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# Multiple intracranial aneurysms: An international consensus statement

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A R T I C L E I N F O

*Keywords:*
Multiple intracranial aneurysms
Subarachnoid hemorrhage
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A B S T R A C T

*Introduction:* Multiple intracranial aneurysms (MIAs) pose diagnostic and therapeutic challenges, and widely used rupture-risk scores have not been validated for this subgroup.

*Research question:* To develop expert-based recommendations for the diagnosis, rupture-risk assessment, treatment selection, and follow-up of patients with MIAs.

*Material and methods:* A modified Delphi process was conducted. After topic generation from the literature, iterative questionnaires were administered anonymously online to invited experts. Consensus was prespecified as ≥70% agreement. Twenty-six of 35 invitees (74.3%) completed the survey.

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*Results:* Consensus identified the ruptured lesion in aneurysmal subarachnoid hemorrhage (aSAH) using computed tomographic angiography (CTA) and 3D rotational digital subtraction angiography (3D-DSA). Increased rupture risk factors included aneurysm size, irregular morphology, posterior circulation location, prior hemorrhage, smoking, and family history. Individualized management was endorsed, with decision drivers such as aneurysm characteristics, patient factors, and institutional expertise. For microsurgery, a unilateral fronto-lateral approach was preferred; for endovascular therapy, coiling was favored for unruptured lesions. Annual imaging for untreated MIAs was recommended, but no consensus was reached on a rupture-risk scale or follow-up protocols.

*Discussion and conclusion:* This consensus emphasizes the importance of accurately identifying aneurysm sources in cases of aSAH and advocates for personalized, multidisciplinary care. While single-stage treatment is recommended when safe, gaps remain, such as the lack of MIA-specific risk score validation and the best practices for post-treatment surveillance. Further multicenter research is needed to address these issues.

## 1. Introduction

Multiple intracranial aneurysms (MIAs) are detected in 7–45% of patients with intracranial aneurysms, with incidence varying widely between angiographic, autopsy, and epidemiological studies (Ostergaard and Høg, 1985; Inagawa, 1990; Rinne et al., 1994; Qureshi et al., 1998; Juvela, 2000; Ellamushi et al., 2001; Wilson et al., 1989; Dong et al., 2016). This variability reflects methodological differences and referral bias toward complex cases. Clinically, MIAs are associated with greater diagnostic and therapeutic complexity and, in several series, less favorable outcomes compared to single aneurysm patients (Qureshi et al., 1998; Juvela, 2000; Ellamushi et al., 2001). Most MIAs involve the anterior circulation, particularly the posterior communicating artery (PcomA), middle cerebral artery (MCA) bifurcation, and anterior communicating artery (AComA), with fewer than 20% located in the posterior circulation (Rinne et al., 1994; Nehls et al., 1985). Pathogenesis is multifactorial, with both genetic factors—such as autosomal dominant polycystic kidney disease, connective tissue disorders, and familial clustering—and acquired risk factors, notably smoking and hypertension, implicated (Qureshi et al., 1998; Ellamushi et al., 2001; Caranci et al., 2013).

Accurate rupture risk assessment is essential but remains challenging. Established risk factors include aneurysm size, irregular morphology (blebs, multilobularity), posterior circulation location, and prior subarachnoid hemorrhage (Juvela, 2000; Nehls et al., 1985; Backes et al., 2014). While scoring systems such as PHASES, ELAPSS, and UIATS are in clinical use, none have been validated specifically for MIAs, and their predictive accuracy in this subgroup is uncertain (Neyazi et al., 2020; Sanchez et al., 2024). Similarly, optimal strategies for identifying the ruptured aneurysm in MIA patients with subarachnoid hemorrhage—often relying on CTA and 3D-DSA—are still debated. Treatment planning for MIAs must integrate aneurysm characteristics, patient comorbidities, procedural risks, and institutional expertise. However, significant variation exists worldwide in the choice between surgical and endovascular techniques, staged versus single-session treatment, and follow-up protocols. In the absence of high-quality evidence, clinical decision-making often depends on individual or institutional preference.

To address these gaps, we convened an international panel of experienced neurosurgeons and interventional neuroradiologists/endovascular neurosurgeons to participate in a multi-round modified Delphi consensus process. The objective was to identify areas of agreement, clarify controversies, and provide expert-based recommendations on the diagnosis, rupture risk assessment, treatment selection, and follow-up of patients with MIAs.

## 2. Methods

### 2.1. Consensus description

The present study was conducted in multiple iterative stages using a modified Delphi methodology to formulate expert-based recommendations on the diagnosis, risk stratification, and management of multiple intracranial aneurysms (MIAs). The Delphi technique is a structured process for collecting and synthesizing expert opinions through sequential questionnaires, with controlled feedback after each round, aiming to achieve consensus in areas where high-level evidence is lacking.

The initial stage involved the identification of controversial and clinically relevant topics in MIA management through a comprehensive literature review. These topics were incorporated into a structured questionnaire. The subsequent Delphi rounds were administered using an anonymous, web-based survey. Consensus was predefined as ≥70% agreement among respondents. A response rate of ≥70% was considered to validate the consensus process.

This study did not involve patients or patient data and, therefore, did not require Institutional Review Board (IRB) approval.

### 2.2. A priori assumptions

This consensus focused exclusively on the management of MIAs, either in the context of ruptured aneurysmal subarachnoid hemorrhage (aSAH) or incidentally discovered unruptured aneurysms. Pathologies other than MIAs were not addressed. The consensus did not aim to cover epidemiology, pathogenesis, or genetic counseling in depth, except where relevant to rupture risk stratification.

### 2.3. Questionnaire development

Two authors (CT, AB) independently reviewed the literature on MIA diagnosis and management to identify potential areas of controversy. Disagreements regarding question inclusion were resolved by a senior author (KF). None of the authors involved in questionnaire development participated in answering the survey. Key topics included: i) estimation of MIA incidence, ii) risk factors and pathogenetic mechanisms, iii) rupture risk prediction (scales, morphology, patient factors), iv) imaging and diagnostic modalities, v) decision-making for surgical versus endovascular treatment, vi) technical preferences for each approach, vii) multidisciplinary team involvement, viii) follow-up protocols, and ix) cost-effectiveness considerations.

Questions were stratified, where applicable, by aneurysm rupture status (ruptured vs. unruptured). The final questionnaire contained 23 questions, combining closed-ended, semi-closed, and open-ended formats. For certain questions, multiple responses were permitted.

### 2.4. Modified delphi methodology

This study employed a modified Delphi methodology, an iterative process involving the collection and distillation of anonymous expert opinions through a series of questionnaires, to achieve consensus.

This multistage approach included:

Round 1: The initial questionnaire was prepared as a Word document and circulated to panelists for feedback on content, clarity, and relevance. Comments were reviewed, and suggested changes were incorporated.

Round 2: The revised questionnaire was built on Google Forms and distributed via email. Panelists provided responses anonymously. Reminders were sent at one, two, and three weeks to maximize participation.

Round 3: The consensus statements were generated based on the anonymized responses, with items achieving 70% or greater agreement among the experts considered to have reached a consensus.

Finalization: Consensus statements were compiled into a draft document and circulated to all panelists for approval regarding style, format, and wording. All contributing experts endorsed the final document (Fig. 1).

### 2.5. Expert panel

Invitations were sent by email to 35 experts from Europe and North America. Panelists were selected based on their recognized expertise in cerebrovascular neurosurgery or interventional neuroradiology, with documented clinical and academic contributions to aneurysm management. Additional selection criteria included: minimum of 10-year clinical experience in vascular neurosurgery or interventional neuroradiology, current or recent appointment at an academic or high-volume cerebrovascular centerrevious authorship of peer-reviewed publications in the field of aneurysm diagnosis or treatment.

### 2.6. Statistical analysis

The primary objective of the statistical analysis was to determine the areas of agreement among experts. Our consensus questionnaire included categorical items. Thus, we used counts and percentages to summarize the poling results.

## 3. Results

### 3.1. Response rate

Twenty-six of the thirty-five invited participants completed the survey, yielding a response rate of 26/35 (74.3%).

### 3.2. Expert panel composition

All 26 respondents who completed the Delphi survey were co-authors of the manuscript. Among them, 11 (42.3%) were hybrid neurosurgeons with expertise in both microsurgical and endovascular techniques, 11 (42.3%) were vascular neurosurgeons, and 4 (15.4%) were interventional neuroradiologists. No neurologists or neurointensivists participated in the survey. It has to be mentioned that 3/29 of the authors (AT, CT, AB) did not participate in our survey, while all respondents are listed among the authors.

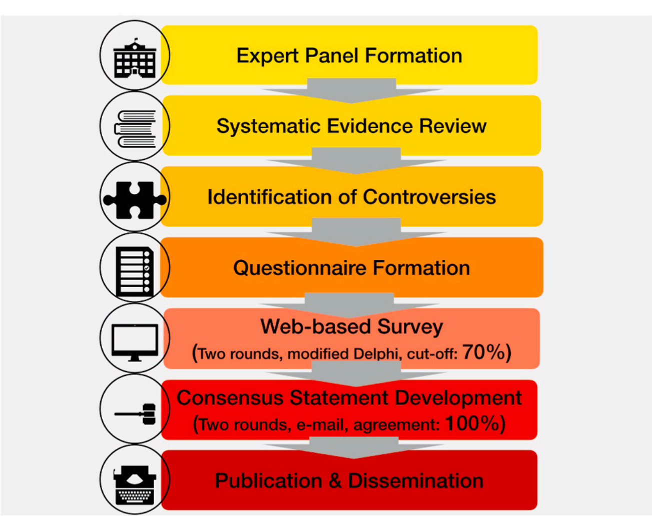


**Fig. 1.** Structured methodological approach of our consensus.

### 3.3. Incidence of Multiple Intracranial Aneurysms (MIAs) (Q1)

No consensus was reached among our participants regarding the actual incidence of MIAs. The most frequently selected estimate, chosen by 9 out of 26 respondents (34.6%), suggested an incidence varying anywhere between 11 and 20%.

### 3.4. Risk factors and pathogenetic mechanisms of MIAs (Q2 & 3)

Autosomal dominant polycystic kidney disease (22/26, 84.6%), family history (20/26, 76.9%), and smoking (19/26, 73.1%) were considered as strong risk factors. For pathogenesis, our panelists reached a consensus (24/26, 92.3%) on identifying genetic factors and family history (20/26, 76.9%) as having an important role in MIAs development.

### 3.5. Markers and imaging characteristics helpful for identifying aneurysms at increased risk of rupture (Q4 & 6)

In the context of MIA cases presenting with aneurysmal subarachnoid hemorrhage (aSAH), a consensus was reached on two key radiological modalities: CT angiography (22/26, 84.6%) and 3D rotational DSA (20/26, 76.9%), both of which are considered reliable tools for identifying the ruptured aneurysms. For incidentally discovered MIAs, our participants reached no consensus on the optimal imaging modality for evaluating these patients. When evaluating specific imaging characteristics associated with increased rupture risk, the panel reached a consensus, 24 out of 26 respondents (92.3%), on the association of aneurysm shape irregularities secondary sac, blebs, and/or multilobularity, with an increased risk of rupture.

### 3.6. Preferred scales for quantifying aneurysm rupture risk (Q5)

No consensus was reached regarding the most reliable scale for quantifying aneurysm rupture risk. It has to be mentioned that the PHASES scale was the most frequently selected, endorsed by 17 out of 26 respondents (65.4%).

### 3.7. Risk factors associated with aneurysm rupture (Q7)

Our panel reached a consensus on identifying certain factors associated with an increased risk of rupture. Aneurysm size was considered a significant risk factor by 25/26 respondents (96.2%), demonstrating the highest level of agreement. Previous SAH (24/26, 92.3%), presence of aneurysmal blebs (23/26, 88.5%), and posterior circulation location (22/26, 84.6%) also identified as critical predisposing to rupture factors, by our participants. Moreover, a consensus was reached on the association of family history (20/26, 76.9%) and smoking (19/26, 73.1%) with an increased risk of rupture.

### 3.8. Management strategy and decision-making criteria for MIAs management (Q8&9)

Our panel unanimously agreed that the management of MIA patients should be individualized, with all 26/26 participants (100%) endorsing this approach (Table 1). Regarding the criteria guiding decision-making for the management of MIAs, the panel reached a consensus on several critical parameters determining the most safe and efficacious

**Table 1**
Microsurgical management of ruptured and unruptured MIAs.

| | Ruptured aneurysms | Unruptured aneurysms |
|---|---|---|
| Individualized microsurgical treatment plan | ✓ | ✓ |
| Criteria for selecting a single or multi-stage microsurgical approach | Aneurysm location<br>Presence of hematoma | Aneurysm location |
| Factors for selecting the most suitable microsurgical approach | Aneurysm location & size<br>Presence of brain edema | Aneurysm location & size |
| Microsurgical single-stage unilateral, fronto-lateral approach | ✓ | ✓ |

Abbreviations: MIA, multiple intracranial aneurysms. ✓ indicates applicable.

management. The aneurysm/s shape (24/26, 92.3%), size (22/26, 84.6%), and the anatomic location and surgical accessibility (23/26, 88.5%) were identified as factors of paramount importance in the decision-making process. Furthermore, a consensus was reached on the importance of the patient's age (24/26, 92.3%), the presence of medical comorbidities (23/26, 88.5%), and the presence of an intracranial hematoma (22/26, 84.6%). The incorporation of adjacent arterial branches by the aneurysmal complex was identified by 21/26 respondents (80.8%) as a crucial factor, favoring microsurgical clipping. Additionally, increased procedural complication risk (20/26, 76.9%), expectation of complete occlusion rate (19/26, 73.1%), and institutional expertise and resource availability for either microsurgical or endovascular approach (19/26, 73.1%) were also considered essential decision-making factors, by our panelists.

### *3.9. Selection of the proper surgical approach in microsurgical management of MIAs (Q10-13)*

When evaluating the preferred surgical approaches for microsurgically treating MIAs, a consensus was reached on the usage of a single unilateral fronto-lateral approach for their treatment. This was favored for unruptured aneurysms by 21/26 respondents (80.8%), but also in cases of ruptured aneurysms by 20/26 respondents (76.9%). A single-stage surgery, whenever feasible, was recommended for unruptured aneurysms by 21 out of 26 respondents (80.8%), and by 19 out of 26 respondents (73.1%) for ruptured aneurysms. In assessing the criteria that influence the decision to choose between a single- or multi-stage surgical approach, the panel reached an agreement on several factors. For unruptured aneurysms, the most significant factor was aneurysm anatomic location, identified by 23 out of 26 respondents (88.5%). For ruptured aneurysms, a consensus was reached on the role of both aneurysm location (21/26, 80.8%), and the presence of a hematoma (21/26, 80.8%). Our panel reached a consensus regarding the role of various parameters, that influence the selection of the most suitable surgical approach for treating both unruptured and ruptured MIAs. For both categories, aneurysm location was recognized as a critical factor, selected by 24/26 respondents (92.3%). Similarly, the anatomic location of the underlying aneurysms was also considered crucial, by 22/26 participants (84.6%) for unruptured aneurysms, and 21/26 (80.8%) for ruptured aneurysms. Likewise, a consensus was reached for both unruptured and ruptured aneurysms aneurysm, 19/26 respondents (73.1%), regarding the role of aneurysmal size in the surgical approach selection. The presence of brain edema was also considered an important factor in cases of ruptured aneurysms by 21/26 participants (80.8%). Comparative results for ruptured and unruptured aneurysms are summarized in Table 1.

### *3.10. Selection of the proper endovascular approach for treating MIAs (Q14-17)*

When evaluating endovascular strategies for the treatment of MIAs, the panel reached a consensus on several available approaches. For unruptured aneurysms, coiling was the most endorsed technique, selected by 22/26 respondents (84.6%). Stent-assisted coiling was favored by 21/26 participants (80.8%), while balloon-assisted coiling and intrasaccular flow disruption devices reached identical agreement rates (19/26, 73.1%). Intraluminal flow diverters were supported by 20/26 respondents (76.9%), reinforcing their role as a valid treatment option in the management of unruptured MIAs. For ruptured aneurysms, stand-alone coiling was the predominant choice, selected by 24/26 respondents (92.3%). Balloon-assisted coiling was also considered helpful by 19/26 respondents (73.1%), reaching a consensus. When assessing any parameters influencing the decision for selecting the most appropriate endovascular approach, our participants identified several factors as important, reaching no consensus, however, on any of them. When evaluating the preferred endovascular strategy for managing MIAs, a consensus was reached on adopting an individualized endovascular approach for unruptured aneurysms (19/26, 73.1%). For ruptured aneurysms though no consensus was reached (17/26, 65.4%). A single-setting endovascular approach was recommended by 19 of 26 respondents (73.1%) for unruptured aneurysms. Comparative results for ruptured and unruptured aneurysms are summarized in Table 2.

### *3.11. Recommended follow-up for MIA patients (Q18&19)*

A consensus, 20 out of 26 respondents (76.9%), was reached on recommending annual imaging follow-up in patients with untreated MIAs. Contrariwise, our panel reached no consensus on the optimal follow-up of treated MIA patients.

### *3.12. Consideration of no treatment in MIA patients (Q20)*

No consensus was reached on this subject. A dichotomized panel was observed with 13 out of 26 respondents (50%) favoring the strategy of leaving untreated aneurysms in certain high-risk patients. Furthermore, 12 respondents (46.2%) explicitly supported the strategy of selectively leaving certain aneurysms untreated.

### *3.13. Multidisciplinary management and Increased rupture risk in unruptured MIAs (Q21&23)*

In determining the best management strategy for MIAs, the panel reached a consensus advocating for a multidisciplinary team approach, as 19 of the 26 participants (73.1%) agreed that MIAs should consistently be managed by a team comprising neurosurgeons, interventional radiologists/endovascular neurosurgeons, and neurologists. Regarding the risk of rupture, 20 out of 26 respondents (76.9%) agreed that the

**Table 2**
Endovascular management of ruptured and unruptured MIAs.

| | Ruptured aneurysms | Unruptured aneurysms |
|---|---|---|
| Individualized endovascular treatment plan | X | ✓ |
| Most suitable endovascular method | Stand-alone coiling<br>Balloon-assisted coiling | Stand-alone coiling<br>Stent-assisted coiling<br>Balloon-assisted coiling<br>Intrasaccular flow disruption devices<br>Intraluminal flow diverters |
| Single-stage endovascular approach | X | ✓ |

Abbreviations: MIA, multiple intracranial aneurysms. ✓ indicates applicable; X indicates not applicable.

overall risk of rupture is indeed increased among MIA patients.

### 3.14. Cost-effectiveness and treatment (Q22)

No consensus was reached on the role of cost-effectiveness in the decision-making treatment process. Only 9 out of 26 respondents (34.6%) agreed that cost-effectiveness should be considered.

## 4. Discussion

The incidence of MIAs is highly variable among different centers. Our panelists reached no consensus on adopting a certain range of incidence, although approximately one third of them consider that the actual incidence is 11-20%. This estimate reflects the expert panel's clinical experience rather than formal epidemiological data. The vast majority of the previously published series reported an incidence varying between 20 and 30%, while the reported range expands from 7 to 45% (Ostergaard and Høg, 1985; Inagawa, 1990; Rinne et al., 1994; Qureshi et al., 1998; Juvela, 2000; Ellamushi et al., 2001; Wilson et al., 1989; Dong et al., 2016). It has to be mentioned that the data in the pertinent literature come from angiographic, autoptic, or epidemiological studies. This may well explain the observed wide variation. Moreover, the possibility of biases in the epidemiological studies cannot be excluded, since these come from specialized, referral neurovascular centers. The actual incidence of MIAs is not only matter of epidemiological significance but has also significant clinical ramifications. There is compelling evidence in the pertinent literature that the management of these patients is more complicated, and their outcome is less favorable (Rinne et al., 1994, 1995; Qureshi et al., 1998; Dong et al., 2016; Kaminogo et al., 2003; Vajda, 1992). However, there are a few reports postulating that there is no significant difference in overall outcome between MIA and single aneurysm patients (Sai et al., 2020).

In addition to the incidence of MIA cases, the anatomic distribution of these cases constitutes another controversial issue. It has been previously reported that the majority of them are anterior circulation aneurysms, with a small percentage (less than 20% according to the previously published series) affecting the posterior circulation. Posterior communicating, middle cerebral bifurcation, and anterior communicating arteries are the three most common sites, followed by the basilar artery tip. It has to be mentioned that the intra-cavernous part of the carotid artery harbors multiple aneurysms in relatively high frequency, although these aneurysms remain clinically silent, since their rupture produce no SAH (Rinne et al., 1994; Nehls et al., 1985).

Pathophysiology of MIAs has remained essentially unknown, despite all the recent advances on genetic and molecular level. Our panelists identified genetic factors such as polycystic kidney disease, and/or connective tissue disorders, as well as familial history as strong pathogenetic factors. Moreover, a consensus was reached among our panelists regarding the role of smoking in MIAs development. Most of the proposed theories converge to the concept of vessel wall structural deficiencies, either congenital or acquired, followed by repetitive turbulent blood flow induced micro-trauma (Ostergaard and Høg, 1985; Qureshi et al., 1998; Campos et al., 1998; Stehbens, 1989). Genetic factors such as certain somatic chromosome alterations, or down-regulation of the NF-kB signaling metabolic pathway, lead to defective collagen production or to an inflammatory process affecting the vessel wall (Caranci et al., 2013). Indeed, the presence of MIAs has been associated with many rare, hereditary, connective tissue disorders such as polycystic kidney disease, Marfan's syndrome, Ehlers-Danlos syndrome, or pseudoxanthoma elasticum (Ellamushi et al., 2001). A documented incidence of familial aneurysms in some populations (Lejeune, 1997), and the presence of multiple aneurysms among relatives (Andrews, 1977), indicates a genetic background. Mirror aneurysms could correspond to bilateral identical impairment of cells of the same embryological territory (Ellamushi et al., 2001). Moreover, external factors such as cigarette smoking may induce endothelial and/or vessel wall elastin degeneration, as well as reduction of the alpha-1 antitrypsin (Qureshi et al., 1998; Juvela, 2000; Baker et al., 1995). These changes trigger an inflammatory process and may lead to MIAs (Ostergaard and Høg, 1985; Qureshi et al., 1998). Female sex has been reported as a predisposing factor by many clinical series (Ostergaard and Høg, 1985; Qureshi et al., 1998). Although there is no clear pathophysiological underlying mechanism for explaining this association, it has been postulated that estrogens may induce some vessel wall changes (Kongable et al., 1996). However, this sex predilection has been questioned by other series (Inagawa, 1990; Rinne et al., 1994; Andrews and Spiegel, 1979). Situations increasing the vessel wall mechanical stress have been implicated in MIAs development. Hypertension, moyamoya disease, and arterio-venous malformations have been associated with MIAs most probably because of the hyperdynamic blood circulation (Ostergaard and Høg, 1985; Andrews and Spiegel, 1979). Animal experimental studies have demonstrated the detrimental effect of induced hypertension to the vessel wall integrity and subsequently the formation of an aneurysm (Ostergaard and Høg, 1985). The association of age and the incidence of MIAs have remained controversial. There are series identifying age as an independent predisposing factor (Juvela, 2000; Stehbens, 1989; Weir, 1987), while others found age having no significant association with MIAs development (Ostergaard and Høg, 1985; Inagawa, 1990; Rinne et al., 1994; Qureshi et al., 1998; Baker et al., 1995).

The calculation of probability of rupture for each aneurysm in cases of unruptured MIAs is of paramount importance for their optimal management. Our panelists reached a consensus on identifying aneurysm's anatomic location (posterior circulation), aneurysmal size and morphology (presence of blebs, irregular shape), and the history of a previous SAH as important rupture risk factors. Moreover, a consensus was reached on the role of family history and smoking in increasing the rupture risk. Numerous morphological (size, shape, and anatomic location of the aneurysm), hemodynamic (hypertension, acute angular flow), as well as patient's related (age, cigarette smoking, alcohol abuse, illicit drug usage, and previous subarachnoid hemorrhage) parameters have been proposed for predicting rupture (Juvela, 2000; Backes et al., 2014; Sanchez et al., 2024; Weir, 1987; Fogelholm et al., 1993; Juvela et al., 1993; Juvela, 1996; Sacco et al., 1984; Longstreth et al., 1992; Longstreth et al., 1992; UCAS et al., 2012; Knekt et al., 1991; Petitti and Wingerd, 1978; Teunissen et al., 1996; Ostbye et al., 1997; Nilsson et al., 2000; Epidemiology of aneurysmal subarachnoid hemorrhage, 2000; Pobereskin, 2001; Greving et al., 2014). Based on these parameters, several scales such as the PHASES, the ELAPSS, and the UIATS have been proposed for calculating this probability. Although the PHASES scale seems to be the most widely used, their overall clinical applicability is quite limited mainly due to their inherent shortcomings (Neyazi et al., 2020; Sanchez et al., 2024). Moreover, none of the available scales has been validated in a prospective study (Sanchez et al., 2024), while all these scales have been proposed for solitary and not multiple aneurysms. Indeed, our survey reached no consensus on which scale is more reliable on estimating rupture risk, although the PHASES scale was the most used among our panelists. Our current study clarifies how experts weigh these factors when several aneurysms are present, offering a more nuanced framework than generic scores. Recently, advanced scales measuring complex hemodynamic parameters such as the blood flow latency period in the aneurysmal sac have been proposed for a more accurate prediction of the rupture probability. It has been postulated that aspect ratio 1 (AR1), which constitutes the ratio of the height of the aneurysm measured vertically to the neck to the maximal diameter at the neck, represents the most reliable morphological factor (Backes et al., 2014). On the other hand, maximal relative residence time (RRTmax) constitutes according to previously published studies the most reliable hemodynamic factor (Neyazi et al., 2020). Previous studies have shown that the AComA aneurysms demonstrate the highest probability for rupturing, while MCA aneurysms the lowest one (Nehls et al., 1985).

The natural course of unruptured aneurysms has remained quite controversial. Several studies have identified that aneurysm's morphology plays a crucial role in the probability of rupture (UCAS et al., 2012; Tong et al., 2023; Clarke et al., 2005). The UCAS Japan Investigators found that the risk of rupture increases with the size of the aneurysm, particularly when the diameter of the aneurysm exceeds 7 mm. They also found that aneurysms of the AComA and PComA were more likely to rupture compared to MCA aneurysms (UCAS et al., 2012). They also reported that aneurysms with a daughter sac were more likely to rupture (UCAS et al., 2012). However, the presence of multiple aneurysms did not significantly influence the risk of rupture of each aneurysm. Interestingly, they postulated that patients with MIAs are subject to the cumulative risk for all individual aneurysms (UCAS et al., 2012), a postulation that need to be verified. Further prospective studies would be crucial for providing a more accurate model predicting the annual rupture risk. Furthermore, advanced MR-based imaging such as high-resolution vascular wall imaging, quantitative susceptibility mapping, and 4D flow MRI may provide insights on this aspect (Leon-Rojas, 2025). The development of machine and/or deep learning prediction models may increase the accuracy of calculating the rupture probability (Tong et al., 2023; Kim et al., 2023; Marasini et al., 2022; Zhou et al., 2024).

The importance of identifying the ruptured aneurysm in the management of patients with MIAs presenting with SAH cannot be overemphasized (Hino et al., 2000). It has been reported that inadequate identification of the ruptured aneurysm at the time of initial surgery represents the primary cause of subsequent rebleeding episodes (Hino et al., 2000). A consensus was reached in our study regarding the crucial role of CTA and 3D-rotational DSA in identifying the ruptured aneurysm. Various methodologies have been used for identifying the ruptured aneurysms. Clinical signs are in most cases lateralizing but not localizing. The distribution of blood in the subarachnoid space or the presence of intracerebral hematomas may be indicative of the ruptured aneurysm, as well as the angiographic characteristics of the aneurysms (Backes et al., 2014). The presence of nipples or blebs, multi-lobularity, an elongated dome, and/or an irregular shape may well be indicators of rupture (UCAS et al., 2012; de Rooij et al., 2009; Matsukawa et al., 2013; San Millán Ruíz et al., 2006). The size of the aneurysm seems to be another relatively accurate indicator, with larger aneurysms having a higher rupture propensity (Backes et al., 2014). Nehls have postulated that aneurysm shape is more accurate than sizein predicting the ruptured aneurysm (Nehls et al., 1985). Moreover, aneurysms with higher AR1 have been demonstrated to carry a higher rupture risk (Beck et al., 2003; Raghavan et al., 2005; Lauric et al., 2012; Nader-Sepahi et al., 2004; Ryu et al., 2011; Baharoglu et al., 2012; Ujiie et al., 2001; Sadatomo et al., 2008; Dhar et al., 2008; Hoh et al., 2007; Laaksamo et al., 2012; Ma et al., 2010; Xiang et al., 2011; Weir et al., 2003; Amenta et al., 2012). The proximity of an aneurysm to unbendable, osseous structures has also been associated with higher rupture risk (San Millán Ruíz et al., 2006; Satoh et al., 2005; Sforza et al., 2012; Sugiu et al., 2000). Advanced MR-based imaging techniques lend themselves into the identification of the ruptured aneurysm Dark blood imaging along with contrast time of flight (TOF) MR-Angiography has been reported to accurately detecting the ruptured aneurysm (Matouk et al., 2013). Although this is undoubtedly a promising emerging technology, there are several limitations in its clinical application (Matouk et al., 2013). Despite the application of all these complementary methods in identifying the source of hemorrhage in MIA cases, there are still cases that the source is misidentified (Orning et al., 2018). Orning reported that the source of hemorrhage was misidentified in 4.3% of their cases (Orning et al., 2018).

Our panelists unanimously agreed that an individualized treatment plan is necessary for managing MIA patients. They also reached a consensus on the importance of having a multidisciplinary team, including at least a vascular neurosurgeon, an interventional neuroradiologist/endovascular neurosurgeon, and a specialized neurologist, for selecting the most proper treatment option for each patient. Moreover, they identified that aneurysm location and morphology, relationship to the parental and/or adjacent vessels, and surgical accessibility are crucial factors in the decision-making process. Furthermore, the patient's age, the existence of any medical comorbidities, the presence of cerebral edema and/or hematoma, the expectation of complete aneurysm obliteration, the probability of any complications, and the institution's experience are all important factors in selecting the most suitable treatment option.

Radiation exposure constitutes another determining factor in selecting the optimal treatment. It has been demonstrated that radiation exposure of both the patient and the medical personnel is higher in complex endovascular cases (Forbrig et al., 2020). It is apparent that the endovascular occlusion of multiple aneurysms increases the total radiation dose and the cumulative fluoroscopy time, while the stent assisted coiling requires higher doses than simple coiling (Forbrig et al., 2020; Tejus et al., 2019). It has been shown that advanced patient's age further increases radiation dose and exposure time, mainly due to the intracranial vessel tortuosity and atheromatic degeneration (Opitz et al., 2023).

No consensus was reached among our panelists regarding intentionally leaving untreated selected unruptured aneurysms. Surgical management of all aneurysms in MIA cases have been proposed by many clinical investigators (Rinne et al., 1995; Jain, 1974; Mount and Brisman, 1971; Moyes, 1971; Salazar, 1980; Samsom et al., 1977). Heiskanen found that the risks of microsurgical treatment for ruptured aneurysms are slightly higher compared to conservative management, but surgical treatment for unruptured aneurysms is more advantageous (Heiskanen, 1981). They postulated that all aneurysms should be microsurgically secured, if this is technically possible (Heiskanen, 1981). Rinne in their series reported that this was achieved in 66% of their MIA cases with a single-stage approach, while in 34% a two-stage approach was necessary (Rinne et al., 1995). When a second surgical procedure was necessary, this was performed 8-10 weeks after the first one (Rinne et al., 1995). However, they reported that despite their aggressive surgical treatment, approximately 30% of the discovered aneurysms remained untreated for various reasons (Rinne et al., 1995). Similarly, Junjua have reported in their series 90.8% complete obliteration rate, while their cumulative complication rate was 15.7% (Janjua et al., 2019). Likewise, Sai-Kiran (Sai et al., 2020) reported 96.2% complete occlusion rate, while many other previously published series reported complete occlusion rates higher than 95%, and complication rates up to 14% (Fig. 2) (Czirják et al., 2002; Rodríguez-Hernández et al., 2012; Martinez-Perez et al., 2020; Yu et al., 2017; Park et al., 2011; Scheer et al., 2019; Paladino et al., 2005; La Rocca et al., 2018; Krisht et al., 2006; Bernat et al., 2017; Mitchell et al., 2005; van Lindert et al., 1998; Burkhardt et al., 2020).

In cases of clipping, a common dilemma faced is the performance of a single-versus multi-stage approach. Our panelists reached a consensus on managing all aneurysms in one setting via a single fronto-lateral approach, whenever this is feasible, in both ruptured and unruptured MIAs. In cases presenting with SAH, it is advocated to start clipping from the ruptured and move from deeply located to more superficial aneurysms. Likewise, in unruptured cases the order is from the aneurysm with the highest probability of rupture to the other ones, and from deeply to superficially. They identified aneurysm location as the most important determining factor in cases of unruptured aneurysms, while in ruptured cases they agreed that location and the presence of a hematoma are the crucial factors in selecting single versus multiple stage surgical approach. Many clinical studies have espoused the advantages of single-stage procedures in reducing patients' cumulative exposure to surgical and anesthetic risks (Panigrahi et al., 2022; Hong and Wang, 2009; Clatterbuck and Tamargo, 2005; Seo et al., 2022; Asiltürk and Abdallah, 2018; King et al., 2025; Murrone et al., 2018; Javadnia et al., 2024). Few reports proposed multiple craniotomies in one setting (Seo et al., 2022). However, other clinical investigators have reported no

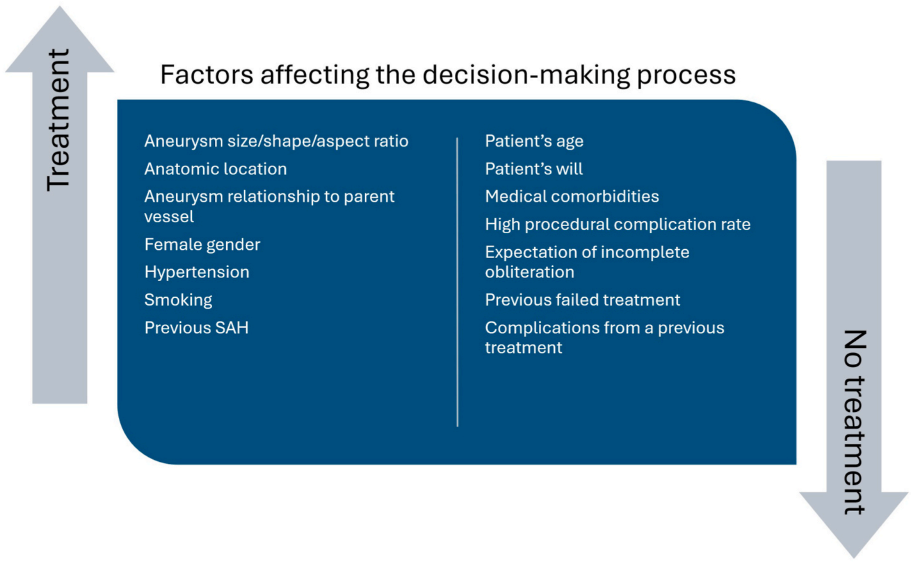


**Fig. 2.** Depiction of the most important factors implicating in the decision-making process for treating or not treating MIA patients.

difference in outcome between single-versus multi-stage clipping (Seo et al., 2022; Yrysov et al., 2019; Duarte-Celada et al., 2024). Several other conditions and comorbidities may affect the decision for a single- or multi-stage approach (Burkhardt et al., 2020). Interestingly, Kaminogo found that the rate of multi-stage clipping decreased as patient age increased (Fig. 3) (Kaminogo et al., 2003).

Our participants reached a consensus on the methods used for endovascular obliteration. For unruptured aneurysms, stand-alone coiling, stent-assisted, and balloon-assisted coiling, intrasaccular flow disruption devices, and flow diverting are treatment options, in this order, according to our current consensus. Likewise, for ruptured aneurysms, a consensus was reached for stand-alone, and balloon-assisted coiling. Endovascular management has been proposed by many clinical series with promising results (Tejus et al., 2019; Jeon et al., 2014; Shen et al., 2014; Chen et al., 2021; Pierot et al., 1997; Wang et al., 2023; Choi et al., 2018). Wang reported a complete occlusion rate of 59.5%, complication rate of 11.1%, and recanalization rate of 8% (Wang et al., 2023). Shen demonstrated 85.7% complete occlusion rate (Shen et al., 2014). Likewise, Pierot reported a complete obliteration rate of 86.5%, permanent neurological deficit incidence of 6.5%, and rebleeding rate of 2.3% (Pierot et al., 1997). Tejus reported complete aneurysm occlusion in 94.4% of their cases (Tejus et al., 2019). Similarly, Choi reported complete occlusion rate of mirror-image aneurysms of 85.6% (Choi et al., 2018). Our panelists reached a consensus on treating all aneurysms in one endovascular setting, whenever feasible. Chen reported their results in patients with unruptured small-size ($\leq$7 mm) MIAs (Chen et al., 2021). They found that endovascular treatment of all aneurysms constituted the most efficacious management option (Fig. 4) (Chen et al., 2021).

A limited number of clinical series have compared head-to-head clipping to endovascular treatment in MIA patients (Dong et al., 2016; Hoh et al., 2010). Dong reported complete occlusion rate of 90.8% for the microsurgical group versus 65% for the endovascular one, while the recanalization rates were 3.6% and 30%, respectively (Dong et al., 2016). They reported a cumulative complication rate of 15.7% for the surgical group and 17.5% for the endovascular one (Dong et al., 2016). Likewise, Jiang in their meta-analysis found that clipping was superior to endovascular treatment in cases of ruptured singular aneurysms (Jiang et al., 2020). However, they reported that clipping was associated with higher incidence of poor overall outcome and bleeding, in cases of

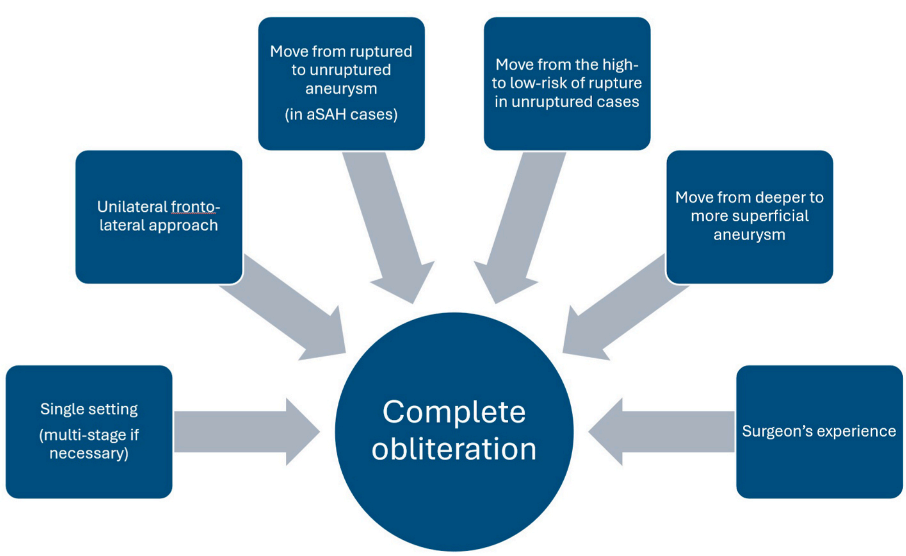


**Fig. 3.** Consolidated practical tips for efficacious microsurgical management of MIA patients.

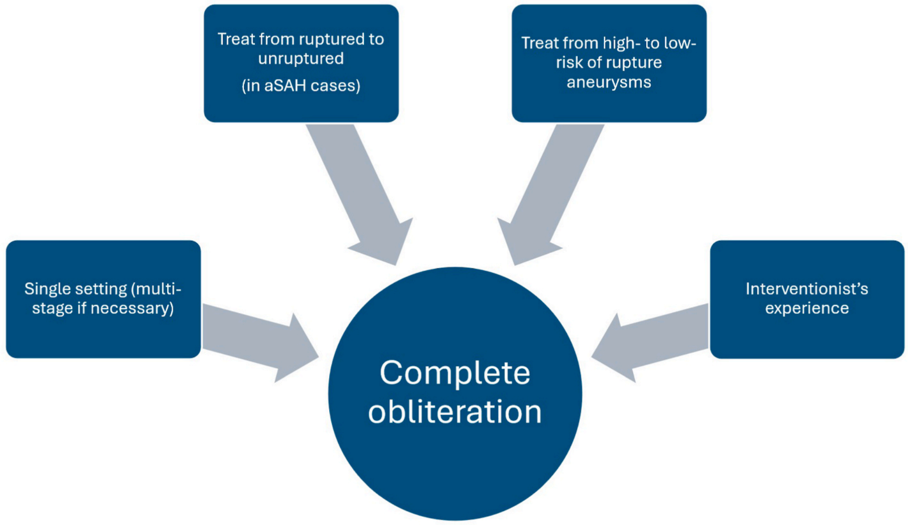


**Fig. 4.** Consolidated practical tips for efficacious endovascular management of MIA patients.

unruptured aneurysms (Jiang et al., 2020). A critical analysis of the previously published data support that clipping offers a higher complete obliteration rate and subsequently lower recurrence and rebleeding incidence, while endovascular treatment is associated with lower complication rate and shorter length of hospital stay (Fig. 5) (Molyneux et al., 2005; Cho et al., 2018; Algra et al., 2019; Campi et al., 2007; Le Roux et al., 2016).

Interestingly, our panelists reached no consensus on the role of the cost effectiveness in the decision-making process of managing MIAs. Hoh examined the length of stay (LOS) and the hospitalization cost in patients with intracranial aneurysms (Hoh et al., 2010). They found that patients undergoing clipping had statistically significant longer length of stay and higher hospitalization costs compared to those receiving endovascular treatment, regardless of whether the aneurysms were ruptured or unruptured (Hoh et al., 2010). However, the reported higher retreatment and rebleeding rates among patients undergoing endovascular treatment, and their impact on the overall treatment cost, need to be taken into consideration (Abecassis et al., 2020). Moreover, certain health care structure differences and access to endovascular treatment worldwide need to be considered. Indeed, Chang found that clipping was associated with statistically significant lower total hospital costs compared to endovascular treatment for both ruptured and unruptured aneurysms in South Korea, although the LOS was longer for patients undergoing microsurgical clipping (Chang et al., 2016). Similarly, Kim found that the total hospitalization cost was significantly higher in patients with unruptured aneurysms undergoing endovascular treatment (Kim et al., 2015). Interestingly, they found that the cost was dramatically increasing with the increasing diameter of the aneurysm (Kim et al., 2015). Likewise, Xie documented a significantly lower hospitalization cost in cases of clipping compared to coiling (Xie et al., 2021). In contrast, Zhang in their meta-analysis found no difference in the hospital cost between clipping and endovascular treatment, while the LOS was significantly shorter for the endovascular group (Zhang et al., 2018).

Although each approach, microsurgical or endovascular, are employed alone and have advantages and disadvantages, there are certain highly complex MIA cases, that a combined approach is necessary (Alobaid et al., 2017; Ulmer et al., 2024; Lawton et al., 2003). Lawton employed a hybrid approach including microsurgical and endovascular treatment in managing complex aneurysms (Lawton et al., 2003). They achieved complete obliteration in 95%, while their

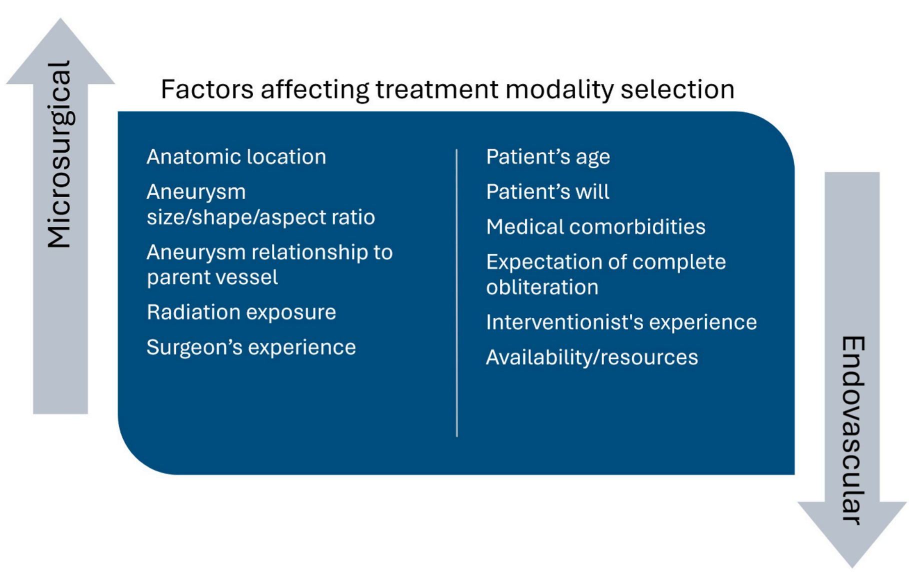


**Fig. 5.** Depiction of the most important factors implicating in the selection of the most proper treatment modality in MIA patients.

observed mortality rate was 9.1%, and a good outcome was obtained in 86% (Lawton et al., 2003). Likewise, Alobaid managed a series of perplex aneurysms by employing a combined approach (Alobaid et al., 2017). They stated that this hybrid approach secured the underlying aneurysms, with a mortality rate of 7.4%, while none of their patients developed a new neurological deficit (Alobaid et al., 2017). Similarly, Ulmer concluded that a combined approach may well be a safe and efficacious management option in complex MIAs (Ulmer et al., 2024). It has to be pointed out that in cases of combined management, microsurgical approach should proceed any endovascular procedures (Fig. 6).

Our panelists reached a consensus on a yearly imaging follow-up of patients with untreated MIAs. It has to be emphasized that the presence of any aggravating factors, such as smoking, female sex, family history, polycystic kidney disease, and the detection of any de novo aneurysms, may dictate the necessity for six-month follow-up. Moreover, no consensus was reached on the necessity and/or the frequency of follow-up for treated MIAs. The optimal pattern of long-term follow-up remains ill-defined. Previous studies have demonstrated that MIAs have the tendency to grow over time (Martinez-Perez et al., 2020; Yu et al., 2017; Molyneux et al., 2005; Hong et al., 2022; Cervoni et al., 1993; Seo et al., 2011; Wermer et al., 2005). Moreover, it has been postulated that patients with MIAs may develop de novo aneurysms (Wermer et al., 2005; Bruneau et al., 2011; Rinne and Hernesniemi, 1993). Meticulous follow up becomes of paramount importance in partially treated MIA patients, with a previous SAH (Rigante et al., 2021). It has been demonstrated that the incidence of a second SAH is significantly higher among these patients, while the rupture risk of de novo and/or mirror images is also higher (Rigante et al., 2021; Zali et al., 2014; Liu et al., 2024).

### 4.1. Limitations

Our current consensus represents an effort to synthesize expert opinion on the optimal management of MIAs among neurosurgeons and interventional neuroradiologists/endovascular neurosurgeons. Some conclusions of our consensus reflect established neurovascular principles. However, our study's main value is in formally structuring international expert agreement, where Level I evidence for MIAs is lacking. By using a structured Delphi approach, we move beyond anecdotal practice to expert consensus, establishing thus a benchmark for decision-making in areas without feasible randomized controlled trials, or with limited clinical high-quality evidence. However, it is essential to acknowledge several inherent limitations that may influence the generalizability, strength, and comprehensiveness of its recommendations. Firstly, our final response rate was 74.3% despite the fact that the Delphi panel was composed of highly experienced experts in the neurovascular field. Although a response rate above 70% is generally considered robust and acceptable for Delphi processes, particularly among clinical specialists, the potential for non-response bias cannot be entirely excluded. Secondly, a significant limitation stems from the paucity of high-grade clinical evidence in the field of MIAs. Consequently, contributing experts frequently have to rely on lower-level evidence, and on their personal experience. Therefore, while this consensus aims to provide guidance, in those fields in which definitive evidence is scarce, it is crucial to recognize that the strength of these recommendations is inherently constrained by the available literature data. Furthermore, the consensus process surfaced considerable heterogeneity in clinical practice across Europe and North America, shaped by geographical, cultural, and socioeconomic factors. It becomes obvious that efforts were made to capture a broad Western countries' perspective. However, these underlying disparities mean that the consensus may not perfectly reflect or be universally applicable to every clinical setting or patient population and definitely needs to be individualized. Moreover, despite the multidisciplinary nature of aneurysm care, there was an underrepresentation of other crucial specialties, such as neurologists and neurointensivists, within the consensus panel. Their limited direct participation in this specific consensus may mean that certain perspectives, particularly regarding non-surgical or adjunctive treatment modalities, might not be as thoroughly integrated as they would be in a fully interdisciplinary guideline. Equally important, even though electronic surveys help reduce the impact of dominant personalities, fully removing such influence is challenging. Question framing, professional hierarchies, and informal communication can still subtly sway responses and consensus, making some implicit bias from prominent figures unavoidable. Similarly, the consensus panel was deliberately aware of the potential for the "lowest common denominator" effect. This describes the tendency for groups seeking broad agreement to settle on the most conservative or least detailed recommendations, avoiding thus contentious issues or firm stances that might hinder

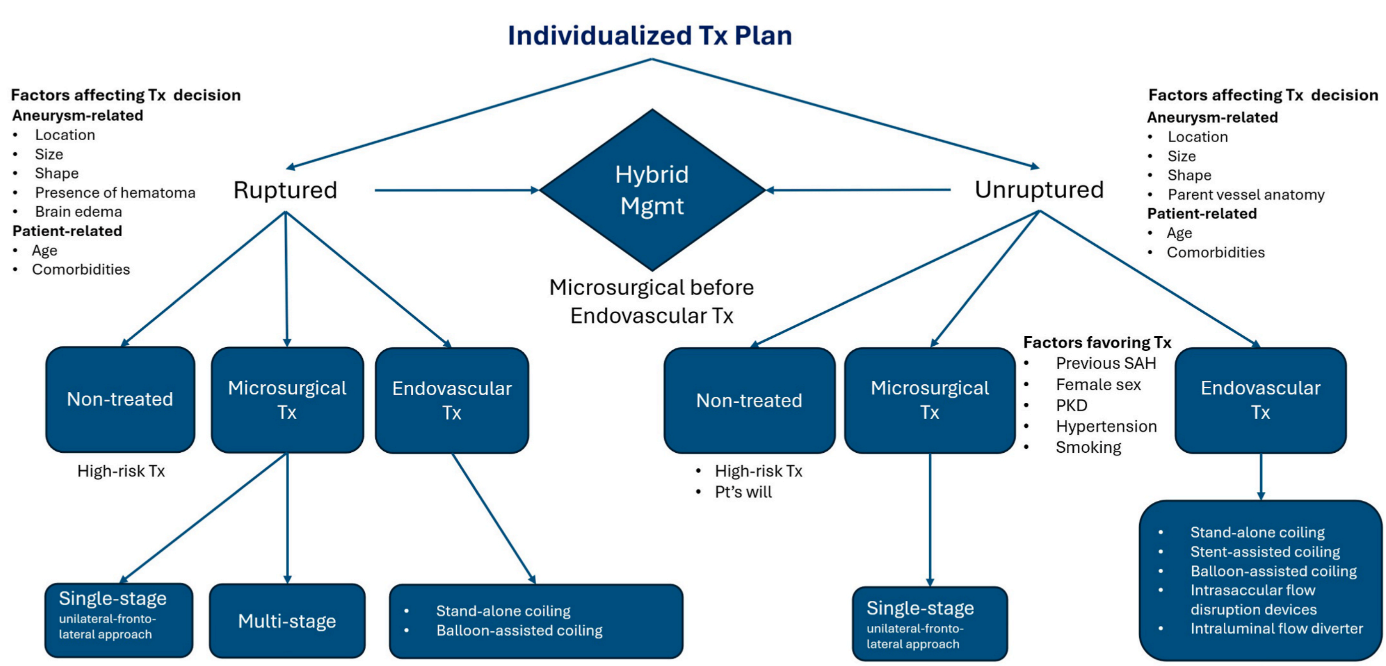


**Fig. 6.** Management algorithm of MIA patients.

unanimous approval. Moreover, the level of expertise for endovascular management varied among our neurosurgeon panelists, and vice versa for interventional neuroradiologists/endovascular neurosurgeons. Likewise, our consensus may lack the necessary detail or clear direction in some fields, which is crucial for handling complex clinical cases. Finally, the patient's voice was not directly included in these recommendations. We appreciate that patient perspectives are vital in aneurysm management; however, this process focused on neurosurgeons and interventional neuroradiologists/endovascular neurosurgeons and lacked direct patient input. Future efforts should better integrate patient perspectives for promoting patient-centered care.

## 5. Conclusions

Managing MIA cases remains a challenging clinical issue particularly in regards to the diagnostic work-up and the optimal management of these patients. This consensus offers practical guidance by emphasizing key areas of common clinical practice, such as the association of aneurysm size, shape, location, and a previous hemorrhage with the risk of rupture. It also highlights the benefits of a single-stage approach, either microsurgical or endovascular, whenever possible, and recommends annual or six-month follow-up imaging for aneurysms that are not treated. Additionally, our findings stress the importance of accurately identifying the ruptured aneurysm, since failure to do so can lead to rebleeding and increased mortality. Providing optimal care involves a multidisciplinary approach that combines neurosurgical and endovascular expertise to develop personalized treatment plans.

Despite these insights, important knowledge gaps still exist, such as the lack of rupture risk prediction scales validated specifically for MIAs, limited evidence on long-term follow-up after treatment, and an uncertain role for hybrid microsurgical–endovascular approaches. Addressing these gaps will require prospective, multicenter research, as well as the integration of advanced imaging, computational modeling, and AI tools. Until such evidence emerges, the current consensus offers a realistic framework to guide clinical decision-making, while highlights the importance of individualized, multidisciplinary care.

## Disclosures

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bas.2026.106091.

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