Review Article

Micro-surgical Clipping versus Endovascular Therapy in Middle Cerebral Artery Aneurysms: Indications, Outcomes, and Contemporary Clinical Considerations

David Daniel Diaz Polo[1*], Fernando Román Sing[2], Victor Fuenmayor Macrobio[3], Bary Gentilini Espinoza[4], Mariel Quiros Arroyo[5], Eric Umaña Miranda[6]

[1,3,4,5]Medical Doctor, Hospital Clínica Bíblica, San José, Costa Rica
[2]Medical Doctor, Clinica Damarjo, Cartago, Costa Rica
[6]Medical Doctor, Rush Urgent Care, Puntarenas, Costa Rica
[*]Corresponding author email: **david.d92@me.com**

International Archives of Integrated Medicine, Vol. 13, Issue 4, April, 2026.
Available online at http://iaimjournal.com/
ISSN: 2394-0026 (P) **ISSN: 2394-0034 (O)**

Received on: 22-3-2026 **Accepted on:** 18-4-2026
Source of support: Nil **Conflict of interest:** None declared.

DOI: **10.5281/zenodo.19816397**

How to cite this article: David Daniel Diaz Polo, Fernando Román Sing, Victor Fuenmayor Macrobio, Bary Gentilini Espinoza, Mariel Quiros Arroyo, Eric Umaña Miranda. Micro-surgical Clipping versus Endovascular Therapy in Middle Cerebral Artery Aneurysms: Indications, Outcomes, and Contemporary Clinical Considerations. Int. Arch. Integr. Med., 2026; 13(4): 233-246.

Abstract

Middle cerebral artery aneurysms represent a significant proportion of intracranial aneurysms and pose important challenges in neurovascular management because of their complex anatomical configuration and variable morphological characteristics. These aneurysms frequently arise at the bifurcation of the middle cerebral artery, where hemodynamic forces and vascular geometry contribute to aneurysm formation and progression. Factors such as aneurysm size, neck width, vessel branching, and local blood flow dynamics influence both rupture risk and treatment selection. Understanding these anatomical and pathophysiological mechanisms is therefore essential for optimizing therapeutic strategies. Microsurgical clipping and endovascular therapy represent the two principal treatment approaches for middle cerebral artery aneurysms. Microsurgical clipping involves the direct exclusion of the aneurysm from the cerebral circulation through clip placement across the aneurysm neck. This technique has demonstrated high rates of complete aneurysm occlusion and long-term durability, particularly in wide-neck or complex aneurysms. However, it is associated with greater surgical invasiveness and a higher risk of perioperative morbidity. In contrast, endovascular therapy aims to exclude the aneurysm from the circulation through catheter-based techniques such as coil embolization, balloon-assisted coiling, stent-assisted coiling, and flow diversion. These approaches are less invasive and are often associated with shorter hospital stays and improved short-term functional outcomes. Nevertheless, endovascular therapy may present higher rates of aneurysm recurrence and the need for retreatment. Current evidence suggests that both treatment modalities achieve comparable overall clinical outcomes, although their advantages differ depending on aneurysm morphology and patient characteristics. As advances in surgical and endovascular techniques continue to evolve, the management of middle cerebral artery aneurysms increasingly relies on individualized treatment selection supported by multidisciplinary neurovascular teams.

Key words

Micro-surgical Clipping, Endovascular Therapy, Middle Cerebral Artery Aneurysms, Indications, Outcomes.

Introduction

Intracranial aneurysms represent a clinically significant cerebrovascular condition because of their potential to rupture and produce subarachnoid hemorrhage; an event frequently associated with severe neurological deficits and considerable mortality [1]. Among the different intracranial aneurysm locations, aneurysms of the middle cerebral artery are particularly common and account for a substantial proportion of all diagnosed cases. These aneurysms frequently present with complex anatomical characteristics, including wide aneurysm necks and the incorporation of branching vessels, factors that contribute to the complexity of their management and therapeutic planning [2].

The anatomical configuration of the middle cerebral artery plays a central role in shaping treatment strategies. This vessel is characterized by a complex architecture that includes bifurcations and multiple collateral branches, features that create technical challenges for both microsurgical and endovascular interventions. The presence of branching vessels at the aneurysm site can complicate clip placement during microsurgery and may also limit the effectiveness of endovascular techniques such as coil embolization [1]. In addition to anatomical considerations, hemodynamic factors contribute significantly to aneurysm development and treatment planning. Blood flow dynamics and the mechanical stress exerted on the aneurysm wall influence aneurysm stability and may affect the suitability and expected outcomes of different therapeutic approaches [2].

Historically, microsurgical clipping has been regarded as the standard treatment for middle cerebral artery aneurysms. This approach has traditionally demonstrated high rates of complete aneurysm occlusion and has therefore been considered a durable and effective treatment option [1]. Over time, however, the development of advanced endovascular techniques has significantly expanded the range of therapeutic possibilities. Innovations such as stent-assisted coiling and flow diversion have increased the applicability of endovascular therapy and have contributed to its growing use in the management of intracranial aneurysms [4].

Comparisons between microsurgical clipping and endovascular therapy have revealed important differences in clinical and angiographic outcomes. Microsurgical clipping is generally associated with higher rates of complete aneurysm occlusion and lower recurrence rates, particularly in the treatment of unruptured aneurysms [4, 5]. In contrast, endovascular therapy, while less invasive, is often associated with more favorable short-term functional outcomes and shorter hospital stays following treatment [6]. In cases involving wide-necked aneurysms, microsurgical techniques tend to provide superior angiographic results, whereas endovascular approaches may be associated with improved early functional recovery [7].

Consequently, the selection of an optimal treatment strategy remains a complex clinical decision influenced by multiple factors. The characteristics of the aneurysm, including size, morphology, and vascular relationships, must be considered alongside patient-related variables and the level of institutional expertise available [2]. Although several studies indicate that microsurgical clipping may provide superior long-term aneurysm occlusion, other investigations emphasize the advantages of endovascular therapy in terms of reduced morbidity and improved functional outcomes [3, 6]. As technological innovations continue to emerge, the debate between these treatment modalities remains ongoing, highlighting the need for further research and randomized clinical trials to clarify the optimal management strategies for middle cerebral artery aneurysms [7].

The objective of this article is to analyze and compare microsurgical clipping and endovascular therapy in the management of middle cerebral artery aneurysms, focusing on their clinical indications, anatomical considerations, and treatment outcomes.

Methodology

Study Design

This study was conducted as a structured narrative review focused on the comparative evaluation of microsurgical clipping and endovascular therapy in the management of middle cerebral artery aneurysms. The objective of the review was to analyze current evidence regarding clinical indications, anatomical considerations, treatment outcomes, and contemporary therapeutic strategies associated with these two treatment approaches. Because the management of middle cerebral artery aneurysms involves complex interactions between aneurysm morphology, rupture status, patient characteristics, and institutional expertise, a narrative synthesis was selected to allow an integrated interpretation of the available literature. The review was developed following general principles for high-quality narrative reviews to ensure transparency and methodological consistency.

Literature Search Strategy

A structured literature search was performed using three major biomedical databases: PubMed, Scopus, and Web of Science. The search included peer-reviewed articles published in English between January 2021 and March 2026. The final literature search was conducted in March 2026. The search strategy combined Medical Subject Headings and free-text terms related to middle cerebral artery aneurysms and their treatment. Keywords included "middle cerebral artery aneurysm," "intracranial aneurysm," "microsurgical clipping," "endovascular therapy," "coil embolization," "stent-assisted coiling," "flow diversion," "aneurysm occlusion," "recurrence," and "treatment outcomes." Boolean operators were used to optimize the sensitivity and specificity of the search. Reference lists of relevant articles were also manually reviewed to identify additional studies that might not have been captured through database searches.

Study Selection

The initial search identified 157 records. After the removal of duplicate entries, 176 articles remained for title and abstract screening. Of these, 83 articles were selected for full-text review. Following detailed evaluation, 30 studies were included in the final narrative synthesis. Study selection was performed independently by two reviewers, and disagreements were resolved through discussion and consensus.

Studies were included if they provided information regarding clinical outcomes, treatment indications, technical considerations, or comparative analyses of microsurgical clipping and endovascular therapy in middle cerebral artery aneurysms. Eligible publications included randomized controlled trials, prospective and retrospective cohort studies, systematic reviews, meta-analyses, and international clinical guidelines related to cerebrovascular disease.

Studies were excluded if they consisted exclusively of isolated case reports, editorials without original data, technical descriptions lacking clinical outcome analysis, duplicate datasets, or articles that did not specifically address aneurysms of the middle cerebral artery.

Data Extraction and Analysis

Relevant information from the selected studies was extracted and organized according to study design, patient population, aneurysm characteristics, treatment modality, and reported outcomes. Extracted variables included aneurysm rupture status, aneurysm size and neck configuration, treatment technique, angiographic occlusion rates, recurrence and retreatment rates, procedural complications, functional outcomes, and duration of follow-up.

The findings from the included studies were synthesized qualitatively to identify consistent patterns across the literature, differences in reported outcomes, and factors influencing treatment selection. This narrative synthesis allowed the integration of surgical, endovascular, anatomical, and clinical perspectives into a unified analytical framework.

Methodological Considerations

As a narrative review, this study does not include a quantitative meta-analysis or pooled statistical estimates. The conclusions are therefore based on the critical interpretation of available evidence rather than statistical aggregation. The methodological quality of included studies was considered narratively, taking into account study design, sample size, follow-up duration, and consistency of reported outcomes. Artificial intelligence–assisted tools were used solely to support literature organization and structural coherence. The final selection of studies, critical evaluation of the evidence, and interpretation of findings were conducted independently by the authors to preserve methodological rigor.

Anatomy and Morphological Characteristics of Middle Cerebral Artery Aneurysms

The middle cerebral artery presents a complex anatomical configuration that plays a critical role in the development and management of intracranial aneurysms. The M1 segment extends from its origin at the internal carotid artery to the point of bifurcation, where it divides into the superior and inferior divisions. This bifurcation represents one of the most common sites for aneurysm formation, largely due to the combined influence of hemodynamic stress and the anatomical configuration of the vessel at this branching point [8, 9]. In addition to the major divisions of the vessel, the M1 segment gives rise to small perforating arteries known as the lenticulostriate arteries. These vessels supply deep brain structures, including the basal ganglia, and their preservation during surgical intervention is essential in order to prevent ischemic complications [10, 11].

The morphological characteristics of middle cerebral artery aneurysms are closely related to the anatomical configuration of the vessel. Aneurysms frequently develop at the bifurcation of the middle cerebral artery, where local hemodynamic conditions contribute to vascular wall stress. Several structural factors influence the likelihood of aneurysm formation at this location, including the bifurcation angle and the diameter of the parent vessels. Larger bifurcation angles and smaller vessel diameters have been associated with an increased risk of aneurysm development, reflecting the influence of flow dynamics and vascular geometry on aneurysm pathogenesis [8, 9, 12]. Although less common, aneurysms may also arise along the lateral wall of the M1 segment. These lateral wall aneurysms are generally related to localized weakness of the vessel wall or specific hemodynamic stress patterns and may present unique clinical challenges because of their proximity to critical perforating arteries [13].

In addition to their anatomical location, the structural characteristics of aneurysms play an important role in determining appropriate treatment strategies. Factors such as aneurysm size, neck width, and overall morphological complexity significantly influence the selection of therapeutic approaches. Larger aneurysms and those with wide necks are particularly challenging to treat and often require more advanced endovascular techniques. Devices such as the Woven EndoBridge have been developed to address these complex configurations and have shown effectiveness in aneurysms that meet specific size and neck width criteria [14, 15].

These anatomical and morphological features also influence treatment selection. Wide-neck aneurysms present important technical challenges for both traditional microsurgical clipping and endovascular coiling, as they increase the risk of incomplete aneurysm occlusion or recurrence. In this context, devices such as the Woven EndoBridge have demonstrated suitability for wide-neck bifurcation aneurysms, offering improved occlusion outcomes in appropriately selected cases [15]. Furthermore, treatment complexity increases when arterial branches are incorporated into the aneurysm sac. In such situations, microsurgical clipping requires meticulous surgical planning and precise technique to ensure preservation of blood flow to critical brain regions while achieving effective aneurysm exclusion [13, 14].

Pathophysiology and Risk of Rupture

The formation of intracranial aneurysms is closely related to hemodynamic forces acting on the arterial wall and the progressive degeneration of vascular structures. Hemodynamic stress plays a fundamental role in this process, particularly through the influence of wall shear stress and complex blood flow patterns within the cerebral circulation. High wall shear stress has been associated with degeneration and thinning of the aneurysm wall, a process that increases the susceptibility of the aneurysm to rupture. In contrast, low wall shear stress has been linked to wall thickening and remodeling processes resembling atherosclerotic changes, which may contribute to relative stabilization of the aneurysm structure [16, 17].

These hemodynamic alterations contribute directly to vascular wall degeneration. Disturbed blood flow patterns can induce a series of cellular and molecular changes within the vessel wall, including inflammatory responses, degradation of the extracellular matrix, and programmed cell death. Together, these processes weaken the structural integrity of the arterial wall and contribute to the development and progression of intracranial aneurysms. The relationship between hemodynamic stress and vascular wall degeneration becomes particularly evident when analyzing the structural characteristics of aneurysm walls under different hemodynamic conditions [18].

Regions exposed to high wall shear stress are frequently associated with thin and translucent aneurysm walls. These fragile areas have been observed during surgical procedures and have also been identified through computational fluid dynamics simulations, which demonstrate the concentration of hemodynamic forces in these locations. Such structural thinning significantly increases the likelihood of aneurysm rupture [17]. In contrast, areas characterized by low wall shear stress tend to develop thicker aneurysm walls. These regions often exhibit prolonged blood residence time and may demonstrate post-contrast enhancement on magnetic resonance imaging, findings that reflect different patterns of vascular remodeling and potentially lower susceptibility to rupture [16].

Several clinical and anatomical factors further influence the risk of aneurysm rupture. Aneurysm size and growth represent important determinants of instability. Larger aneurysms and those that demonstrate progressive enlargement are associated with a greater risk of rupture. As aneurysms increase in size, hemodynamic conditions within the aneurysm sac may change, including reductions in wall shear stress, which can contribute to increasing structural instability [19, 20]. In addition to size, the anatomical location and geometry of the aneurysm also influence rupture risk. The configuration of the parent artery, whether involving bifurcation or sidewall locations, affects local blood flow patterns at the aneurysm neck and therefore contributes to variations in rupture susceptibility [21].

These pathophysiological considerations have important clinical implications in the management of both ruptured and unruptured middle cerebral artery aneurysms. The principal treatment options include microsurgical clipping and endovascular therapy. Endovascular therapy is often favored because of its minimally invasive nature, while microsurgical clipping may provide more durable aneurysm exclusion, particularly in aneurysms with wide necks or complex anatomical configurations [4, 22]. Consequently, the selection between endovascular and microsurgical treatment strategies depends on a combination of aneurysm-related characteristics and patient-specific factors. Although endovascular therapy may be associated with improved functional outcomes at the time of hospital discharge, microsurgical clipping frequently achieves more complete aneurysm occlusion [4].

Microsurgical Clipping

Microsurgical aneurysm clipping is a well-established treatment strategy for intracranial aneurysms, particularly those located in the middle cerebral artery. The primary objective of this procedure is the permanent exclusion of the aneurysm from the cerebral circulation, thereby preventing rupture and the occurrence of subarachnoid hemorrhage. Achieving durable aneurysm occlusion while maintaining adequate cerebral perfusion represents the central goal of this surgical intervention. At the same time, preservation of the parent vessels and the surrounding perforating arteries is essential to maintain normal cerebral blood flow and to minimize the risk of postoperative neurological deficits [7, 22].

The surgical technique for microsurgical clipping typically involves a pterional craniotomy, which provides optimal exposure of the middle cerebral artery and its branches. This approach allows the surgeon to access the Sylvian fissure and the aneurysm while maintaining adequate visualization of the surrounding vascular structures. Following the craniotomy, careful dissection of the Sylvian fissure is performed in order to expose the aneurysm and identify adjacent vascular structures. Particular attention is directed toward the identification and protection of perforating arteries, which are critical for preventing ischemic complications during and after the procedure. Once the aneurysm neck has been adequately exposed, a surgical clip is applied across the neck of the aneurysm to isolate it from the circulation. Intraoperative verification techniques are then used to confirm complete aneurysm occlusion while ensuring that normal blood flow is preserved in the parent vessels and adjacent branches [23].

Microsurgical clipping offers several important advantages. One of the most significant benefits is the high rate of complete aneurysm occlusion achieved with this technique, which frequently exceeds the occlusion rates reported with endovascular treatments [22, 23]. In addition, microsurgical clipping is widely recognized for its long-term durability, which substantially reduces the likelihood of aneurysm recurrence over time [5]. This technique is also particularly effective in the management of wide-neck aneurysms and other complex aneurysm configurations that may be difficult to treat with endovascular approaches [7, 24].

Despite these advantages, microsurgical clipping is associated with several limitations and potential complications. As an open surgical procedure, it carries a risk of surgical morbidity, including neurological deficits and complications related to the operative approach [5, 7]. In addition, there is a possibility of injury to the parent vessel or nearby perforating arteries during dissection or clip placement, which may result in ischemic events [23]. Postoperative complications may also occur and can influence clinical outcomes. These complications may include ischemia or the development of hydrocephalus, both of which can affect the patient's neurological recovery following surgery [22].

Endovascular Therapy

Endovascular therapy has become an important treatment option in the management of intracranial aneurysms, particularly as technological advances have expanded its applicability in complex vascular lesions. The primary objective of endovascular treatment is the endoluminal exclusion of the aneurysm from the circulation. This strategy involves sealing the aneurysm from the bloodstream while preserving the integrity and functional patency of the parent vessel, thereby reducing the risk of aneurysm rupture without disrupting normal cerebral blood flow [4, 5]. This therapeutic goal is achieved through the deployment of specialized devices either within the aneurysm sac or across its neck, which prevents blood from entering the aneurysm cavity and promotes progressive thrombosis of the lesion [25].

Several endovascular techniques have been developed to accomplish this objective. One of the most widely used methods is coil embolization, which involves filling the aneurysm sac with detachable coils that induce thrombosis and effectively occlude the aneurysm. In cases involving wide-neck aneurysms, adjunctive techniques may be necessary to improve treatment stability and effectiveness. Balloon-assisted coiling utilizes a temporary balloon positioned within the parent vessel to support coil placement and prevent coil prolapse into the vessel lumen during the procedure [4, 5]. Another commonly employed approach is stent-assisted coiling, in which a stent is placed across the aneurysm neck to create a scaffold that facilitates coil retention within the aneurysm sac. This technique is particularly useful in aneurysms with complex neck morphology [4]. In addition to these methods, flow diversion has emerged as an alternative strategy in selected cases. This technique employs devices such as the Pipeline Embolization Device to redirect blood flow away from the aneurysm, promoting progressive thrombosis within the aneurysm sac while maintaining flow through the parent vessel [4, 25].

Endovascular therapy offers several advantages compared with traditional microsurgical clipping. One of its principal benefits is its minimally invasive nature, as the procedure is performed using catheter-based techniques that avoid the need for open cranial surgery. As a result, patients often experience shorter recovery periods and reduced hospital stays following treatment [4, 5]. Furthermore, endovascular therapy may represent a particularly suitable treatment option for patients considered to be at high surgical risk because of underlying comorbidities or complex aneurysm locations, providing a less invasive therapeutic alternative [26].

Despite these advantages, endovascular therapy also presents certain limitations and potential complications. One important concern is the higher rate of aneurysm recurrence and recanalization reported after endovascular treatment compared with microsurgical clipping, which may necessitate additional interventions during long-term follow-up [27]. The use of stents and other endovascular devices can also increase the risk of thromboembolic complications, making careful patient selection and perioperative management essential [25]. In addition, questions regarding long-term durability remain relevant, as incomplete occlusion or later recanalization may require follow-up procedures, particularly in aneurysms with wide necks or complex anatomical configurations [4, 5].

Comparative Clinical Outcomes

Comparisons between microsurgical clipping and endovascular therapy in the treatment of intracranial aneurysms frequently focus on differences in aneurysm occlusion rates, functional outcomes, recurrence, and procedural complications. One of the most consistently reported findings in the literature is the higher rate of complete aneurysm occlusion achieved with microsurgical clipping. In one study, clipping achieved a total occlusion rate of 98.2% following treatment, whereas lower occlusion rates were observed with various endovascular techniques, including flow diverters and stent-assisted coiling [28]. Similar findings have been reported in other investigations. For example, another study demonstrated that clipping resulted in a 90.4% complete occlusion rate at discharge, which was significantly higher than the 58.8% occlusion rate achieved with endovascular therapy [4].

In contrast to these angiographic outcomes, functional and neurological recovery often favors endovascular therapy. Functional outcomes in patients treated for intracranial aneurysms are commonly assessed using the modified Rankin Scale. Studies have shown that patients undergoing endovascular therapy frequently demonstrate better short-term functional outcomes, with a greater proportion of individuals achieving a modified Rankin Scale score of 0 at discharge and during follow-up when compared with patients treated with microsurgical clipping [4]. Long-term neurological outcomes have also been reported to favor endovascular approaches, with a higher percentage of patients maintaining good functional status at one year after treatment [7].

Another important consideration in the comparison of treatment strategies involves recurrence and retreatment rates. Microsurgical clipping is generally associated with lower recurrence rates and a reduced need for additional procedures. For example, one study reported a retreatment rate of 0% in patients treated with clipping, compared with a rate of 12.7% among those treated with endovascular therapy for wide-neck aneurysms [7]. The long-term durability of aneurysm exclusion following microsurgical clipping has also been demonstrated through superior angiographic outcomes observed at one-year follow-up [5].

Despite the durability advantages associated with microsurgical clipping, the two treatment approaches differ in their profiles of periprocedural complications. Clipping has been associated with higher rates of certain complications, including the development of new neurological deficits and longer hospital stays. One study reported a 22% incidence of new neurological deficits following clipping compared with a 12% incidence in patients treated with endovascular therapy [5]. Although endovascular therapy is generally considered less invasive and safer, it is not without risks. Complications such as thromboembolic events and device-related issues may occur during or after the procedure. However, these complications are often less severe than those associated with open surgical treatment [7, 28].

Treatment Selection and Clinical Decision-Making

The selection of an optimal treatment strategy for middle cerebral artery aneurysms is influenced by multiple aneurysm-related and patient-related factors. Among the aneurysm-related characteristics, aneurysm size represents an important determinant in therapeutic decision-making. Larger aneurysms are often more challenging to treat using endovascular techniques because of the increased risk of incomplete occlusion and recurrence. In these situations, microsurgical clipping may be preferred, as the direct visualization provided by the surgical approach facilitates complete aneurysm occlusion and may reduce the likelihood of retreatment [2, 4].

Morphological characteristics and neck configuration also play a critical role in treatment selection. Wide-neck aneurysms, typically defined by a neck width of at least four millimeters or a dome-to-neck ratio of less than two, present significant challenges for endovascular treatment strategies. Although advances in endovascular devices have improved the feasibility of treating such aneurysms, microsurgical clipping is often favored in these cases because it allows for direct control of the aneurysm neck and facilitates complete occlusion [4, 5]. The anatomical location of the aneurysm and the presence of arterial branches originating from the aneurysm neck or dome further complicate treatment planning. Middle cerebral artery aneurysms frequently involve important vascular branches, and microsurgical clipping may be more suitable in these circumstances because it allows for precise identification and preservation of these vessels while securing the aneurysm. This approach helps reduce the risk of ischemic complications related to branch occlusion [2, 22].

In addition to aneurysm characteristics, patient-related factors must also be carefully considered when determining the most appropriate treatment modality. Age and life expectancy are particularly relevant considerations. Younger patients with longer anticipated survival may benefit from the long-term durability associated with microsurgical clipping, which has been associated with lower retreatment rates compared with endovascular therapy [5, 7]. Conversely, patients with significant comorbid conditions may be more suitable candidates for endovascular treatment because of its minimally invasive nature and the reduced perioperative risk associated with catheter-based procedures. The patient's initial neurological status also influences treatment decisions. Baseline neurological condition, often assessed using the modified Rankin Scale, can help guide therapeutic planning. Patients who present with better neurological function may tolerate the potential risks associated with microsurgical clipping more effectively [4, 5].

Given the complexity of these variables, multidisciplinary decision-making has become a key component in the management of intracranial aneurysms. A neurovascular team approach that includes neurosurgeons, interventional neuroradiologists, and other specialists allows for a comprehensive assessment of both aneurysm characteristics and patient-specific factors. Through collaborative evaluation, the risks and benefits of each treatment modality can be carefully weighed to optimize treatment outcomes. Effective communication and coordination between neurosurgeons and interventional neuroradiologists are particularly important, as they ensure that all viable treatment options are considered. This collaborative approach is especially valuable in cases where the most appropriate treatment strategy is not immediately evident and both surgical and endovascular interventions represent feasible alternatives [2, 29].

Current Evidence and Comparative Studies

Several clinical investigations have contributed to the current understanding of treatment strategies for intracranial aneurysms, including aneurysms of the middle cerebral artery. Among these, the EVERRUN Registry represents an important multicenter prospective study that compared endovascular therapy and microsurgical clipping in the treatment of ruptured wide-neck aneurysms. The findings of this registry demonstrated that both treatment modalities achieved similar clinical outcomes at one year of follow-up. However, microsurgical clipping was associated with greater durability, as reflected by lower retreatment rates compared with endovascular approaches [5, 7].

Additional evidence has been provided by randomized clinical trials evaluating treatment effectiveness in intracranial aneurysms. A pragmatic randomized trial comparing surgical clipping with endovascular treatment for unruptured intracranial aneurysms found that clipping was more effective in reducing treatment failure. This advantage was primarily attributed to superior angiographic outcomes observed at one year following treatment. Despite these favorable occlusion results, the study also reported that surgical clipping was associated with higher rates of neurological deficits and longer hospitalizations when compared with endovascular therapy [5].

Observational studies have also provided valuable comparative data regarding the management of middle cerebral artery aneurysms. A retrospective Italian multicenter study specifically examining middle cerebral artery aneurysms reported that surgical clipping achieved higher rates of complete aneurysm occlusion both at hospital discharge and during follow-up when compared with coiling techniques. Despite these differences in angiographic outcomes, the study found that both treatment modalities demonstrated similar clinical safety profiles [23]. In contrast, other observational research has suggested a gradual shift toward endovascular approaches in the management of ruptured middle cerebral artery aneurysms. One study reported that endovascular repair in such cases was associated with improved functional outcomes at six months compared with open surgical treatment [6].

Evidence synthesized through systematic reviews and meta-analyses has further contributed to the evaluation of these treatment modalities. One systematic review protocol was designed to assess the effectiveness of microsurgical clipping compared with endovascular treatment for ruptured aneurysms of the anterior communicating artery complex, including aneurysms of the middle cerebral artery. This review proposed to evaluate functional outcomes, angiographic results, and safety outcomes; however, specific results related exclusively to middle cerebral artery aneurysms were not detailed in the available description [1]. Similarly, a meta-analysis comparing microsurgical clipping with advanced endovascular techniques for unruptured aneurysms of the anterior communicating artery complex found that clipping achieved higher post-treatment total occlusion rates. Nevertheless, endovascular techniques were associated with a greater margin of safety and favorable clinical outcomes [27].

Emerging Trends and Future Perspectives

Advances in microsurgical vascular techniques have contributed to maintaining microsurgical clipping as an important treatment option for middle cerebral artery aneurysms, particularly in complex cases. Improvements in surgical methods have expanded the ability to manage aneurysms with challenging anatomical features, including fusiform morphology, large size, and the presence of vessels originating from the aneurysm sac. Techniques such as bypass procedures have enhanced the capacity to address these complex configurations while preserving cerebral blood flow and ensuring adequate vascular reconstruction when necessary [2]. In addition to these technical developments, microsurgical clipping continues to demonstrate favorable angiographic outcomes. Studies have reported higher rates of complete aneurysm occlusion at discharge following microsurgical clipping compared with endovascular therapy, an advantage that contributes to greater long-term durability and lower retreatment rates [4].

At the same time, significant progress has been made in the development of endovascular devices and technologies, which has expanded the therapeutic possibilities for aneurysm treatment. Innovations such as intrasaccular flow disruptors and stent-assisted coiling systems have increased the applicability of endovascular therapy for middle cerebral artery aneurysms, particularly those characterized by wide necks or complex morphology. These technological advances have also contributed to improvements in procedural safety and clinical outcomes. Endovascular therapy has demonstrated favorable safety profiles and functional outcomes, with studies reporting similar intraoperative and postoperative complication rates when compared with microsurgical clipping. In addition, patients treated with endovascular approaches often experience better functional outcomes at the time of discharge and during follow-up evaluations [1, 4].

These parallel developments in surgical and endovascular techniques have encouraged the adoption of increasingly personalized treatment strategies in cerebrovascular disease. The management of middle cerebral artery aneurysms is progressively based on individualized decision-making that considers multiple variables, including aneurysm morphology, patient age, comorbid conditions, and the experience of the treating physician. This tailored approach aims to optimize treatment selection by aligning therapeutic strategies with the specific characteristics and needs of each patient [30]. In this context, decision-making algorithms that incorporate criteria related to aneurysm complexity have been introduced to support clinical judgment. These frameworks assist clinicians in selecting the most appropriate treatment strategy, whether surgical, endovascular, or a combination of both approaches [2].

Conclusions

The management of middle cerebral artery aneurysms is strongly influenced by their complex anatomical configuration and the hemodynamic forces acting on the vascular wall. Factors such as aneurysm size, neck morphology, bifurcation geometry, and branch incorporation play a central role in both aneurysm formation and rupture risk, while also determining the feasibility and effectiveness of available treatment strategies. Understanding these anatomical and pathophysiological characteristics is therefore essential for guiding therapeutic decision-making.

Microsurgical clipping and endovascular therapy represent complementary treatment modalities with distinct advantages and limitations. Microsurgical clipping generally provides higher rates of complete aneurysm occlusion and long-term durability, particularly in complex or wide-neck aneurysms, whereas endovascular therapy offers a less invasive approach associated with better short-term functional outcomes and faster recovery. Consequently, optimal management requires individualized treatment selection supported by multidisciplinary evaluation and consideration of both aneurysm-related and patient-specific factors.

References

1. Nowicki J, Harding M, Aromataris E. Clinical outcomes of microvascular clipping compared to endovascular coiling for ruptured anterior communicating artery aneurysms: a systematic review protocol. JBI Evidence Synthesis [Internet]. 2022 Jul 14;20(8):2032–9. Available from: https://doi.org/10.11124/jbies-21-00332
2. Auricchio AM, Di Bonaventura R, Marchese E, Della Pepa GM, Sturiale CL, Menna G, et al. Navigating Complexity: A comprehensive approach to middle cerebral artery aneurysms. Journal of Clinical Medicine [Internet]. 2024 Feb 24;13(5):1286. Available from: https://doi.org/10.3390/jcm13051286
3. Sturiale CL, Scerrati A, Ricciardi L, Rustemi O, Auricchio AM, Norri N, et

al. Clipping versus coiling for treatment of middle cerebral artery aneurysms: a retrospective Italian multicenter experience. Neurosurgical Review [Internet]. 2022 Jun 4;45(5):3179–91. Available from: https://doi.org/10.1007/s10143-022-01822-3

4. Padmanaban V, Zhu J, Zhou S, Ansari SA, Howington JU, Sahlein DH, et al. Safety and efficacy of endovascular versus microsurgical treatment of unruptured wide-necked middle cerebral artery aneurysms: a propensity score–matched analysis of the NeuroVascular Quality Initiative Quality Outcomes Database Cerebral Aneurysm Registry. Journal of Neurosurgery [Internet]. 2023 Dec 30;140(6):1736–44. Available from: https://doi.org/10.3171/2023.10.jns231659
5. Darsaut TE, Findlay JM, Bojanowski MW, Chalaala C, Iancu D, Roy D, et al. A pragmatic randomized trial comparing surgical clipping and endovascular treatment of unruptured intracranial aneurysms. American Journal of Neuroradiology [Internet]. 2023 May 11;44(6):634–40. Available from: https://doi.org/10.3174/ajnr.a7865
6. Diestro JD, Li Y, Omar B, Kishore K, Montanera W, Sarma D, et al. 555 A Shift from Open to Endovascular Repair in the Treatment of Ruptured Middle Cerebral Artery Aneurysms and its Association With Improved 6-Month Functional Outcomes: A Single Institution Experience. Neurosurgery [Internet]. 2023 Mar 16;69(Supplement_1):122. Available from: http://dx.doi.org/10.1227/neu.0000000000002375_555
7. Mascitelli JR, Mocco J, Hardigan T, Hendricks BK, Yoon JS, Yaeger KA, et al. Endovascular therapy versus microsurgical clipping of unruptured wide-neck aneurysms: a prospective multicenter study with propensity score analysis. Journal of Neurosurgery [Internet]. 2022 Jan 7;137(2):352–9. Available from: https://doi.org/10.3171/2021.10.jns211942
8. Zhang J, Can A, Lai PMR, Mukundan S, Castro VM, Dligach D, et al. Geometric Features Associated with Middle Cerebral Artery Bifurcation Aneurysm Formation: A Matched Case-Control Study. Journal of Stroke and Cerebrovascular Diseases [Internet]. 2021 Dec 30;31(3):106268. Available from: https://doi.org/10.1016/j.jstrokecerebrovasdis.2021.106268
9. Wang S, Li L, Gao H, Zhang K, Shao QJ, Li T, et al. Middle cerebral artery bifurcation aneurysms are associated with patient age, sex, bifurcation angle, and vascular diameters. Scientific Reports [Internet]. 2023 Dec 21;13(1):22844. Available from: https://doi.org/10.1038/s41598-023-50380-1
10. Das K, Rai S, Katyayan I, Madhesiya S, Srivastava AK, Jaiswal AK. Microsurgical preservation of lenticulostriate artery perforators in insular glioma: the two point antegrade skeletonization technique. Acta Neurochirurgica [Internet]. 2025 Jan 11;167(1):11. Available from: https://doi.org/10.1007/s00701-025-06422-w
11. Li R, Lyu J, Hu R, Duan Q, Wang W, Bian X, et al. Morphological study on lenticulostriate arteries in patients with middle cerebral artery stenosis at 7 T MRI. Journal of Magnetic Resonance Imaging [Internet]. 2025 Jan 9;62(1):201–12. Available from: https://doi.org/10.1002/jmri.29693
12. Malek AM, Hippelheuser JE, Lauric A. Vortex formation and associated

aneurysmogenic transverse rotational shear stress near the apex of wide-angle cerebral bifurcations. Journal of Neurosurgery [Internet]. 2021 Nov 5;136(6):1726–37. Available from: https://doi.org/10.3171/2021.6.jns204385

13. Basma J, Saad H, Abuelem T, Krisht K, Cai L, Pravdenkova S, et al. Anterior perforated substance region aneurysms: review of a series treated with microsurgical technique. Neurosurgical Review [Internet]. 2021 Feb 4;44(6):2991–9. Available from: https://doi.org/10.1007/s10143-021-01485-6
14. Auricchio AM, Di Bonaventura R, Marchese E, Della Pepa GM, Sturiale CL, Menna G, et al. Navigating Complexity: A comprehensive approach to middle cerebral artery aneurysms. Journal of Clinical Medicine [Internet]. 2024b Feb 24;13(5):1286. Available from: https://doi.org/10.3390/jcm13051286
15. Adeeb N, Musmar B, Salim HA, Aslan A, Alla A, Cancelliere NM, et al. Defining ideal middle cerebral artery bifurcation aneurysm size for Woven EndoBridge embolization. Journal of Neurosurgery [Internet]. 2024 Oct 1;142(3):1–11. Available from: https://doi.org/10.3171/2024.5.jns232204
16. Rajabzadeh-Oghaz H, Siddiqui AH, Asadollahi A, Kolega J, Tutino VM. The association between hemodynamics and wall characteristics in human intracranial aneurysms: a review. Neurosurgical Review [Internet]. 2021 Apr 29;45(1):49–61. Available from: https://doi.org/10.1007/s10143-021-01554-w
17. Veeturi SS, Patel TR, Baig AA, Chien A, Monteiro A, Waqas M, et al. Hemodynamic Analysis Shows High Wall Shear Stress Is Associated with Intraoperatively Observed Thin Wall Regions of Intracranial Aneurysms. Journal of Cardiovascular Development and Disease [Internet]. 2022 Nov 29;9(12):424. Available from: https://doi.org/10.3390/jcdd9120424
18. Sunderland K, Jiang J, Zhao F. Disturbed flow's impact on cellular changes indicative of vascular aneurysm initiation, expansion, and rupture: A pathological and methodological review. Journal of Cellular Physiology [Internet]. 2021 Sep 6;237(1):278–300. Available from: https://doi.org/10.1002/jcp.30569
19. Cornelissen B, Leemans EL, Slump CH, Van Den Berg R, Marquering HA, Majoie CBLM. Hemodynamic changes after intracranial aneurysm growth. Journal of Neurosurgery [Internet]. 2021 Nov 5;136(6):1738–44. Available from: https://doi.org/10.3171/2021.6.jns204155
20. Fukuda S, Shimogonya Y, Watanabe A, Yonemoto N, Fukuda M, Yasoda A. Abstract 81: New Insights into the Hemodynamic Environment Inducing Cerebral Aneurysm Growth: the NHO CFD ABO Study. Stroke [Internet]. 2025 Jan 30;56(Suppl_1). Available from: https://doi.org/10.1161/str.56.suppl_1.81
21. Tang Y, Wei H, Zhang Z, Fu M, Feng J, Li Z, et al. Separate aneurysmal neck is essential for analyzing hemodynamics and predicting instability of intracranial aneurysms. Annals of Medicine [Internet]. 2025 Aug 4;57(1):2539308. Available from: https://doi.org/10.1080/07853890.2025.2539308
22. Sturiale CL, Scerrati A, Ricciardi L, Rustemi O, Auricchio AM, Norri N, et al. Clipping versus coiling for treatment of middle cerebral artery aneurysms: a retrospective Italian multicenter experience. Neurosurgical Review [Internet]. 2022b Jun 4;45(5):3179–91. Available from:

https://doi.org/10.1007/s10143-022-01822-3

23. Krisht AF, Pravdenkova S, Cai L. 478 Microsurgical outcome of unruptured middle cerebral artery aneurysms. Neurosurgery [Internet]. 2023 Mar 16;69(Supplement_1):102. Available from: http://dx.doi.org/10.1227/neu.0000000000002375_478
24. Chacón-Quesada T, Mielke D, Rohde V, Hernández-Durán S. Microsurgical clipping vs Woven EndoBridge (WEB) device for the management of unruptured wide-neck bifurcation aneurysms. Neurosurgical Review [Internet]. 2022 Apr 11;45(4):2717–22. Available from: https://doi.org/10.1007/s10143-022-01781-9
25. Mouchtouris N, Hasan D, Samaniego EA, Saiegh FA, Sweid A, Abbas R, et al. The Woven EndoBridge (WEB) device: feasibility, techniques, and outcomes after FDA approval. Journal of Neurosurgery [Internet]. 2021 Oct 22;136(5):1266–72. Available from: https://doi.org/10.3171/2021.5.jns21889
26. Ishikawa T, Ikawa F, Ichihara N, Yamaguchi K, Funatsu T, Nakatomi H, et al. Superiority of endovascular coiling over surgical clipping for clinical outcomes at discharge in patients with Poor-Grade subarachnoid hemorrhage: a registry study in Japan. Neurosurgery [Internet]. 2023 Dec 1;94(5):1051–60. Available from: https://doi.org/10.1227/neu.0000000000002782
27. Wach J, Vychopen M, Güresir A, Guranda A, Nestler U, Güresir E. A Long-Term Comparative Analysis of Endovascular coiling and clipping for Ruptured Cerebral aneurysms: An Individual Patient-Level Meta-Analysis Assessing Rerupture Rates. Journal of Clinical Medicine [Internet]. 2024 Mar 20;13(6):1778. Available from: https://doi.org/10.3390/jcm13061778
28. Diana F, Pesce A, Toccaceli G, Muralidharan V, Raz E, Miscusi M, et al. Microsurgical clipping versus newer endovascular techniques in treatment of unruptured anterior communicating artery-complex aneurysms: a meta-analysis and systematic review. Neurosurgical Review [Internet]. 2021 Oct 7;45(2):1089–100. Available from: https://doi.org/10.1007/s10143-021-01647-6
29. Boisseau W, Darsaut TE, Fahed R, Findlay JM, Bourcier R, Charbonnier G, et al. Surgical or Endovascular Treatment of MCA aneurysms: An agreement study. American Journal of Neuroradiology [Internet]. 2022 Sep 22;43(10):1437–44. Available from: https://doi.org/10.3174/ajnr.a7648
30. Lee KS, Zhang JJY, Nguyen V, Han J, Johnson JN, Kirollos R, et al. The evolution of intracranial aneurysm treatment techniques and future directions. Neurosurgical Review [Internet]. 2021 Apr 23;45(1):1–25. Available from: https://doi.org/10.1007/s10143-021-01543-z