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European survey on follow-up strategies for unruptured intracranial aneurysms

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ABSTRACT

Introduction: The increasing detection rates of unruptured intracranial aneurysms (UIA) pose a challenge for both neurovascular centers, tasked with managing a growing pool of patients requiring regular monitoring with imaging, and the healthcare system that must bear the costs of such surveillance. While there is consensus on the need for follow-up of UIA, uncertainties persist regarding the optimal cessation of surveillance, especially when considering diverse patient risk factors and, notably, in cases of treated aneurysms with stable rest perfusion. Detailed guidelines on UIA follow-up are currently lacking, exacerbating these challenges.
Research question: We sought to investigate European strategies for follow-up of untreated, microsurgically and endovascularly treated UIA.
Material and methods: An online survey consisting of 15 questions about follow-up management of UIA was sent out to the cerebrovascular section of the European Association of Neurosurgical Societies (EANS).
Results: The survey response rate was 27.3% (68/249). There was consenus upon the necessity for long-term follow-up of UIA (100% [n = 68]). The recommendation to perform follow-up was inversely correlated with patient age and more prevalent among endovascularly compared to microsurgically treated patients (92.6% [n = 63] vs. 70.6% [n = 48]). A majority recommended continued follow-up of treated aneurysms with stable rest perfusion, with lifelong surveillance in patients under 60 years and continuation for 5–10 years in patients aged 61–80, irrespective of whether they underwent microsurgical (38.3% [n = 23]; 33.3% [n = 20]) or endovascular (41.9% [n = 26]; 30.6% [n = 19]) treatment.
Discussion and conclusion: This survey confirmed a European consensus on the necessity of long-term follow-up for untreated UIA. However, significant variations in follow-up strategies, especially for treated UIA and post-treatment rest perfusion, were noted. Despite limited evidence suggesting low risk from aneurysm remnants, respondents favored long-term follow-up, highlighting uncertainty in management. This underscores the need for collaborative research on aneurysm remnants and standardized follow-up protocols for UIA in Europe.

1. Introduction

Unruptured intracranial aneurysms (UIA) are prevalent in approximately 3% of the global population (Renowden and Nelson, 2020; Salih et al., 2021; Vlak et al., 2011). The trend towards increasing use of cerebral imaging leads to more incidental discoveries of UIA that need management by specialized neurovascular centers. In cases where the decision is taken to forego preventive occlusion of the aneurysm, consensus exists on the necessity of follow-up using serial imaging to detect aneurysm growth, which is an important risk factor for rupture (Backes et al., 2017; Van Der Kamp et al., 2021). However, guidelines regarding frequency of follow-up and the criteria for its discontinuation are missing, which is reflected in markedly heterogeneous management strategies for UIA among neurovascular centers throughout Europe and the United States (Fargen et al., 2018; Skodvin et al., 2021). Further, the rising number of incidentally discovered UIA necessitating follow-up poses a snowballing challenge for neurovascular centers that must organize and keep track of a growing population of patients requiring regular imaging, which is also leading to relevant healthcare costs (Gupta et al., 2016).

Current UIA guidelines of the European Stroke Organization

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Abbreviations list

AHA/ASA = American Heart Association/American Stroke Association
CT-A = Computed tomography angiography
CV = Cerebrovascular
DSA = Digital subtraction angiography
EANS = European Association of Neurosurgical Socities
MR-A = Magnetic resonance angiography
SAH = Subarachnoid hemorrhage
UIA = Unruptured intracranial aneurysm

recommend follow-up with computed tomography angiography (CT-A) for aneurysms treated with clipping, magnetic resonance angiography (MR-A) for aneurysms treated endovascularly and digital subtraction angiography (DSA) only for cases in which CT-A or MR-A are inconclusive (Etminan et al., 2022). However, consensus is lacking on the optimal frequency for such follow-up, particularly when considering varying patient scenarios that include different patient ages, risk profiles, under which follow-up could be safely discontinued. Further, there is a non-negligible risk for de-novo aneurysm formation, particularly in younger patients with significant risk factors in whom an aneurysm has already been occluded successfully (Hu et al., 2019). In such cases, follow-up may still be necessary, yet there is currently no established consensus or recommendation for de-novo aneurysm screening.

The need for unified follow-up strategies among European neurovascular surgeons was stated many times in the literature (Gondar et al., 2016; Gupta et al., 2016; Malhotra et al., 2018; Obermueller et al., 2021). Given the absence of guidelines and in pursuit of advancing standardization, we conducted a survey within the cerebrovascular section of the European Association of Neurosurgical Societies (EANS) to assess the current patterns of follow-up for untreated and treated UIA.

2. Methods

2.1. Study design

A web-based survey was constructed using Google Forms (Google LLC, Mountain View, California, USA). The survey consisted of 15 questions addressing the management of follow-up of untreated, microsurgically treated, and endovascularly treated UIA. The format varied between single and multiple-choice questions. A link to the survey was distributed via the mailing list of all members of the cerebrovascular section of the EANS. Following the initial distribution of our survey, we sent two reminders at intervals of 3 and 6 weeks. Additionally, we disseminated a QR code with the survey link during the 2023 annual EANS vascular section meeting, held on September 7th and 8th in Marseille, France, to further enhance participation.

Participation in our survey was entirely voluntary, and we refrained from sending personal solicitations to complete it. Ethical approval from a local Ethics Committee was deemed unnecessary, as we collected no personal information from participants or patients. Data processing was performed using Microsoft © Excel (Version 16.79.1, Microsoft, Redmond, Washington, USA). Flowcharts were designed using Microsoft © Powerpoint (Version 16.86, Microsoft, Redmond, Washington, USA).

2.2. Survey structure

The survey was structured into three sections: 1) untreated UIA, 2) microsurgically treated UIA, and 3) endovascularly treated UIA. Within the sections addressing microsurgically and endovascularly treated UIA, we differentiated between completely occluded aneurysms and those rest perfusion after treatment. Further, we considered three different age groups in the survey: age ≤60 years, age 61–80 years, and age ≥80 years.

2.3. Analysis

We conducted solely descriptive analyses. The maximum number of respondents was n = 68, although this number could fluctuate if a respondent skipped a question. The percentages reported in this survey are calculated by dividing the responses for each item by the total number of respondents for each specific question.

3. Results

The survey was distributed to 249 members of the CV section of the EANS and to approximately 50 people during the annual vascular section meeting of the EANS in Marseille, France. A total of 68 individual survey responses were collected and included in the analysis. Of the respondents, 91.2% (n = 62) confirmed their affiliation with the EANS, whereas 8.8% (n = 6) indicated they were not members of the EANS. The survey questions are provided in the supplementary material.

3.1. Follow-up of untreated UIA

3.1.1. Patient age and risk factors

All respondents 100% (n = 68) reported that they generally conduct follow-up for UIA in their institutions. We noted a general decrease in the recommendation for follow-up as patient age increased. In patients aged <60 years, the proportion ranged from 67.7% to 82.4%, while in those aged >80 years, it varied between 16.2% and 39.7%. When stratified by dome size (<7 mm and ≥7 mm) and the presence or absence of risk factors (smoking, hypertension, previous subarachnoid hemorrhage (SAH), family history of SAH/UIA, female sex, genetic predisposition) in patients with no risk factors and dome size <7 mm, follow-up was more frequently indicated compared to patients with ≥1 risk factor and dome size ≥7 mm (80.9% and 82.4% vs 70.6% and 67.7%, respectively). In patients >80 years, this trend reversed, with those having no risk factors and dome size <7 mm being less frequently recommended for follow-up compared to patients with ≥1 risk factor and a dome size ≥7 mm (16.2% and 19.1% vs 26.5% and 39.7%). We generally observed similar results for dome size <7 mm and patients with no risk factors in all age groups (Fig. 1A).

3.1.2. Imaging modality and time intervals

MR-A was the most frequently chosen imaging modality for follow-up before CT-A. When considering modalities together with time points, annual MR-A was the single most chosen combination with 52.2%, followed by MR-A every 2 years (23.9%) and annual CT-A (16.4%). DSA was negligible for follow-up of untreated UIA (Fig. 1B).

3.1.3. Discontinuation of follow-up based on patient age

When inquiring about the duration of stable follow-up, after which respondents would consider discontinuing further monitoring or alternatively performing lifelong follow-up, almost half of the respondents (47.8% [n = 32]) chose to perform lifelong follow-up for patients younger than 60 years of age. For patients aged 61–80 years, a majority of 43.3% (n = 28) favored a maximum follow-up duration of 5–10 years. In patients older than 80 years, 19.4% (n = 13) indicated to discontinue after 1 year and 25.4% (n = 17) responded to discontinue after 2 or 5 years of stable follow-up. Only a minority in this age group opted for longer follow-up (Fig. 1C).

3.2. Follow-up of microsurgically treated aneurysms

3.2.1. Microsurgically completely occluded, singular aneurysms without rest perfusion

70.6% (n = 48) of respondents reported that they typically conduct

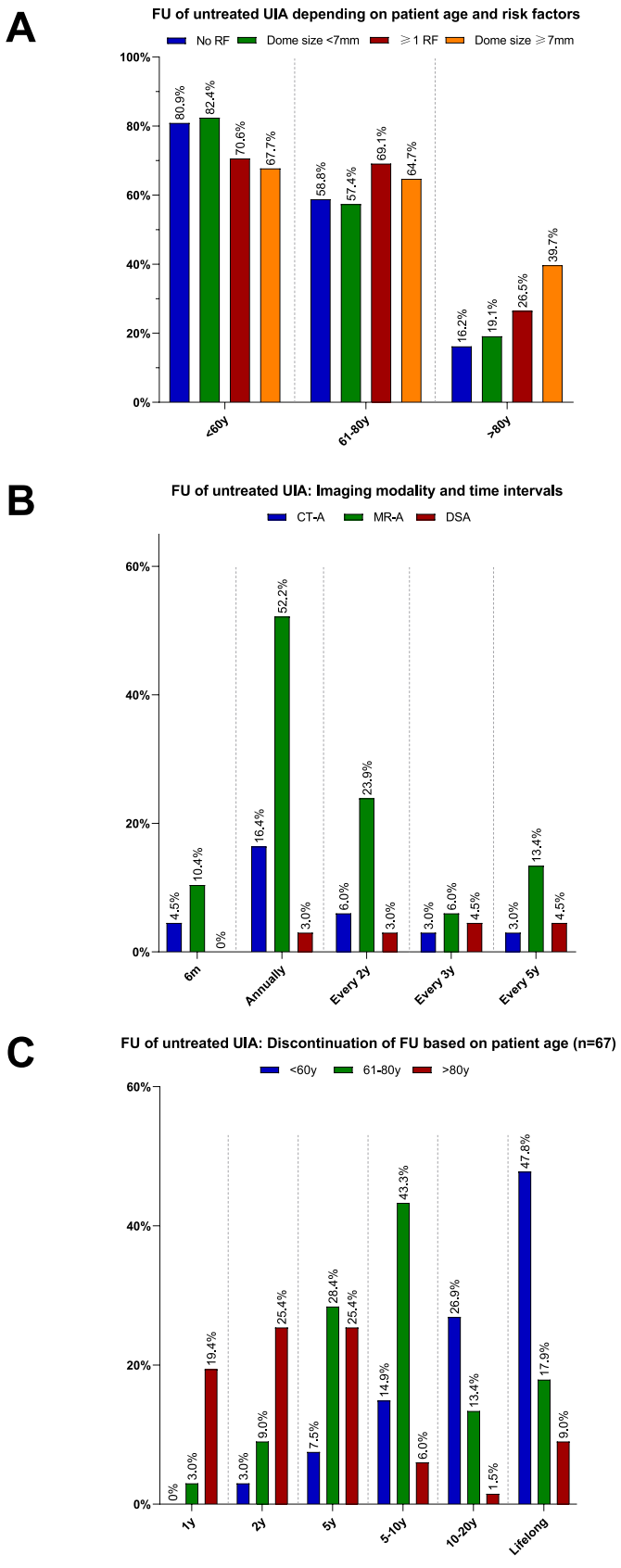

Fig. 1. Follow-up of untreated UIA.

follow-up for microsurgically, completely occluded, singular aneurysms without rest perfusion, while 29.4% (n = 20) reported they do not. When asked about imaging modalities and time points of such follow-up, also considering screening for de-novo aneurysms, most perform a single DSA (25.5% [n = 12]) or CT-A (19.1% [n = 9]) after 6 months. 21.3% (n = 10) reported they conduct a CT-A every 5 years. MR-A as an imaging modality and other time points of follow-up were much less favored (Fig. 2A).

3.2.2. *Microsurgically treated aneurysms with rest perfusion*

88.2% (n = 60) of respondents reported that they typically conduct follow-up of microsurgically treated aneurysms with rest perfusion, while 11.8% (n = 8) reported they do not. DSA once after 6 months (33.3% [n = 20]) and CT-A every year (31.7% [n = 19]) were the most frequently chosen combinations for follow-up in this scenario (Fig. 2B).

3.2.3. *Discontinuation of follow-up for microsurgically treated aneurysms with stable rest perfusion*

When inquiring about the duration of follow-up after which respondents would consider discontinuing further monitoring, or alternatively perform lifelong follow-up in case of stable rest perfusion after microsurgery, the majority indicated that they would indicate lifelong follow-up (38.3% [n = 23]) for patients <60 years of age. As age increased, we observed a decreased tendency to conduct prolonged follow-up: in the age group 61–80 years and >80 years, most indicated to stop follow-up after 5–10 years (33.3% [n = 20]) and after 5 years (25.0% [n = 15]), respectively (Fig. 2C).

3.3. *Follow-up of endovascularly treated aneurysms*

3.3.1. *Endovascularly completely occluded, singular aneurysms without rest perfusion*

92.6% (n = 63) of respondents reported that they typically conduct follow-up for endovascularly completely occluded singular aneurysms without rest perfusion, while 7.4% (n = 5) reported they do not. When aksed about imaging modalities and time points of such follow-up, DSA (38.7% (n = 24) and MR-A (29% [n = 18) once after 6 months as well as annual MR-A (37.1% [n = 23]) were the most frequent types of indicated follow-up. The fraction of participants who chose follow-up with CT-A was negligible (Fig. 3A).

3.3.2. *Endovascularly treated aneurysms with rest perfusion*

For endovascular treatment with rest perfusion, 95.6% (n = 65) answered to conduct follow-up, while 4.4% (n = 3) would not perform further monitoring. The majority of respondents indicated to follow-up remants after endovascular treatment with DSA once after 6 months 37.5% (n = 24) and annual MR-A 35.9% (n = 23) (Fig. 3B).

3.3.3. *Discontinuation of follow-up for endovascularly treated aneurysms with stable rest perfusion*

Analogous to the microsurgical group, 41.9% (n = 26) conduct lifelong controls for the age group under 60 years in case of an endovascularly treated aneurysm with stable rest perfusion. For the age group between 61 and 80 years, the majority of respondents favored discontinuing follow-up after 5–10 years and after 5 years in those older than 80 (30.6% [n = 19], in both groups) (Fig. 3C).

Fig. 4 provides a summary of the key findings for each survey category.

4. Discussion

In this survey, we found consensus on the necessity for long-term follow-up of UIA. Generally, the indications to perform follow-up were inversely correlated with patient age and more prevalent among patients who underwent endovascular treatment than among patients who underwent microsurgical treatment. However, in the case of aneurysm rest

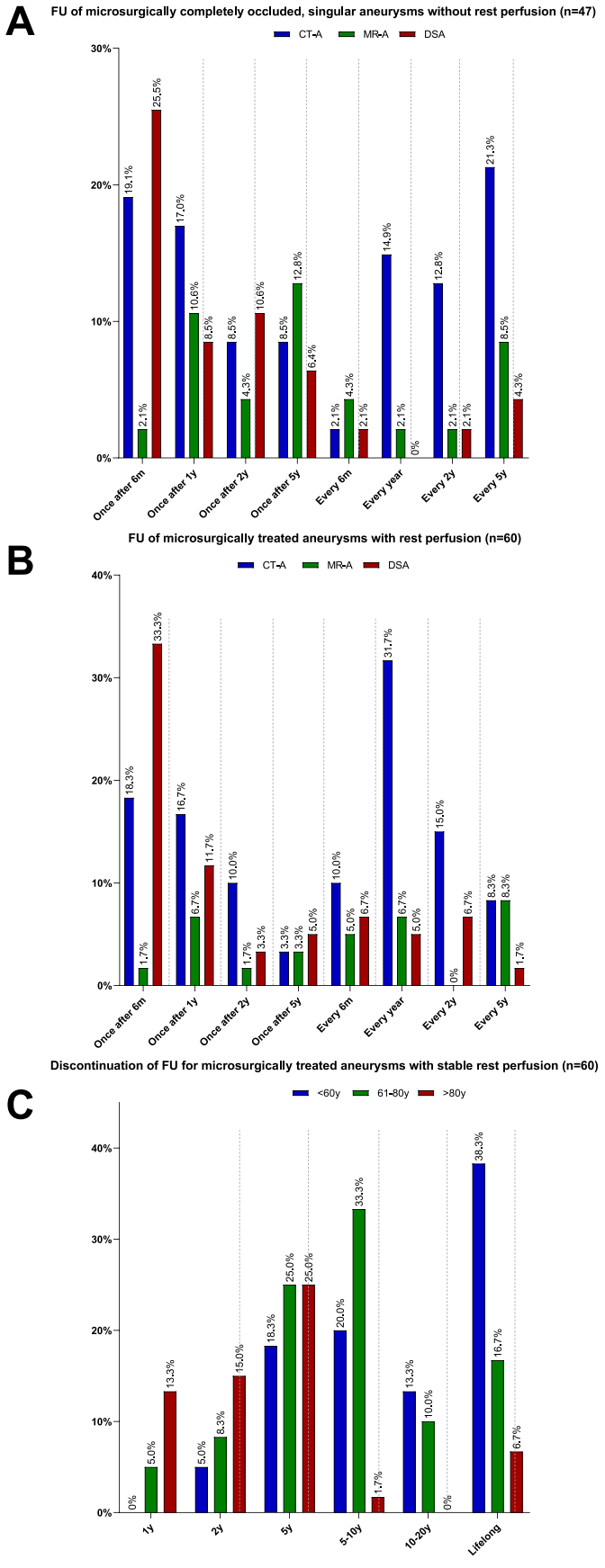

Fig. 2. Follow-up of microsurgically treated UIA.

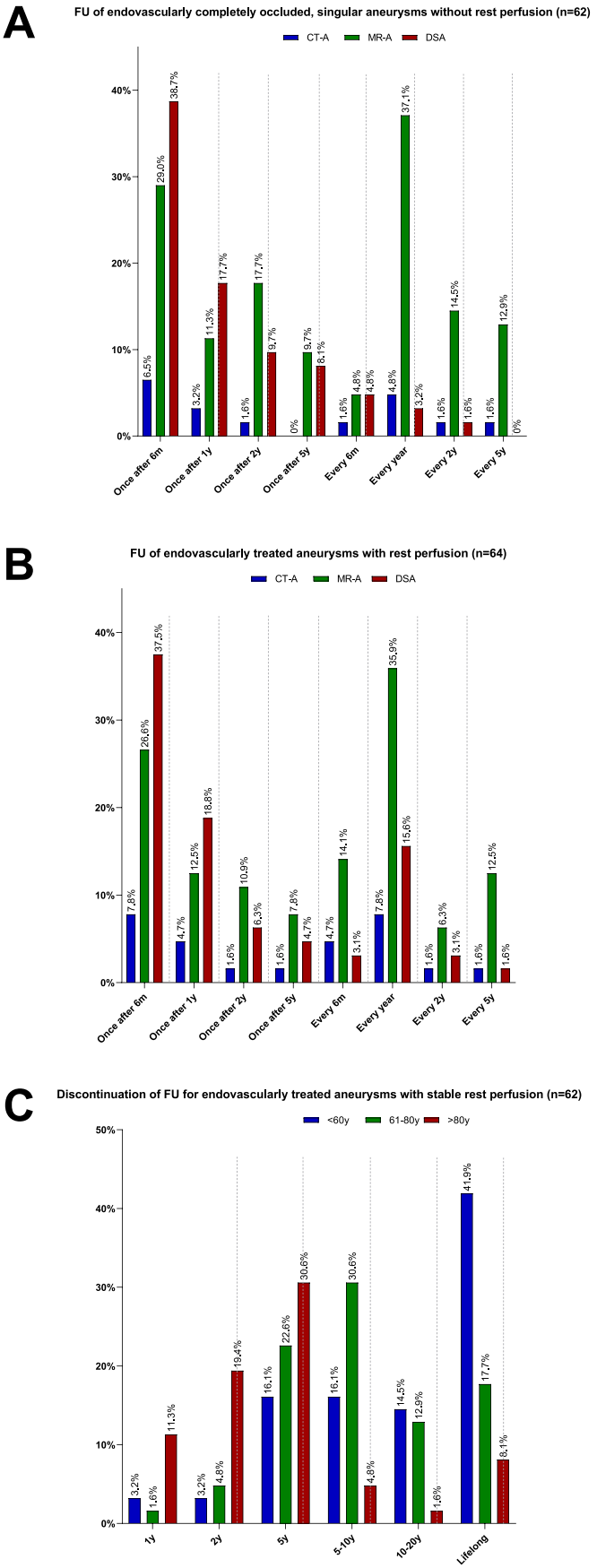

Fig. 3. Follow-up of endovascularly treated UIA.

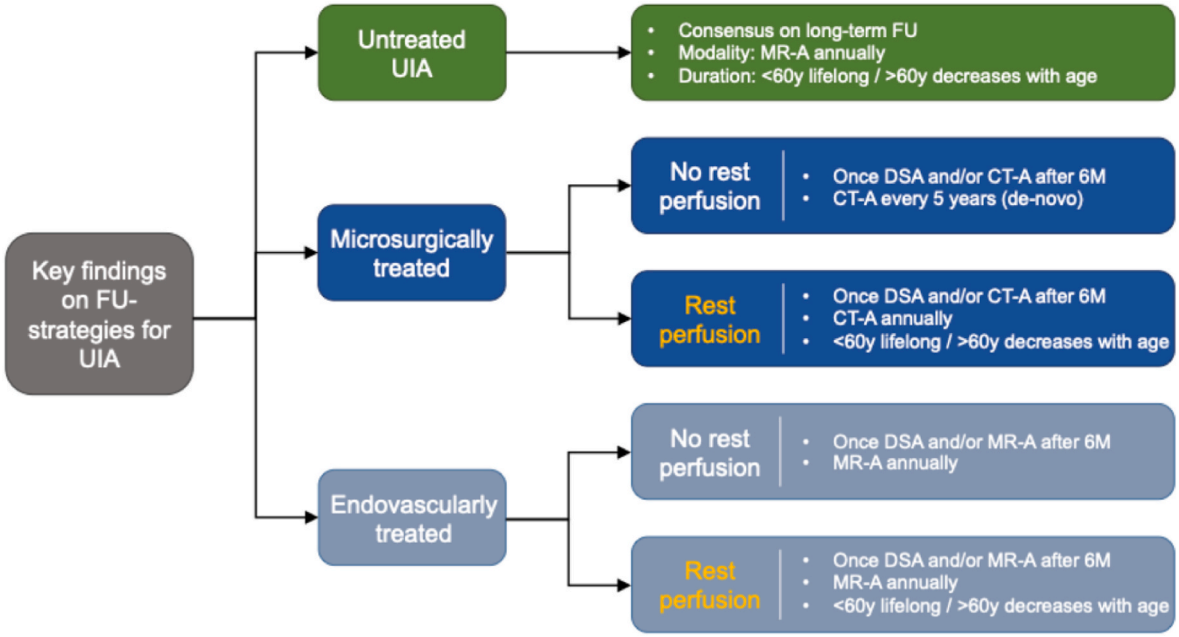

Fig. 4. Summary of key findings of the survey.

perfusion after treatment, equally long-term follow-up was recommended for both endovascularly and microsurgically treated patients.

All participants in this survey reported that they conduct follow-up for UIA in their centers. Besides that, most respondents opt for similar follow-up strategies, although a notable proportion deviates from this by adopting various alternative follow-up patterns. As expected, we observed an inverse correlation between the patient's age and the duration of follow-up. Approximately fifty percent of respondents endorsed the concept of lifelong follow-up for UIA in patients under 60. This practice aligns intuitively with the well-established risk of aneurysm growth and rupture that may manifest even after extended periods of stable monitoring (Backes et al., 2017; Wermer et al., 2006). As age increased, the maximum duration of subsequent follow-up diminished, with the majority suggesting a range of 5–10 years for patients aged 60 to 80 and follow-up intervals of 1–5 years for those above 80. This reflects well how, with advancing age, the balance between the risk associated with preventive aneurysm occlusion and risk of the natural history of the aneurysm throughout the remaining life expectancy leans increasingly towards a scenario where treatment no longer provides a favorable risk-benefit ratio, consequently negating the need for continued monitoring.

In this survey, patients under 60 without risk factors and a dome size <7 mm were more likely to have follow-up recommended compared to patients with at least one risk factor and a dome size of 7 mm or larger, probably since respondents would suggest treatment for the latter group. In older patients, this trend was reversed, likely reflecting the preference for observation over treatment among older individuals with higher-risk aneurysms and no need for further monitoring in older patients with low-risk aneurysms.

The reported primary imaging modality for the follow-up of untreated UIA was predominantly MR-A, most likely because of its high-resolution, non-invasive, and non-ionizing characteristics. This is in coherence with the literature, where most authors favor MR-A over CT-A or DSA (Burns et al., 2009; Malhotra et al., 2019; Renowden and Nelson, 2020; Salih et al., 2021). However, using MR-A instead of CT depends on local resources and will most likely not be feasible for all hospitals. In these cases, CT-A is the imaging technique of choice with approximately the same sensitivity and specificity as MR-A (Thompson et al., 2015). CT-A was also the next most frequently used imaging modality in this survey.

Follow-up was more frequently recommended for patients following endovascular treatment (92.6% [n = 63]) compared to those who underwent microsurgical treatment (70.6% [n = 48]). Further, microsurgery most frequently resulted in single-time follow-up compared to endovascularly treated aneurysms, which underwent follow-up for an extended duration. This distinction reflects the higher likelihood of remnants and, notably, the potential for coil compaction with reperfusion of the aneurysm during subsequent follow-up in endovascularly treated patients (Abdihalim et al., 2014; Darsaut et al., 2017; Sluzewski et al., 2004).

DSA once after 6 months and CT-A every 5 years were the most frequently chosen combinations of modality and time point after microsurgery. Performing CT-A every 5 years appears to be a strategy for detecting de-novo aneurysms. The American Heart Association/American Stroke Association (AHA/ASA) guidelines indicate long-term follow-up after microsurgical clipping of UIA and screening for de-novo aneurysms (Thompson et al., 2015). Tsutsumi et al. found de-novo aneurysm formation after clipping at an annual rate of 0.89% with a cumulative risk of approximately 10% after 9 years (Tsutsumi et al., 2001). Other studies reported lower incidences of de-novo aneurysm formation (Ferns et al., 2011; Giordan et al., 2019; Gupta et al., 2016; Yeon et al., 2020). Still, further monitoring seems recommended after complete occlusion of singular aneurysms, regardless of treatment modality (Kemp et al., 2013; Tsutsumi et al., 2001).

The most frequently reported follow-up procedures for endovascularly treated aneurysms without rest perfusion were DSA once after 6 months and MR-A annually. Here, beam hardening artifacts are not an issue, and MR-A is considered the imaging modality of choice compared to CT-A, both in our survey and the literature (Ferns et al., 2011).

In case of microsurgically treated aneurysms with rest perfusion, the majority recommended DSA once after 6 months and/or CT-A every year. This aligns with the recommended management outlined by Obermueller et al. who reported a reperfusion rate of 12% following clipping. Their findings prompted the suggestion of early postoperative angiography follow-up and planning of future management based on its findings (Obermueller et al., 2021). MR-A for follow-up of microsurgically treated aneurysms with rest perfusion was negligible, most likely due to the known artifacts caused by most clips when using MR-A.

For endovascularly treated aneurysms with rest perfusion, preferences for imaging modality and time points closely mirrored those

without rest perfusion (DSA once after 6 months and MR-A annually). Generally, follow-up of aneurysms with stable rest perfusion was recommended by a majority of respondents, particularly for endovascularly treated aneurysms with rest perfusion compared to those without.

When queried about the possibility of discontinuing follow-up for stable aneurysm rest perfusion, participants suggested comparably prolonged follow-up strategies for both microsurgically and endovascularly treated aneurysms. Notably, in the age group younger than 60, the majority advocated for lifelong follow-up of rest perfusion (microsurgery: 38.3%; endovascular treatment: 41.9%). This recommendation persisted in the 61 to 80 age group, with a majority suggesting further follow-up for 5–10 years. Even in patients aged over 80, the majority suggested follow-up by an additional 5 years. This is interesting, as there is limited data regarding the re-rupture of treated index aneurysms with rest perfusion. In the existing data, primarily for endovascularly treated and ruptured aneurysms, the incidence of re-rupture stemming from rest perfusion appears to be quite low (Fleming et al., 2011; Johnston et al., 2008; Molyneux et al., 2015). Nevertheless, the willingness to conduct extended follow-up in cases of stable rest perfusion suggests a degree of uncertainty in a scenario with a limited amount of available data.

This study has several limitations. Firstly, the response rate from members of the cerebrovascular section of the EANS was 27.3%, which, although consistent with comparable studies (Weaver et al., 2019; Wu et al., 2022), does pose a potential source of bias and limits the generalizability of the findings. To streamline the survey and enhance response compliance, we made the decision not to collect information on respondents' location, type of hospital, amount of training, and experience. This limitation may affect the interpretation of results and restrict our ability to analyze geographical and training-associated response variations. Secondly, our survey primarily targeted the European neurosurgical vascular community, limiting its ability to fully represent the perspectives of colleagues and institutions outside of Europe, and those solely trained endovascularly. Finally, the total number of responses varied among questions, introducing a limitation in terms of data interpretation.

5. Conclusion

This European-wide survey confirmed consensus on the necessity for long-term follow-up in untreated UIA. However, significant variations in follow-up strategies emerge, particularly for treated UIA and in the context of rest perfusion after treatment. Although limited evidence suggests that aneurysm remnants after treatment pose a low risk, respondents indicated notably long-term follow-up, underscoring the uncertainty in handling these scenarios and highlighting the need for broader collaborative research on the natural history of aneurysm remnants and the establishment of standardized follow-up protocols for UIA across the European neurovascular community.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bas.2024.102864.

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