (red arrow) are shown. **B)** Distal and proximal markers of the stent (Acclino 3.5x25 mm) placed into the inferior trunk (yellow arrows) and the coil microcatheter within the aneurysm dome (red arrow) are visible. **C)** Final control angiogram after completion of the coiling procedure. **D)** Initial coiling procedure performed for the left PICA aneurysm. **E)** Loose coiling at the aneurysm neck to preserve the proximal segment of the PICA. **F)** Distal and proximal markers of the DERIVO-2 4×15 mm flow diverter stent (blue arrows) placed to promote remodeling of the residual neck filling (red arrow) over time.

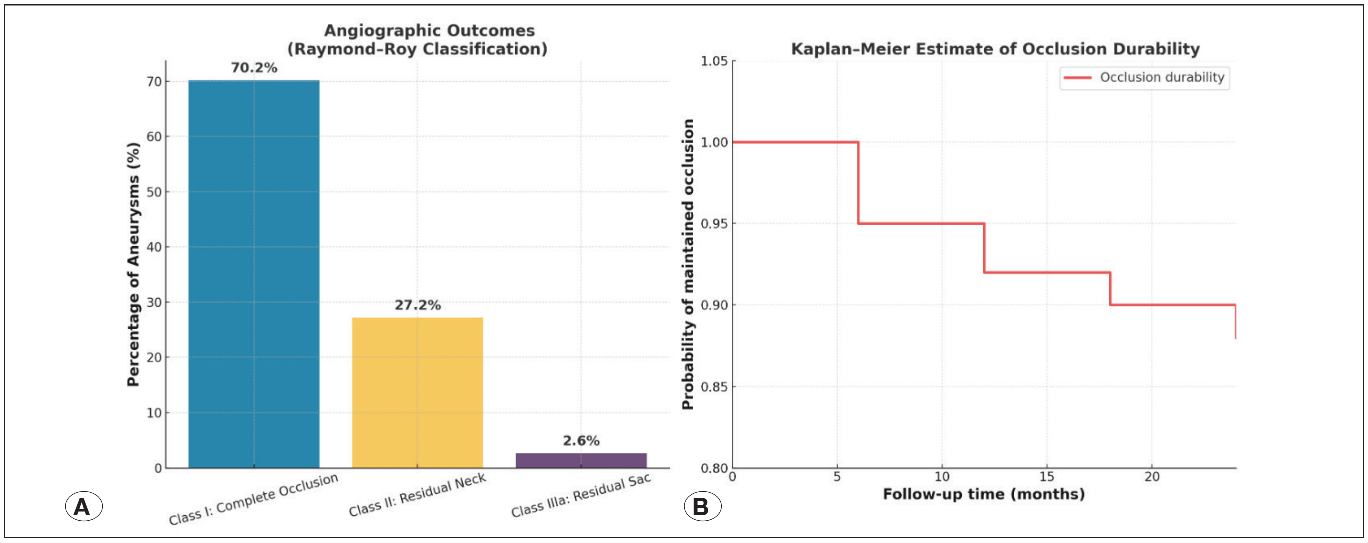

Figure 3: Summary of angiographic and follow-up outcomes in patients with multiple intracranial aneurysms treated endovascularly. **A)** Distribution of angiographic results according to the Raymond–Roy Occlusion Classification. Complete occlusion (Class I) was achieved in 70.2% of aneurysms, whereas residual neck (Class II) and residual sac (Class IIIa) were seen in 27.2% and 2.6%, respectively. **B)** Kaplan–Meier estimate of occlusion durability. The majority of aneurysms maintained stable occlusion during the first year of follow-up, with only a modest decline observed at 18–24 months. Median follow-up was 8.5 months and extended imaging data in a subset of patients confirmed continued stability without significant late recanalization.

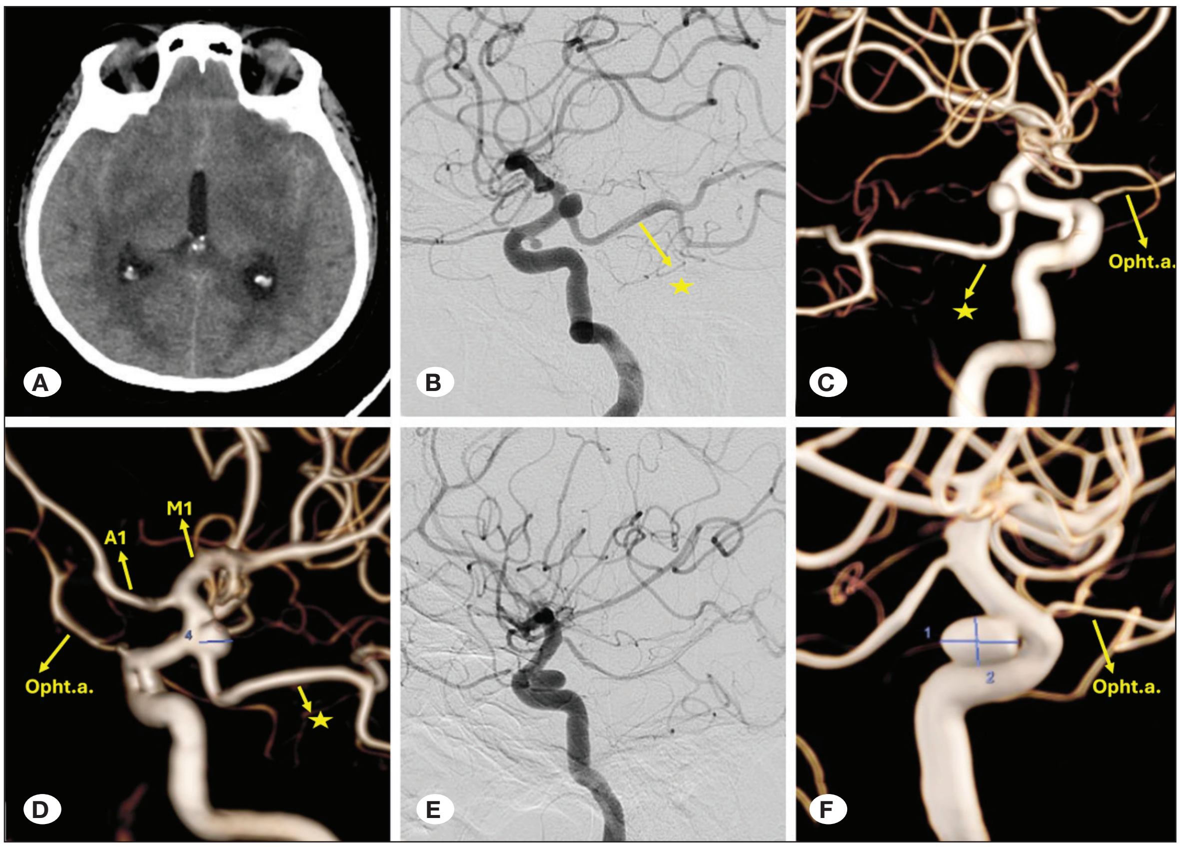

Figure 4: Pre-treatment imaging in a patient with bilateral ICA aneurysms. **A)** Axial cranial CT scan showing subarachnoid hemorrhage in the bilateral Sylvian cisterns. **B)** Lateral view DSA image following right ICA injection, demonstrating two saccular, wide-necked aneurysms: an inferiorly projecting aneurysm at the right ICA paraophthalmic segment measuring 2.8 × 2.4 mm, and an aneurysm originating from the right ICA Pcom segment measuring 6.6 × 4.4 mm. (yellow star: fetal Pcom). **C)** 3D reconstructed DSA image (oblique view) and **D)** posterior-anterior view of the same right ICA aneurysms. **E, F)** Lateral view and 3D reconstructed DSA image following left ICA injection, showing a saccular, wide-necked aneurysm at the left ICA paraophthalmic segment measuring 7.6 × 4.8 mm.

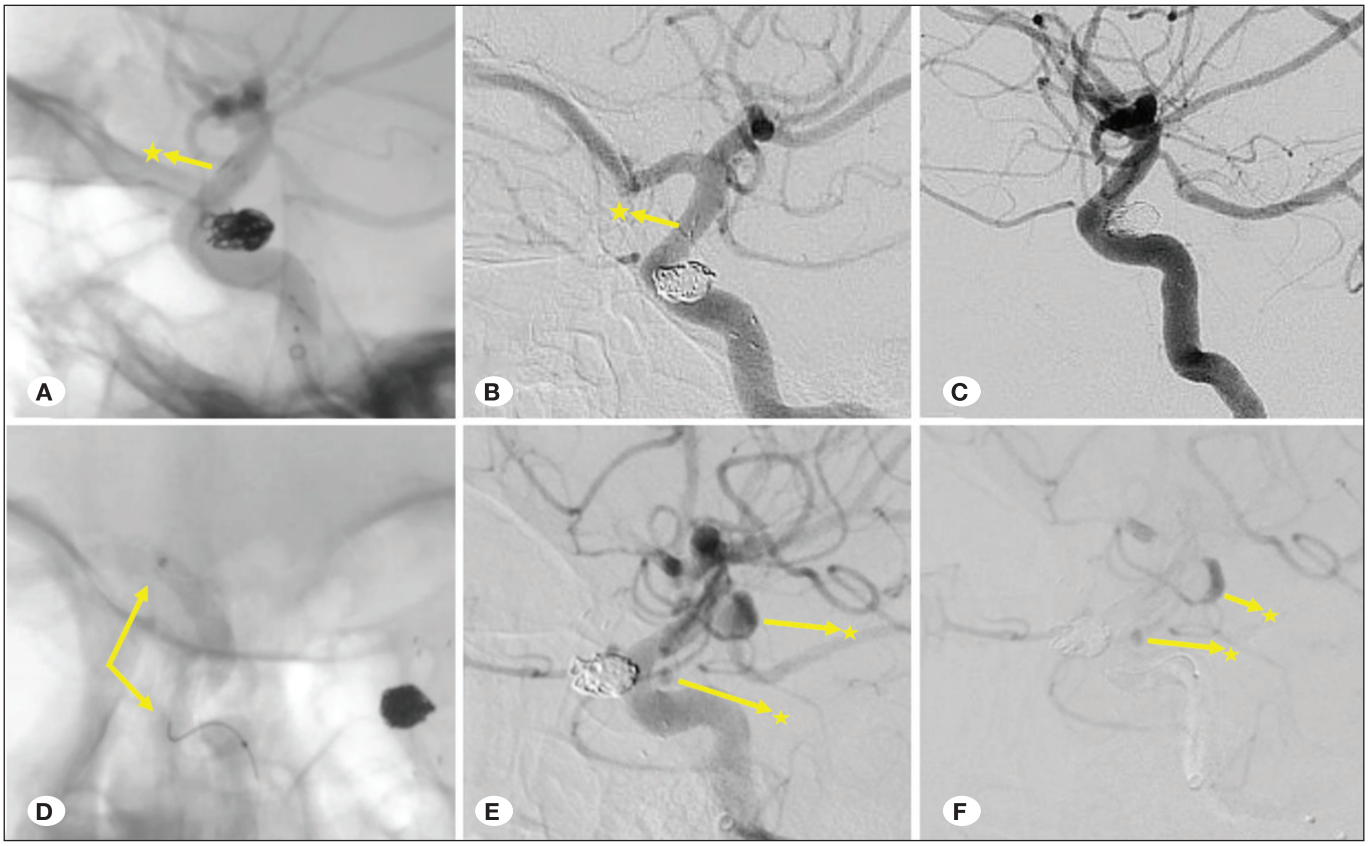

Figure 5: Treatment images of left and right ICA aneurysms. **A)** Unsubtracted view and **B)** subtracted view during stent-assisted coil embolization of the left ICA aneurysm, showing the proximal marker (yellow star) of the Neuroform Atlas stent (4.5 × 21 mm). **C)** Post-procedural control image in lateral projection in the same patient. **D)** Unsubtracted view during flow diverter stent placement for right ICA aneurysms, showing proximal and distal markers of the Surpass Evolve stent (4 × 17 mm). **E)** Delayed arterial phase and **F)** capillary phase images demonstrating contrast stagnation within the aneurysms located at the right ICA Pcom origin and paraophthalmic segment (yellow stars).

DISCUSSION

This multicenter retrospective study aimed to evaluate endovascular strategies in the treatment of MIAs, focusing on morphological predictors and clinical outcomes. Our findings demonstrated that endovascular strategies resulted in high overall occlusion rates with favorable clinical recovery. Moreover, our results highlighted the significant impact of aneurysm location and aspect ratio on treatment success. One of the most critical challenges in managing MIAs is accurately identifying the source of hemorrhage. Nehls et al. correctly localized bleeding aneurysms in up to 98% of the cases in their study through detailed CT and angiographic analysis, considering parameters such as aneurysm size, shape, wall irregularities, and adjacent vasospasm (16). In our cohort, prioritizing the treatment of the ruptured lesion was critical, often dictating the sequence and strategy for managing coexisting unruptured aneurysms.

Following the occlusion rate of the ruptured aneurysm, management of coexisting unruptured lesions can be considered either in the same session or in a staged approach. In particular, treating ipsilateral aneurysms sharing the same vascular access in a single session is advantageous because it minimizes vascular manipulation, reduces endothelial trauma, and facilitates neointimal healing when stents are deployed (15).

The choice between microsurgical clipping and endovascular intervention in the treatment of multiple aneurysms remains nuanced. With advancements in neurointerventional technology—particularly the development of flow-diverter stents and improved angiographic visualization—endovascular treatment has become increasingly preferred in recent years (7). Broad-necked aneurysms, often encountered in cases featuring multiple aneurysms, represent a challenge for microsurgical access but are amenable to endovascular techniques. At 10-year follow-up in the Barrow Ruptured Aneurysm Trial, clipping of anterior circulation aneurysms was associated with lower rates of rebleeding, retreatment, and incomplete occlusion compared with coiling, although both groups showed comparable clinical outcomes (25). At 1-year follow up in the International Subarachnoid Aneurysm Trial, endovascular coiling resulted in improved independent survival compared with surgery in favorable cases, but the trial results highlighted the necessity of follow-up to monitor the rare occurence of late rerupture (13). Morsy et al. reported an occlusion rate of 92.5% in wide-necked aneurysms treated with endovascular methods, underscoring the efficacy of such methods (15). In our study, Raymond–Roy Class I and II occlusion rates were achieved by 97.4% of the patients (Class I: 70.2%, Class II: 27.2%), and aneurysm aspect ratio and location significantly influenced occlusion rates, with higher incomplete occlusion noted in Acom, Pcom, and MCA bifurcation aneurysms.

In cases involving giant aneurysms, which are frequently associated with multiple aneurysms, endovascular treatment is generally preferred due to the elevated perioperative risk associated with microsurgical clipping. Santoro et al. found that while both approaches yielded comparable mortality rates, microsurgery was associated with higher morbidity and intraoperative complication rates, whereas endovascular techniques were associated with lower morbidity but higher recurrence rates (20). In our study, we treated eight giant aneurysms using endovascular techniques.

Interestingly, aneurysm location may influence long-term outcomes depending on the treatment modality. Yamada et al. reported a reduced incidence of secondary normal-pressure hydrocephalus in patients treated with endovascular coiling compared with microsurgical clipping (28). Similarly, Dong et al. observed no persistent neurological deficits in the endovascular group, suggesting a potential safety advantage over microsurgery despite similar complication rates (3). In patients without massive subarachnoid hemorrhage or severe vasospasm, endovascular approaches are generally preferred due to their minimally invasive nature.

Liu et al. proposed a novel zonal classification of the cranial cavity from the falx cerebri to the tentorium cerebelli to guide the selection of treatment modality on the basis of aneurysm location (10). Furthermore, Song et al. demonstrated the safety and efficacy of single-session endovascular treatment in midline or symmetrically distributed aneurysms, such as mirror aneurysms (24). The ongoing debate between single-session and staged treatment strategies is especially relevant in MIA management. Several studies have advocated for single-session treatment to mitigate the risk of rebleeding during the interventional interval (9,22,23,29). However, Andic et al. emphasized that while single-session endovascular treatment is effective in complex cases, it may carry an elevated risk of thromboembolic complications, particularly in patients with bilateral ICA aneurysms. In such cases, a staged approach should be considered (1).

Deniwar reported that aneurysm size and location, radiological signs of impending rupture, and clinical presentation are critical factors in determining the optimal treatment modality and timing (2). Similarly, Kim and Song identified endovascular treatment as the standard of care for multiple aneurysms, cautioning that limiting treatment only to the ruptured lesion could underestimate the true risk of hemorrhage from untreated aneurysms (6). Supporting this recommendation, Massaud et al. reported superior outcomes and shorter procedural times for endovascular approaches in posterior circulation aneurysms, attributing this to the complexity of microsurgical access in such locations (11).

Several studies advocate for primary coil embolization in single-session treatments, citing its efficacy in reducing hemorrhage risk and limiting vessel trauma and dissection (4,17). In addition to primary coiling, other endovascular techniques such as stent-assisted coiling and primary stenting have demonstrated high success rates, especially in wide-necked or proximally situated multiple aneurysms (14,21,24,27).

In cases involving multiple ipsilateral aneurysms near the ophthalmic segment of the ICA, Tang et al. emphasized the importance of aneurysm geometry in selecting the optimal endovascular strategy, achieving complete occlusion through tailored techniques in a single session (26). Similarly, Lee et al. demonstrated that flow-diverter stents are effective in treating proximally spaced ipsilateral aneurysms, achieving successful occlusion across multiple lesions (8). In our study, flow-diverter stents were preferentially used in wide-necked aneurysms of the ICA, while coiling approaches were applied to bifurcation or distal branch aneurysms.

Limitations

This study has some limitations. First, the study is retrospective in design with a moderately sized patient cohort. Second, heterogeneity in endovascular devices, procedural protocols, operator experience, and institutional case volumes could have influenced treatment selection and outcomes. Finally, the relatively short median follow-up of 8.5 months may underestimate the incidence of late recanalization, particularly in bifurcation aneurysms treated with coiling. Nevertheless, the value of this study lies in its pioneering contribution to the understanding of treatment selection and efficacy in the management of multiple aneurysms. To strengthen the generalizability of these findings and support global standardization, future studies should aim for larger, prospectively collected datasets with standardized protocols.

CONCLUSION

Endovascular techniques represent a valuable treatment option for MIAs, achieving favorable occlusion rates and clinical outcomes. However, the choice of strategy should be individualized, considering aneurysm location, morphology, and patient-specific factors. Our findings underscore the importance of a morphology-driven, patient-tailored approach in optimizing treatment success. Further prospective multicenter studies with longer follow-up are warranted to validate these results and refine therapeutic strategies.

Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: LA, MBE, MET

Data collection: LA, MBE, CT

Analysis and interpretation of results: LA, EK, FY, CT

Draft manuscript preparation: LA, MBE, FY

Critical revision of the article: EK, FY, MET, CE

Other (study supervision, fundings, materials, etc...): LA, MBE, MET, CE

All authors (LA, MBE, CT, CE, EK, FY, MET) reviewed the results and approved the final version of the manuscript.

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