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Physician factors influencing endovascular treatment decisions in the management of unruptured intracranial aneurysms

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Abstract

Purpose Deciding about whether an unruptured intracranial aneurysm (UIA) should be treated or not is challenging because robust data on rupture risks, endovascular treatment complication rates, and treatment success rates are limited. We aimed to investigate how neurointerventionalists conceptually approach endovascular treatment decision-making in UIAs.

Methods In a web-based international multidisciplinary case-based survey among neurointerventionalists, participants provided their demographics and UIA treatment-volumes, estimated 5-year rupture rates, endovascular treatment complication and success rates and gave their endovascular treatment decision for 15 pre-specified UIA case-scenarios. Differences in estimated 5-year rupture rates, endovascular treatment complication and success rates based on physician and hospital characteristics were evaluated with the Kruskal-Wallis test. Multivariable logistic regression analysis was used to derive adjusted effect size estimates for predictors of endovascular treatment decision.

Results Two hundred-thirty-three neurointerventionalists from 38 countries participated in the survey (median age 47 years [IQR: 41–55], 25/233 [10.7%] females). The ranges of estimates for 5-year rupture risks, endovascular treatment complication rates, and particularly endovascular treatment success rates were wide, especially for UIAs in the posterior circulation. Estimated 5-year rupture risks, endovascular treatment complication and success rates differed significantly based on personal and institutional endovascular UIA treatment volume, and all three estimates were significantly associated with physicians' endovascular treatment decision.

Conclusion Although several predictors of endovascular treatment decision were identified, there seems to be a high degree of uncertainty when estimating rupture risks, treatment complications, and treatment success for endovascular UIA treatment. More data on the clinical course of UIAs with and without endovascular treatment is needed.

Keywords Unruptured intracranial aneurysm · Coiling · Complications

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Introduction

Unruptured intracranial aneurysms (UIAs) are present in approximately 3% of the adult population [1]. The vast majority of UIAs are asymptomatic and often incidentally detected, when neuroimaging is performed for non-specific symptoms. Evidence for the management of UIAs is scarce: reported rupture risks in the literature vary widely, and numerous predictors of rupture risk have been described, some of which with controversial clinical significance [2]. Treatment complication rates differ substantially between studies and treatment modalities [3]. Since the publication of the International Subarachnoid Aneurysm Trial (ISAT) results [4, 5], more and more UIAs are being treated with endovascular techniques, and several new intrasaccular devices have been developed recently [6]. Reliable estimates for complication risks with novel endovascular treatment technologies are challenging because of the limited available data. Even less is known about treatment "success" rates. Thus, treatment decision making in patients with UIAs is challenging and heavily depends on soft factors, such as patient and physician preferences. Most guidelines suggest to manage UIA patients in the framework of a multidisciplinary team and recommend taking all patient-related risk factors and preferences into account [7], but because of the many unknowns, it is mostly left to the physicians' discretion how exactly these factors should play into treatment decision-making. We set out to investigate how neurointerventionalists estimate UIA rupture rates, endovascular treatment complication and success rates, and how physician-related factors influence these estimates and endovascular treatment decisions.

Methods

Survey participants

We conducted an international web-based survey (Qualtrics.com) to explore how neurointerventionalists approach the management and particularly endovascular treatment decision making in patients with UIAs. Response data were obtained from April 3 to 24, 2020. Survey participants were selected based on the authors' academic collaborations and personal and institutional networks. In the first survey part, participants were asked to provide their demographic baseline characteristics (age, gender, specialty, career stage, years of neurointerventional experience, personal and institutional endovascular UIA treatment volume).

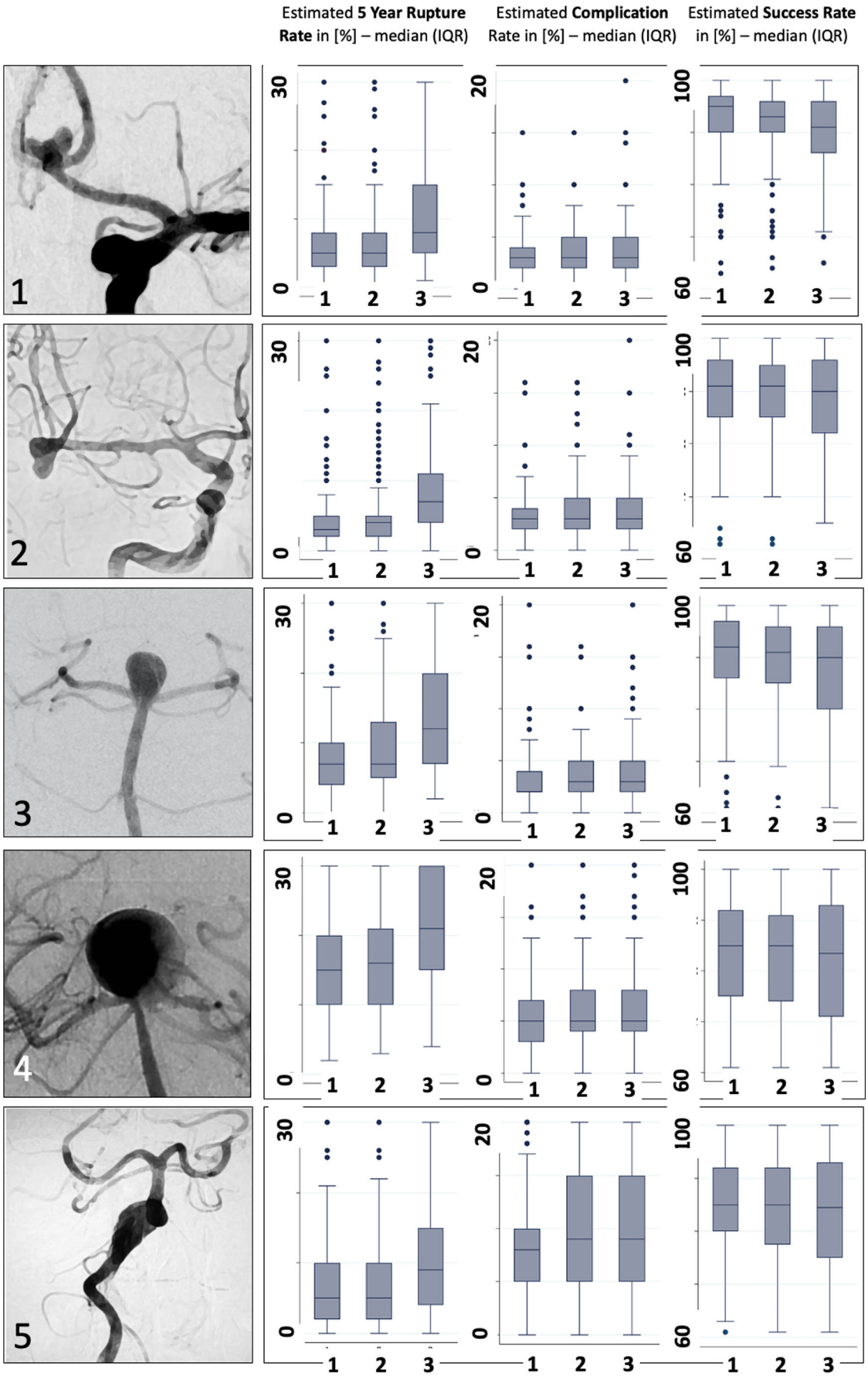
Case scenarios

In the second part of the survey, physicians were confronted with digital subtraction images of UIAs in five different locations and with different shapes (1: anterior communicating artery, 2: middle cerebral artery bifurcation, 3 and 4: basilar tip, 5: fusiform basilar aneurysm, see Fig. 1), each with three distinct short clinical vignettes (scenario 1: 40-year old non-smoker, negative family history, no hypertension; scenario 2: 70-year old non-smoker, negative family history, no hypertension; scenario 3: 55-year old smoker (20 pack years, no intention to give up smoking), positive family history (sibling with previous aneurysm rupture, no hypertension)). Physicians were then asked to estimate (a) 5-year-rupture risks, (b) endovascular treatment complication rates, and (c) treatment success rates for each given aneurysm and clinical case vignette (i.e., 15 case-scenarios in total), and stated whether or not they would offer endovascular treatment to this patient. A complication was hereby defined as an event that leads to a permanent neurological deficit. Treatment success was defined as a negligible (i.e., very low) likelihood of aneurysm recurrence and/or subarachnoid hemorrhage after the procedure.

Statistical analysis

Estimated 5-year rupture risks, endovascular treatment complication rates, and endovascular treatment success rates were summarized using descriptive statistics and compared between physicians of different specialties and career stages, physicians with different institutional and personal UIA treatment volumes (per 20/10 cases increase in annual UIA case volume respectively), and based on the frequency of UIA case discussions in a multidisciplinary board (not at all vs. selected UIA cases vs. all UIA cases) using the Kruskal Wallis test. Additionally, Spearman rank correlation was used to assess for correlation of continuous and pseudo-continuous physician baseline variables and estimated 5-year rupture rates, endovascular treatment complication and success rates. Physicians' estimates and treatment decisions were also reported separately for each geographic region. Two separate multivariable logistic regression models clustered by UIA scenario were constructed to obtain adjusted measures of effect size for the association of physicians' baseline characteristics and estimated 5-year rupture rates, endovascular treatment complication rates, and endovascular treatment success rates with

Fig. 1 Median estimated 5-year rupture risks (second column), endovascular treatment complication rates (third column), and endovascular treatment success rates (fourth column) in percent with respective interquartile ranges. Values are shown for each UIA (shown in the first column). Numbers on the *x* axis represent the clinical case-scenarios 1–3. A complication was defined as an event that leads to a permanent neurological deficit. Treatment success was defined as a negligible (i.e., very low) likelihood of aneurysm recurrence and/or subarachnoid hemorrhage after the procedure. For a detailed overview of median estimates with interquartile ranges for each case-scenario, see suppl. Table 2. Region-specific estimates and treatment decisions are shown in suppl. Table 3


Estimated 5 Year Rupture Rate in [%] – median (IQR)
Estimated Complication Rate in [%] – median (IQR)
Estimated Success Rate in [%] – median (IQR)
1
2
3
4
5
0
30
20
100
60
1
2
3

endovascular treatment decisions. Model 1 included physician baseline demographics: specialty (interventional neuroradiology vs. neurosurgery vs. neurology vs. other), gender, age (continuous), career stage (resident vs. fellow vs. junior staff vs. senior staff), years of neurointerventional experience (continuous), personal/institutional annual endovascular UIA treatment volume (per 10/20 cases increase), and frequency of UIA case discussion in a multidisciplinary board (not at all vs. selected UIA cases vs. all UIA cases). Model 2 included physicians' personal estimates of 5-year rupture rates, endovascular treatment complication rates, and endovascular treatment success rates (in percent, included as continuous variables). All tests were two-sided, and conventional levels of significance (alpha = 0.05) were used for interpretation. Data analyses were performed in Stata 15.1. All participants gave their consent prior to answering the survey, and participation was voluntary. Because no patient data was used, an ethics approval was not necessary for this study.

Results

Out of 1302 neurointerventionalists, 369 neurointerventionalists initiated the survey (survey initiation rate: 28.3%), 233 of which completed the survey, herein referred to as "survey participants" (completion rate: 63.1%). The survey participants represented neurointerventionalists from 38 countries (median age 47 years [IQR 41–55], 25/233 [10.7%] females, Table 1) and provided 3495 treatment decisions and estimates for 5-year rupture risk, endovascular treatment complication rate, and endovascular treatment success rate for 15 UIA case-scenarios. For an overview of survey participants by country, see suppl. Table 1.

Table 1 Survey participants' baseline characteristics ($N = 233$)

Variable	
Age in years–median (IQR)	47 (41–55)
Female sex–*n* (%)	25 (10.73)
Career stage–*n* (%)	
Resident	4 (1.72)
Fellow	7 (3.00)
Junior staff (within 5 years from board certification)	22 (9.44)
Senior staff (greater than 5 years from board certification)	200 (85.84)
Specialty–*n* (%)	
Interventional neuroradiology	151 (64.81)
Neurology	15 (6.44)
Neurosurgery	65 (27.9)
Other	2 (0.86)
Years of neurointerventional experience–median (IQR)	15 (10–21)
Personal annual endovascular UIA treatment volume–*n* (%)	
< 10	25 (10.73)
10–20	51 (21.89)
20–30	57 (24.46)
30–40	29 (12.45)
40–50	17 (7.30)
> 50	54 (23.18)
Institutional annual UIA treatment volume–*n* (%)	
< 20	25 (10.73)
20–40	40 (17.17)
40–60	52 (22.32)
60–80	33 (14.16)
80–100	25 (10.73)
> 100	58 (24.89)
Frequency of UIA case discussion in a multidisciplinary board–*n* (%)	218 (93.56)
Not at all	14 (6.0)
Only selected UIA cases	87 (37.3)
All UIA cases	132 (56.7)

IQR interquartile range

Estimated 5-year rupture risks, endovascular treatment complication, and success rates

Figure 1 summarizes participants' median estimated 5-year rupture risks (second column), endovascular treatment complication rates (third column), and endovascular treatment success rates (fourth column) for each aneurysm and clinical case vignette. The range of estimates was generally wider in UIAs in the posterior circulation (aneurysms 3–5), and in the third clinical scenario (55-year-old smoker with positive family history). Endovascular treatment complication rates were estimated highest, and treatment success rates lowest in the fusiform basilar aneurysm (5).

Estimated 5-year rupture risks stratified by physician and hospital characteristics

Estimated 5-year rupture risks differed significantly between specialties, career stages, and by personal and institutional endovascular UIA treatment volume ($p < .001$ respectively). Neurologists and fellows provided the lowest estimates of all specialties and career stages respectively (suppl. Fig. 1A & B), and estimated rupture risks tended to be lower in physicians with higher institutional and intermediate personal endovascular UIA treatment volume (suppl. Fig. 1C & D). There was a significant positive correlation of age and neurointerventional experience with estimated 5-year rupture rates and a significant negative correlation with institutional annual endovascular UIA caseload, although the strength of these correlations was weak (suppl. Table 4).

Estimates for endovascular treatment complication rates differed significantly by personal and institutional endovascular UIA treatment volume and based on the frequency of UIA case discussion in a multidisciplinary board ($p < .001$ respectively), whereby estimated complication rates generally decreased with increasing personal and institutional treatment volume (i.e., there was a significant, negative association with personal/institutional annual endovascular caseload, shown in suppl. Table 4) and increased when more cases were discussed in a multidisciplinary board (suppl. Fig. 2A–C). Furthermore, there was a significant, albeit weak positive correlation with age and neurointerventional experience (suppl. Table 4).

Neurologists' estimated treatment success rates were highest among all specialties (suppl. Fig. 3A), and junior staff physicians' estimates lowest among all career stages (suppl. Fig. 3B). There was a significant positive association of estimated treatment success rates with higher personal and institutional endovascular UIA treatment volumes and neurointerventional experience (suppl. Table 4), while estimated treatment success rates decreased when more cases were discussed in a multidisciplinary board (suppl Fig. 3C–E).

Participants' endovascular treatment decisions

Figure 2 shows the proportion of physicians who would offer endovascular treatment for each of the 15 case-scenarios. Proportions were lowest for the fusiform basilar aneurysm (aneurysm 5), and when physicians were confronted with clinical scenario 2 (70-year-old non-smoker with negative family history and no hypertension).

Association of Physicians' baseline characteristics and estimates with endovascular treatment decision

In multivariable logistic regression clustered by Scenario ID, the specialties neurosurgery ($_{adj}$OR 0.66, [CI_{95} 0.54–0.79]) and neurology ($_{adj}$OR 0.74, [CI_{95} 0.63–0.87]), more frequent UIA case discussion in a multidisciplinary board ($_{adj}$OR 0.74, [CI_{95} 0.60–0.89]) and higher institutional endovascular UIA caseload ($_{adj}$OR 0.94, [CI_{95} 0.90–0.97] per 20 case increase) were associated with a decision to refrain from endovascular UIA treatment, while higher personal endovascular UIA treatment volume ($_{adj}$OR 1.14, [CI_{95} 1.06–1.22] per 10 case increase) was associated with a decision to offer endovascular UIA treatment.

Higher estimated 5-year rupture rates ($_{adj}$OR 1.18, [CI_{95} 1.12–1.24]) and endovascular treatment success rates ($_{adj}$OR 1.01, [CI_{95} 1.004–1.01]) were significantly associated with a decision to offer endovascular UIA treatment, while higher estimated endovascular complication rates ($_{adj}$OR 0.80, [CI_{95} 0.75–0.86]) were significantly associated with a decision to refrain from endovascular UIA treatment.

Discussion

Although several predictors of endovascular treatment decision were identified in this study, the variability in physicians' estimates of 5-year rupture risk, endovascular treatment complication rate, and endovascular treatment success rate for a given aneurysm was high.

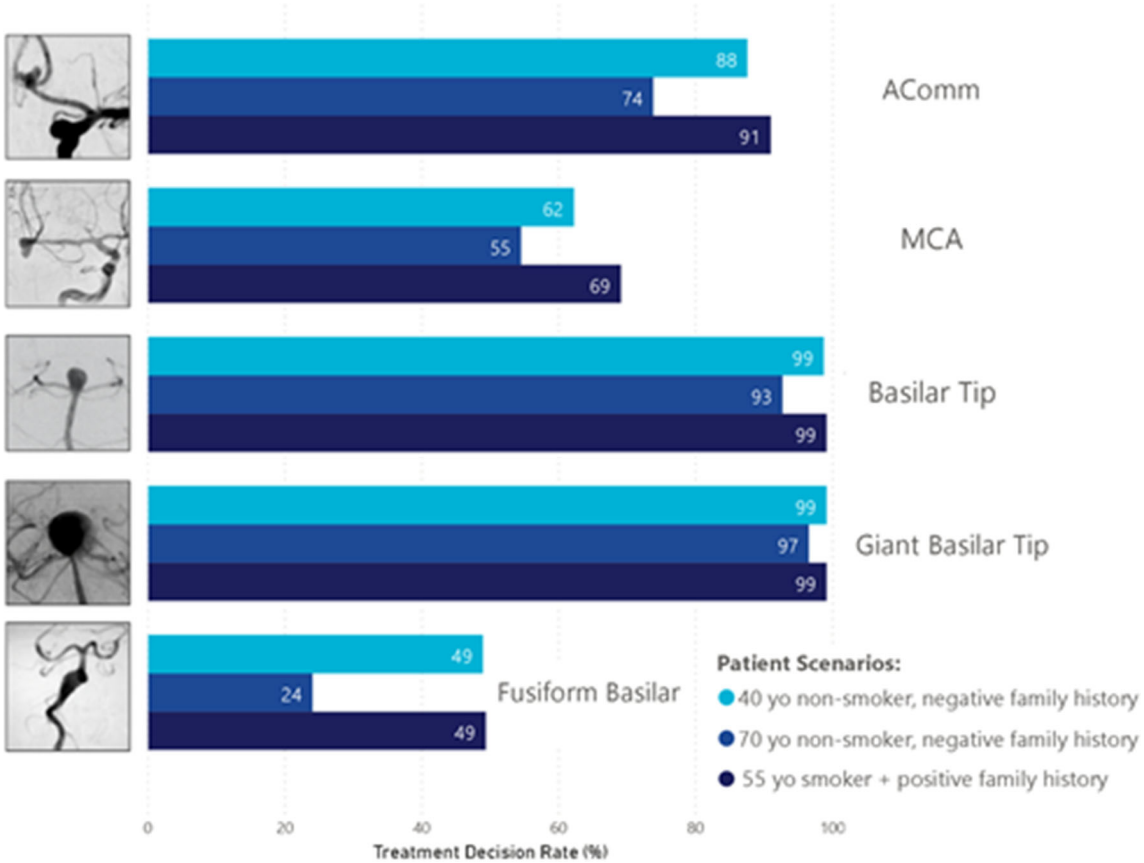


Fig. 2 Proportions of physicians who would offer endovascular treatment for each UIA (left) and clinical case vignette (1–3, see right lower corner) in percent

Among all specialties, neurosurgeons and neurologists were less likely to offer endovascular treatment. Neurosurgeons are more familiar with clipping as a treatment option and might thus decide to treat certain aneurysms surgically rather than endovascularly. Estimated endovascular treatment complication risks were higher and success rates lower when UIA cases were frequently discussed in a multidisciplinary board, which was also significantly associated with a decision to refrain from endovascular UIA treatment, perhaps because a multidisciplinary board indicates that alternative treatment options are available, and the presence of other specialties might lead to a more balanced and possibly more conservative management approach ins some cases. Endovascular treatment complication rates were estimated lower, and success rates higher when personal and institutional endovascular UIA treatment volume increased, indicating that a higher caseload might lead to increased operator confidence. Except for aneurysm 5 (fusiform basilar aneurysm), median estimated complication rates ranged between 3 and 5%, which is lower than most published complication rates in the literature [3]. Somewhat counterintuitively, a high institutional endovascular UIA treatment caseload was associated with a decision refrain from endovascular UIA repair, while a high personal endovascular UIA treatment volume was associated with a decision to offer endovascular UIA repair. It is possible that neurointerventionalists who perform many endovascular UIA cases themselves are convinced that they offer the best possible solution to patients, while those in hospitals with high endovascular UIA treatment volume may perceive their colleague's treatment decisions as overly aggressive and might prefer a more conservative approach themselves. The association of estimated 5-year-rupture risks, endovascular treatment complication rates, and success rates with endovascular treatment decisions was highly significant, indicating that physicians heavily rely on their own estimates when deciding whether or not to treat an UIA with endovascular means. However, physicians' estimates varied widely. The variability was highest in UIAs in the posterior circulation (aneurysms 3–5), which are known to have a higher rupture rate [2], but are also more challenging to treat, especially in the case of a wide neck (as in aneurysm 4) or a fusiform shape (as in aneurysm 5) [8]. Somewhat contradictory to our findings, a DELPHI consensus statement by Etminan and colleagues found excellent consensus among experts of different specialties on UIA management [9]. This could possibly be related to a selection bias: the consensus panel in Etminan's study consisted of 69 highly informed experts, whereas our study included more than 200 individuals with varying degree of experience. The findings of our study therefore reflect the uncertainty that is involved in real-life endovascular treatment decision-making for UIAs across a wide spectrum of physician specialties and career stages, which is expected to be higher than in a selected group of experts, and our results clearly emphasize the need for more robust data on natural history and treatment-specific complication risks. One possibility to achieve this could be large international and national UIA registries, which would ideally be funded by governments or public funding agencies rather than by industry. Large, unbiased databases would also contribute to a better understanding of the clinical course of treated UIAs, since at the time being, there is relative paucity of data regarding success rates of endovascular UIA treatment strategies. In fact, there is not even a clear consensus on how "treatment success" should be defined. Complete aneurysm occlusion has been used as an imaging surrogate for treatment success in some trials, but this definition is controversial [10], partly because results from the International Subarachnoid Aneurysm Trial (ISAT) trial are somewhat inconclusive and could do not provide clear evidence for near-complete occlusion of ruptured intracranial aneurysms, which can often be achieved much more easily and safely, being inferior to complete occlusion in terms of preventing re-bleeds [4]. Of note, the comparison is limited since the ISAT trial included patients with ruptured intracranial aneurysms rather than UIAs. In the latter, it is even harder to know whether treatment was "successful" or "effective," because event rates without treatment are so low that it is challenging to determine a significant reduction in event rates following treatment. A large, prospective database could not only help to optimize interventional and surgical management of UIAs, it could also be used to determine additional prognostic factors that could be used for risk stratification, e.g., imaging features on vessel wall imaging, and to assess the benefit of medical therapies (e.g., treatment with antiplatelet agents). The lack of evidence regarding endovascular UIA management was reflected in the wide range of physicians' estimated treatment success rates. Median estimated success rates for aneurysms 4 and 5 were well below 90%, indicating that one should be cautious not to think of a treated UIA as one whose rupture risk is permanently eliminated.

Limitations

Our study has several limitations. First, participants of this survey were selected based on personal networks and academic collaborations, and they might therefore not be representative of the neurointerventional community as a whole. Furthermore, a multidisciplinary approach to UIA treatment is crucial, but the weighing of endovascular vs. surgical treatment options was not addressed in this paper, since we aimed to primarily investigate endovascular treatment approaches to UIAs. Thus, the target audience mostly comprised of neurointerventionalists rather than open vascular surgeons and/or dual-trained physicians. That being said, this manuscript is not in any way intended to promote one treatment option over another. Second, the case-scenarios that were used in this survey were simplified and did not describe an individual case in full detail with all the nuances that might be relevant for endovascular treatment decision-making in clinical reality. The limited information also prohibited a comparison of estimated rupture risks with risk stratification tools such as

the PHASES score [11]. Third, endovascular treatment technologies are constantly evolving, and neurointerventionalists' estimates of endovascular treatment complication and success rates might change when novel technologies and/or more sophisticated iterations of existing devices become available. Fourth, we did not address surgical treatment decision making in this study. Fifth, the case-scenarios provided no longitudinal information on aneurysm morphology, but it is known that changes in aneurysm shape and aneurysm growth over time influence the risk of UIA rupture [2].

Conclusion

The high variability in physicians' estimates of rupture risk, endovascular treatment complication, and treatment success rates in this survey shows that endovascular treatment decision-making in UIAs is characterized by a high degree of uncertainty. Our findings emphasize the need for more and better data on the clinical course of UIAs with and without preventive endovascular treatment.

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Compliance with ethical standards

Conflict of interest Johanna Ospel is supported by the University of Basel Research Foundation, Julia Bangerter Rhyner Foundation, and Freiwillige Akademische Gesellschaft Basel. The remaining authors have nothing to disclose. Mayank Goyal is a consultant for Medtronic, Stryker, Microvention, GE Healthcare, Mentice. The remaining authors have nothing to disclose.

Ethical approval For this type of study formal consent is not required.

Informed consent Informed consent was obtained from all individual participants included in the study.

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