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ORIGINAL ARTICLE - VASCULAR

Decision-making and neurosurgeons' agreement in the management of aneurysmal subarachnoid haemorrhage based on computed tomography angiography

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Abstract

Background To determine the neurosurgeon's agreement in aneurysmal subarachnoid haemorrhage (aSAH) management with special emphasis on the rater's level of experience. A secondary aim was to analyse potential aneurysm variables associated with the therapeutic recommendation.

Method Basic clinical information and admission computed tomography angiography (CTA) images of 30 consecutive aSAH patients were provided. Twelve neurosurgeons independently evaluated aneurysm characteristics and gave recommendations regarding the emergency management and aneurysm occlusion therapy. Inter-rater variability and predictors of treatment recommendation were evaluated.

Results There was an overall moderate agreement in treatment decision [κ = 0.43; 95% confidence interval ((CI), 0.387–0.474] with moderate agreement for surgical (κ = 0.43; 95% CI, 0.386–0.479) and endovascular treatment recommendation (κ = 0.45; 95% CI, 0.398–0.49). Agreement on detailed treatment recommendations including clip, coil, bypass, stent, flow diverter and ventriculostomy was low to moderate. Inter-rater agreement did not significantly differ between residents and consultants. Middle cerebral artery (MCA) aneurysm location was a positive predictor of surgical treatment [odds ratio (OR), 49.57; 95% CI, 10.416–235.865; $p < 0.001$], while patients aged >65 years (OR, 0.12; 95% CI, 0.03–0.0434; $p = 0.001$), fusiform aneurysm type (OR, 0.18; 95% CI, 0.044–0.747; $p = 0.018$) and intracerebral haematoma (ICA) aneurysm location (OR, 0.24; 95% CI, 0.088–0.643; $p = 0.005$) were associated with a recommendation for endovascular treatment.

Conclusions Agreement on aSAH management varies considerably across neurosurgeons, while therapeutic decision-making is challenging on an individual patient level. However, patients aged >65 years, fusiform aneurysm shape and ICA location were associated with endovascular treatment recommendation, while MCA aneurysm location remains a surgical domain in the opinion of neurosurgeons without formal endovascular training.

Keywords Subarachnoid haemorrhage · Inter-rater reliability · Inter-rater agreement · Neurovascular imaging · Aneurysm morphology · CT angiography

No parts of this manuscript have been presented previously

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Introduction

Aneurysmal subarachnoid haemorrhage (aSAH) has a high morbidity and mortality, and early aneurysm obliteration is crucial to prevent rebleeding within the first hours [24]. Therefore, physicians face an enormous responsibility regarding prompt treatment recommendations. Nowadays, direct aneurysm occlusion using open microsurgical or endovascular techniques is the "gold standard" to treat ruptured intracranial aneurysm and the treatment decision is usually a result of an interdisciplinary discussion [14]. It is already known that the treatment recommendation of cerebrovascular surgeons frequently deviates greatly from their endovascular trained colleagues [2, 4]. However, little is known about different treatment opinions among microsurgically trained neurosurgeons. While randomised controlled trials (RCTs) have shown the benefits and limits of each technique, decision-making on the individual patient level remains challenging [13, 22]. Several factors, including patient age, clinical status and radiological findings such as aneurysm location, shape and size, are known to influence treatment decisions [1, 2, 16, 18]. However, there is a lack of evidence concerning the importance of each factor, and the combination of these factors in a patient admitted to the emergency room needs to be integrated to manage individual patients adequately. Given the lack of clear evidence in these scenarios, treatment recommendations are heavily influenced by the neurosurgeon's experience, supported by expert opinion from specialised "cerebrovascular teams" or senior members of the team. Moreover, the management of common complications in aSAH such as hydrocephalus or intracerebral haematomas (ICHs) add to the complexity of a case. Altogether, the multi-dimensional process of the individual physician's decision-making is poorly understood and the level of agreement between multiple neurosurgeons is unclear [4, 11, 27].

The Swiss study of aSAH (Swiss SOS) promotes collaborative aSAH research on a national level [21, 28]. Within this network, we designed a study to determine the inter-rater agreement of common treatment recommendations in aSAH with a special emphasis on the neurosurgeon's level of experience. A second goal was to estimate the influence of relevant clinical and radiological variables on the neurosurgeon's decision-making in aSAH.

Material and methods

Hypothesis

The first hypothesis is that inter-rater agreement on decision-making in aSAH is generally good, but less distinctive among neurosurgery residents. The second hypothesis is that that factors like patient age, clinical status, aneurysm location and morphology are influencing the treatment decision.

Cases and raters

We included $n = 30$ consecutive aSAH cases admitted to the Department of Neurosurgery of the University Hospital Zurich between January and September, 2012. The only exclusion criterion was an absence of in-house computed tomography (CT) and CT angiography (CTA) data at admission, in order to ensure a patient sample representative of daily clinical practice. Six centres with expertise in the interdisciplinary treatment of aneurysms participated in the study: University Hospital Zurich, Cantonal Hospital Aarau, University Hospital Basel, University Hospital Geneva, University Hospital Lausanne and University Hospital Bern. At each centre, a resident (postgraduate year 1-5) and a vascular neurosurgeon (board certified neurosurgeon with vascular expertise and a minimum of 8 years of neurosurgical experience) performed a standardised evaluation between April and December, 2016.

Variables and image data read-out

CT and CTA data was anonymised and saved on a USB memory stick. Integration of a built-in DICOM Viewer (iQ-View Pro version 2.7.0, www.image-systems.biz) ensured standardised image presentation. Besides CTA data, the following clinical information from the admission status were provided: patient age, general health status before ictus [based on the modified Rankin Scale (mRS)], Glasgow Coma Scale (GCS) and World Federation of Neurological Surgeons (WFNS) grading scale, unilateral or bilateral pupil dilatation, sedation and intubation status. We asked each rater to analyse the cases independently. Raters were asked to describe the ruptured aneurysm location according to the following categories: ACOM, anterior communicating artery; ICA, internal carotid artery; MCA, middle cerebral artery; PCOM, posterior communicating artery; PC, including the posterior cerebral artery, the basilar artery, the superior cerebellar artery, the anterior inferior cerebellar artery, posterior inferior cerebellar artery and vertebral artery. Furthermore, each rater had to measure the maximum diameter, dome and neck of the aneurysm in millimetres, as well as to specify a fusiform aneurysm type (yes/no) and presence of an ICH (yes/no). Instructions or definitions on how to evaluate aneurysm morphology and size was not given, hence reproducing a realistic clinical situation. The results of the inter-rater agreement on aneurysm morphology had been reported previously [11].

Standardised case evaluation

The present study focused on the inter-rater agreement on SAH and aneurysm management. Based on the provided clinical information and the CT/CTA images, raters were asked to decide on the treatment that they considered best for the individual patient. Participating neurosurgeons were asked to choose between microsurgical, endovascular or no aneurysm occlusion therapy (conservative or palliative). If microsurgical treatment was recommended, each rater had to choose between the following detailed options: "direct" clipping or "complex" procedure with bypass (and trapping). If endovascular treatment was recommended, each rater was asked to choose between "direct" coiling (including balloon-assisted) or "complex" procedure including the deployment of a stent or flow diverter. Furthermore, raters had to decide whether ventriculostomy by external ventricular drain (EVD) and evacuation of an ICH was indicated, if present.

Statistical analysis

To test the first null-hypothesis, the inter-rater agreement for all neurosurgeons was measured using the Fleiss kappa analysis. The analysis was repeated for the subgroups of residents or consultants only. Kappa values were interpreted according to standard cutoffs established by Landis and Koch [10] with values of 0.99–0.81 indicating almost perfect agreement, 0.61–0.80 substantial agreement, 0.41–0.60 moderate agreement, 0.21–0.40 fair agreement and 0–0.20 no or slight agreement. To test the second null-hypothesis, we assumed the following variables as possible factors related to treatment decision based on clinical reasoning and available literature: raters experience (residents vs consultants), high WFNS grade (WFNS 4 & 5), patient age >65 years, aneurysm size >10 mm, dome to neck ratio <1.5, fusiform aneurysm type, presence of ICH and aneurysms location (ACOM, ICA, MCA, PCOM, PC) [4, 6, 17, 18, 20]. All variables were compared between groups (microsurgical vs endovascular) using a Pearson chi-squared test. To further determine these variables as possible predictors of treatment decision, binary logistic regression analysis was performed with microsurgical versus endovascular treatment as the dependent variable. Results were presented as odds ratio (OR) with 95% confidence interval (CI) for surgical treatment choice. All statistical analyses were performed using SPSS software, Version 23.0.0.0 (IBM, Armonk, NY, USA). A p value of <0.05 was considered statistically significant.

Ethical considerations

This was an analysis of prospectively collected anonymised data within the framework of a nationwide multicentre registry on patients with aSAH (Swiss SOS). The study was approved by the ethics committee in each participating centre (under the supervision of the Geneva institutional review board no. 11-233R, NAC 11-085R) [21].

Results

Twelve raters participated in the study including six neurosurgical residents with a mean neurosurgical experience of 3 years and six consultants with a mean experience of 13 years. Patient and aneurysm characteristics for the provided cohort of cases are illustrated in Table 1.

Table 1 Summary of patient characteristics

	Value
Sex (m/f)	7 (23.3%) / 23 (76.7%)
Median GCS (IQR)	13 (12)
mRS before ictus	
mRS 0–1	30 (100%)
mRS > 2	0 (0%)
WFNS grade	
Low grade (1–3)	15 (50%)
High grade (4–5)	15 (50%)
Intubated at admission (yes/no)	10 (33%) / 20 (67%)
Sedated at admission (yes/no)	11 (37%) / 19 (63%)
Pupils dilated (both/one side/no)	1 (3%) / 1 (3%) / 28 (94%)
Aneurysm location	
Acom	8 (27%)
ICA	4 (13%)
MCA	6 (20%)
Pcom	8 (27%)
PC	4 (13%)
Median aneurysm diameter in millimetres (IQR)	
Maximal	6.5 (3)
Neck	3.2 (1.1)
Dome	4 (2.6)
Dome/neck ratio	1.3 (0.5)
Aneurysm morphology	
Saccular	28 (93%)
Fusiform	2 (7%)
Presence of intracerebral haemorrhage	
Yes	6 (20%)
No	24 (80%)
Total	n = 30/100%

As documented during the patients' hospital stay

ACOM anterior communicating artery, *ICA* internal carotid artery, *IQR* interquartile range, *MCA* middle cerebral artery, *mRS* modified Rankin scale, *PCOM* posterior communicating artery, *PC* posterior circulation aneurysms, *SD* standard deviation

Inter-rater agreement in treatment decision

Inter-rater agreement in treatment and procedure decision for all neurosurgeons is displayed in Table 2. We found an overall moderate agreement in treatment decision, a moderate agreement for surgical and endovascular treatment and a fair agreement for conservative treatment choice. While there was a moderate agreement for clipping, there was a fair to low agreement for bypass, coiling only, stenting or flow diverter placement. The agreement for EVD placement was fair to low. Recommendation for ICH evacuation showed an excellent interobserver agreement. Table 3 depicts the result for inter-rater agreement, discriminated between groups of resident and consultant neurosurgeons. With closely overlapping CIs there was no significant difference in the agreement between the two groups.

Treatment and procedure choice

In total, endovascular treatment ($n = 207$, 58%) was favoured over microsurgery ($n = 142$, 39%) and conservative treatment ($n = 9$, 3%). Three out of 360 ratings had to be excluded from the analysis, since the observer did not detect an aneurysm responsible for the SAH and therefore could not decide on the type of treatment. With regards to the detailed treatment type, most raters proposed direct coiling ($n = 185$, 52%), followed by direct clipping ($n = 136$, 38%), and the raters were more restrained concerning complex types of aneurysm occlusion. Neurosurgeons recommended EVD placement 148/360 times (41%) and ICH evacuation 51/360 times (14%).

Table 2 Inter-rater agreement in treatment decision

	Fleiss' κ	Agreement	95% CI	*p* value
Treatment				
overall	0.43	Moderate	0.387–0.474	<0.001
surgical	0.43	Moderate	0.386–0.479	<0.001
endovascular	0.45	Moderate	0.398–0.491	<0.001
conservative	0.24	Fair	0.197–0.29	<0.001
Treatment detail				
clip	0.47	Moderate	0.423–0.516	<0.001
bypass	0.03	Slight	−0.13 - 0.080	0.154
coil	0.37	Fair	0.328–0.421	<0.001
stent	0.13	Slight	0.081–0.174	0.081
flow diverter	0.26	Fair	0.214–0.307	<0.001
EVD	0.40	Fair	0.351–0.439	<0.001
ICH evacuation	0.75	Substantial	0.709–0.797	<0.001

CI confidence interval, *EVD* external ventricular drainage, *ICH* intracerebral haemorrhage

Variables associated with treatment decision

For further analysis, ratings for conservative treatment ($n = 9$) and ratings in which the observer did not detect an aneurysm ($n = 3$) were excluded. The therapeutic decision was therefore dichotomised into microsurgical or endovascular treatment (Table 4). Patient characteristics revealed significantly less patients aged over 65 years of age, in which surgical treatment was recommended, compared to endovascular (2% vs 27%, $p < 0.001$). Assignment to microsurgical treatment was less frequent for fusiform aneurysm type (6% vs 14%, $p < 0.05$), but more frequent in the presence of ICH (37% vs 7%, $p < 0.001$). Regarding the aneurysm location, microsurgical treatment was much more often considered for MCA aneurysms (47% vs 1%, $p < 0.001$), while ICA (4% vs 27%, $p < 0.001$) and posterior circulation aneurysms location (4% vs 46%, $p < 0.001$) were significantly more often considered for endovascular treatment. All other factors were not different between proposed treatment type.

To determine the effect sizes, binary logistic regression was performed (Table 5). Patient age >65 years [odds ratio (OR), 0.12; 95% CI, 0.03–0.0434; $p = 0.001$], fusiform aneurysm type (OR, 0.18; 95% CI, 0.044–0.747; $p = 0.018$) and ICA aneurysm location (OR, 0.24; 95% CI, 0.088–0.643; $p = 0.005$) were significantly associated with endovascular treatment, while MCA aneurysm location was the only positive predictor of microsurgical treatment choice (OR, 49.57; 95% CI, 10.416–235.865; $p < 0.001$). Neurosurgeons' level of experience (residents vs consultants), WFNS grade, aneurysm size, dome/neck ratio, presence of ICH, PCOM and PC aneurysm location did not predict treatment modality within our model.

Discussion

The main finding of this study is that there is a substantial variability among neurosurgeons' recommendations regarding the best management of aSAH patients in the acute setting. Both categorical decisions (microsurgical vs endovascular aneurysm treatment), as well as the detailed treatment recommendations vary between neurosurgeons. Although our results need to be interpreted with caution, since raters were provided with only the initial CT/CTAs and a range of key clinical information, they reflect the current discussion on published RCTs examining the outcome between clipping versus coiling in ruptured aneurysms [9, 14, 22]. While these trials demonstrated a slight advantage for coiling over clipping especially in posterior circulation aneurysms, the results and weaknesses of each study have been fiercely debated [5, 8]. The randomised International Subarachnoid Aneurysm Trial (ISAT) included most patients and seemed to have had a great impact on the neurosurgical community. However, its

Table 3 Inter-rater agreement in treatment decision for neurosurgical residents and consultants

	Residents				Consultants			
	Fleiss' κ	Agreement	95% CI	*p* value	Fleiss' κ	Agreement	95% CI	*p* value
Overall	0.42	Moderate	0.331–0.504	< 0.001	0.39	Fair	0.295–0.48	< 0.001
Surgical	0.42	Moderate	0.331–0.516	< 0.001	0.39	Fair	0.287–0.482	< 0.001
Endovascular	0.42	Moderate	0.331–0.516	< 0.001	0.41	Moderate	0.314–0.508	< 0.001
Conservative	0.3	Fair	0.192–0.376	< 0.001	0.12	Slight	0.02–0.214	0.019

CI confidence interval

constraint of including only patients that would be suitable for both endovascular and surgical treatment (therapeutic equipoise) reduced the number of eligible cases from 9,559 to only 2,143 patients (22%), therefore limiting the applicability of the study to clinical practice [12]. The Barrow Ruptured Aneurysm Trial (BRAT), on the other hand, tried to overcome this dilemma by strictly randomising all referred aSAH patients to either surgical or endovascular treatment. However, before embarking on any randomly allocated treatment, involved physicians had the "right of first refusal" if the assigned treatment was felt to be inferior to the alternative. In those cases, the patient would cross-over to the other treatment modality [12]. Considering our present findings showed large inhomogeneity regarding the best treatment, it is most likely that the decision to "cross-over" would have varied widely between different neurosurgeons. The high level of disagreement over the treatment choice in our study reflects the difficulty that clinicians face in acute decision-making, as well as the vague and subjective interpretation of the criterion of therapeutic equipoise. Ultimately, this creates a selection bias which results in limited applicability of study results in clinical practice. If one defines a consensus in treatment recommendation as an agreement of at least 80% of polled raters, this consensus was reached in only 53% of cases within all raters in our cohort and 57% within consultants. Therefore, the question remains how to treat an individual patient if the immediate best therapeutic decision remains unclear. Our study does not provide answers to the questions raised, but points out an important issue in daily patient care.

When analysing the proposed aneurysm treatment in detail, there was moderate agreement between neurosurgeons

Table 4 Case characteristics by treatment choice

Characteristics	Treatment choice		*p*
	Surgical (*n* = 142, 41%)	Endovascular (*n* = 207, 59%)	value
Resident rater, *n* (%)	73 (41)	103 (59)	0.762
High WFNS (WFNS 4 & 5), *n* (%)	78 (45)	94 (55)	0.081
Patient age >65 years, *n* (%)	3 (5)	55 (95)	<0.001
Aneurysm size >10 mm, *n* (%)	13 (30)	31 (70)	0.108
Dome/neck ratio <1.5, *n* (%)	76 (42)	106 (58)	0.671
Fusiform, *n* (%)	8 (22)	29 (78)	<0.05
ICH, *n* (%)	53 (78)	15 (22)	<0.001
Aneurysm location, *n* (%)			
ACOM	38 (41)	53 (59)	0.809
ICA	6 (10)	55 (90)	<0.001
MCA	67 (91)	2 (9)	<0.001
PCOM	25 (32)	51 (68)	0.118
PC	6 (12)	46 (88)	<0.001

Conservative treatment choice excluded. Percentages of characteristics within each treatment choice as a share of the number in all non-conservative ratings (*n* = 349)

ACOM anterior communicating artery, *ICA* internal carotid artery, *ICH* intracerebral haemorrhage, *MCA* middle cerebral artery, *PCOM* posterior communicating artery, *PC* posterior circulation aneurysms including anterior inferior cerebellar artery, basilar artery, superior cerebellar artery and vertebral artery aneurysms

Table 5 Predictors of surgical treatment choice

Factor	OR (95% CI)	*p* value
Resident rater	1.26 (0.711–2.234)	0.428
High WFNS (>WFNS 3)	1.25 (0.658–2.36)	0.499
Patient age >65 years	0.12 (0.03–0.0434)	0.001
Aneurysm size >10 mm	1.08 (0.455–2.567)	0.861
Dome/neck ratio <1.5	1.14 (0.612–2.131)	0.676
Fusiform	0.18 (0.044–0.747)	0.018
ICH	1.74 (0.736–4.129)	0.206
Aneurysm location, *n* (%)		
Constant	0.53	0.097
ICA	0.24 (0.088–0.643)	0.005
MCA	49.57 (10.416–235.865)	<0.001
PCOM	0.79 (0.394–1.571)	0.496
PC	0.81 (0.234–2.82)	0.743

Binary logistic regression analysis

ACOM anterior communicating artery, *CI* confidence interval, *ICA* internal carotid artery, *ICH* intracerebral haemorrhage, *IQR* interquartile range, *MCA* middle cerebral artery, *OR* odds ratio, *PCOM* posterior communicating artery, *PC* posterior circulation aneurysms regarding the allocation to clipping. However, there was a distinctly lower agreement for endovascular treatment recommendation, including coiling and the deployment of a stent or flow diverter (Table 2). Contrary to the USA, in Europe endovascular aneurysm occlusion is commonly performed by interventional neuroradiologists. Since only one rater had formal training in interventional neuroradiology (D.Z.), it is conceivable that this trend can be explained by the lack of experience with these devices among the polled neurosurgeons. The results therefore highlight the value of interdisciplinary discussion when it comes to ruptured intracranial aneurysm treatment. It remains unclear from our data whether the agreement for "direct" coiling would have been higher among interventional neuroradiologists and neurosurgeons with training in interventional neuroradiology. It is of interest to note, however, that previous studies demonstrated high disagreement regarding the indication of flow diverters among neuroradiologists as well [3].

Contrary to what was assumed, agreement was not worse between residents when compared to experienced vascular neurosurgeons. Neither did we find a significant imbalance among residents towards one treatment choice (41% surgical vs 59% endovascular), therefore opposing a recent survey which found that residents favoured clipping over coiling [2]. The slightly higher tendency of residents towards endovascular treatment is stunningly identical to the treatment allocation within the overall cohort. This trend might show the successful implementation of recent RCTs within resident training programs and the fact that neurosurgeons do not a priori favour surgical treatment over coiling. Since the confidence intervals in both groups are a complete overlap no statistical significant difference between residents and consultants can be concluded. We believe that treatment decisions are based on two factors: education and experience. While one would intuitively expect inter-rater agreement to increase with experience, this hypophysis was not supported by our data. In our view, this finding illustrates the power of neurosurgical education by allowing residents to achieve similar homogeneity in treatment recommendation than their more experienced colleagues by following published guidelines. It is important to point out that within our study design we did not rate individual treatment choices based on a predetermined "correct" treatment option; therefore a comparison of the validity in therapeutic decisions between residents and consultants is not intended nor possible. While we do not doubt experienced surgeons evaluate a case in more depth than their younger colleagues, we, nevertheless, observed that this does not translate into a more uniform treatment recommendation.

The management of aSAH patients is not limited to the mere decision whether to clip or coil an aneurysm but includes the treatment of complications such as acute hydrocephalus or ICH. Our study demonstrated a high agreement regarding the evacuation of an ICH, if present. We observed a distinctive poorer agreement regarding the need to place an EVD. This is surprising at first since all raters were provided with relevant clinical data, including GCS score and WFNS grade as well as CT images. Nevertheless, a systematic review by Gigante et al. [7] illustrated a broad range of clinical and imaging features that favour EVD placement in published trials, which could cause diverging recommendations. Facing the lack of evidence for the optimal time for EVD placement and lack of definitive practice guidelines, this decision is dependent on institutional management principles and ultimately the attending physician.

If the best treatment option for an individual patient is unclear, decision-making becomes complex. On what basis does a neurosurgeon recommend a treatment? Published literature establishes several factors associated with an advantage for either surgical or endovascular treatment and therefore potentially influences a physician's therapeutic decision: patient's age, severity of the bleeding (WFNS), aneurysm's size, morphology and dome/neck ratio, as well as aneurysm's location [4, 13, 17, 18, 20, 22, 25]. Within our study, MCA aneurysm location was the single most important variable associated with microsurgical treatment choice (OR, 49.57; 95% CI, 10.416–235.865). Although MCA aneurysms within the ISAT cohort were under-represented due to the inclusion criteria (therapeutic equipoise), it was the only aneurysm location with a better outcome in the surgical cohort [14]. In the years following ISAT, several experienced neurovascular centres advocating surgical clipping as the principal treatment strategy for ruptured MCA aneurysms published their surgical outcomes, which compared favourably with endovascular results [19, 23, 26]. With only two allocations of endovascular treatment out of 69 individual MCA aneurysm treatment recommendations, neurosurgeons seem to have adopted this notion by highly favouring microsurgical treatment. While the presence of an ICH resulted in a higher rate of microsurgical treatment, it did not translate into a significant predictor of surgical treatment choice. On the other hand, ICA aneurysm location and fusiform aneurysm type resulted in significantly lower allocation to surgical treatment. In fact, within ISAT, outcomes in ICA aneurysms after 1 year of follow-up were shown to be highly in favour of endovascular treatment. Interestingly, patient age over 65 years was a significant predictor for endovascular treatment, in accordance with a subgroup analysis of elderly patients that indicated a better outcome in aSAH patients treated endovascularly, especially in good grade patients with anterior circulation aneurysms [20]. While PC aneurysms were significantly more often allocated to endovascular treatment (88% vs 12%, $p < 0.001$), this specific location did not seem to be associated with surgical treatment choice in multivariate logistic regression analysis. However, since there were only four patients with PC aneurysms in our cohort, this result would need to be confirmed in a larger cohort. When comparing the rate of ACOM aneurysms between surgical and endovascular treatment, our study interestingly showed the most balanced distribution between both treatment options (41% surgery vs 59% endovascular treatment), reflecting the ongoing discussion in neurosurgical literature about how to best treat ACOM aneurysms. In a recent subanalysis of all ACOM aneurysms within the BRAT trial, there was no significant difference in outcome based on treatment modality. The authors emphasise the heterogeneity in ACOM aneurysm morphology, as well as the need to evaluate every case individually [15].

Study limitations

Several limitations of this study need to be mentioned. For reasons of feasibility and to ensure a high attention from each neurosurgeon, we limited our patient sample to 30 cases. Moreover, decision-making in the setting of this study certainly differs from treating acute patients in the emergency setting. Since the clear majority of participating neurosurgeons do not personally perform endovascular aneurysm treatment (as this is mostly done by interventional neuroradiologists in Switzerland), the specific endovascular treatment recommendations should be interpreted with caution. We strongly believe in an interdisciplinary team approach in neurovascular decision-making and our results cannot be translated into the actual treatment decision. It is well known that open cerebrovascular and endovascular specialists frequently disagree in their recommended aneurysm treatment [2, 4]. Our goal was to analyse the homogeneity in treatment recommendation by microsurgically trained neurosurgeons with special emphasis on the neurosurgeon's level of experience. Assessing the rater's description of basic radiological characteristics for each case provided us with a deeper understanding of the reasons for an individual rating. It is certainly controversial to include residents in the evaluation of a treatment decision that requires experience and may best be taken by a team of particularly trained consultants. Nevertheless, by evaluating inter-rater agreement within each group separately (residents vs consultants), we could show that the agreement for treatment allocation did not increase with experience. Since only some (21/30) of our patients underwent digital subtraction angiography (DSA) before aneurysm treatment, we did not include DSA images into the analysis. Inter-rater agreement on aneurysm treatment might have been higher, if this additional information had been present. Finally, to better simulate a realistic clinical situation, we did not control for CT/CTA image quality, which could impact the treatment decision [11].

Conclusions

Inter-rater agreement of neurosurgeons is moderate to low regarding the best management of aSAH patients, when asked independently and provided with key clinical information and CT/CTA imaging data. Furthermore, inter-rater agreement does not increase among more experienced neurosurgeons. Within the cohort, therapeutic decisions follow general recommendations derived from published literature. Patients aged >65 years, fusiform aneurysm shape and ICA location were associated with endovascular treatment recommendation, while MCA aneurysm location remains a surgical domain. However, on an individual case level it seems that neurosurgeons follow subjective criteria for treatment decisions. These findings are important for several reasons. First, it implies that aSAH treatment varies greatly between different neurosurgeons and single-centre expertise. Second, it underlines the importance of better exploring and understanding the decision-making process in vascular neurosurgery. Finally, it might indicate the need for future treatment trials, taking into consideration that therapeutic equipoise may be a vague and subjective notion.

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Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organisation or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

For this type of study formal consent is not required.

This article does not contain any studies with human participants or animals performed by any of the authors.

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