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Anatomical configuration of the Sylvian fissure and its influence on outcome after pterional approach for microsurgical aneurysm clipping

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Abstract

Background: The sylvian fissure (SF) is the anatomical pathway used in a pterional approach, which leads to most aneurysms. There are four different anatomical variants of the SF described. In the present retrospective study the four different categories of the SF were studied in order to evaluate any correlation of these variants to surgical outcome.

Methods: Patients treated for intracranial aneurysms by a pterional transsylvian approach during 2003-2012 ($N = 237$) were included in the study. The SF category was determined by analysis of preoperative computed tomography (CT) scanning. Patients were grouped into unruptured intracranial aneurysms (UIA) and ruptured intracranial aneurysms with subarachnoid hemorrhage (SAH) according to the Hunt and Hess grades. Brain edema, vasospasms, ischemic lesion rate, and outcome were evaluated for possible correlation with SF anatomical variants.

Results: Postsurgically brain edema formation correlated significantly with more complex anatomical variants of the SF in patients with UIAs and in patients with Hunt and Hess 1 and 2. Ischemia rate, vasospasms, or clinical outcome was not negatively affected though.

Conclusion: The classification of the SF as proposed by Yasargil is more than a pure anatomical observation. In this retrospective study, we show that the anatomical variants of the SF can be associated to postoperative complications like formation of brain edema or ischemic lesions Preoperative knowledge of the SF anatomy and possibly consecutive adapted extend of the surgical approach can decrease procedure-related morbidity.

Key Words: Aneurysm, sylvian fissure, subarachnoid hemorrhage

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INTRODUCTION

The pterional approach to aneurysms of the circle of Willis is one of the most common approaches in vascular neurosurgery.[1-3] There are different variants of the pterional approach described, such as the orbito-cranial approach as an extended and the sphenoid ridge keyhole approach as a less invasive approach.[11,12] The aim of the pterional approach is to use a naturally occurring plane, through the sylvian fissure (SF), to approach an aneurysm without extensive brain retraction.[12] Yasargil described four different types of intraoperatively observed anatomical SF variants:[20] Category I is a straight wide SF, II a straight narrow SF, III a herniated frontal lobe into the SF and IV is a herniated temporal lobe into the SF. The SF categories used in the present work are based on the Yasargil classification with slight modifications since we categorized the SF on cranial computed tomography (CCT) scans and not anatomically.

A more complex SF anatomy could affect the surgical outcome by a pterional approach. In the present study, we aimed to analyze systematically the role of the anatomical variants of the SF and its influence on procedure-related complications like edema, ischemic lesions, and cerebral vasospasm and outcome. Furthermore, we considered the question of whether a complex SF anatomy affect postsurgical outcome and should play a role in the planning of the extend of the pterional approach to intracranial aneurysms.

MATERIALS AND METHODS

In this study, we retrospectively reviewed the charts of all patients with operatively treated aneurysms at our department from 2003 to 2012 ($N = 239$) by a classical pterional approach. The preoperative CCTs, digital subtraction angiograms (DSA) and CT angiograms (CTA), were evaluated to specify the anatomy of the SF as characterized by Yasargil. However, we slightly modified the classification to enable categorization on the CCTs (category I-IV)[20] [Figures 1 and 2] and to identify the aneurysms (localization, shape, size).

SF category I: Straight and wide or narrow, II: Wide fissure with herniation of the frontal or temporal lobe, III: Herniation of the frontal or temporal lobe and narrow SF and IV: Herniation of the temporal- and frontal-lobe into the fissure. The Fisher grade was evaluated on the CCT.[5] The postoperative CCT and CTA as well as DSA were studied to evaluate the degree of postoperative edema, ischemic lesions and occlusion rates of the aneurysms. The postsurgical CCT was performed 12-18 hours after surgery. The patient charts were evaluated in regard of demographic data and to specify the severity of bleeding in cases of subarachnoid hemorrhage (SAH). For classification of SAH we used the Hunt and Hess (HH) and the WFNS classification system.[7,8] The presence of vasospasms (diagnosed by transcranial Doppler, Mean flow velocity >120 cm/s) and ischemic lesions were taken into account. Ischemic lesions were defined as hypodensity on postoperative CCT 12-

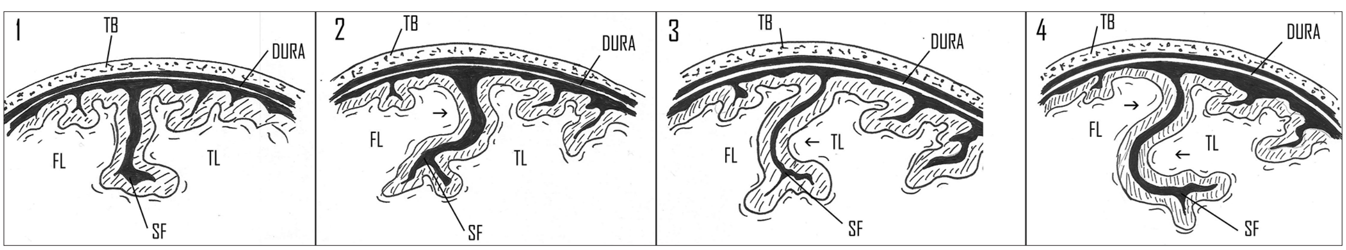


Figure 1: Sylvian fissure categories. 1: Straight wide or narrow SF; 2: Wide fissure with herniation of the frontal or temporal lobe; 3: Herniation of the frontal or temporal lobe and narrow SF; 4: Herniation of temporal and frontal lobe.
TB: Temporal bone, SF: Sylvian fissue, FL: Frontal lobe, TL: Temporal lobe, Arrow: Herniation of frontal or temporal lobe

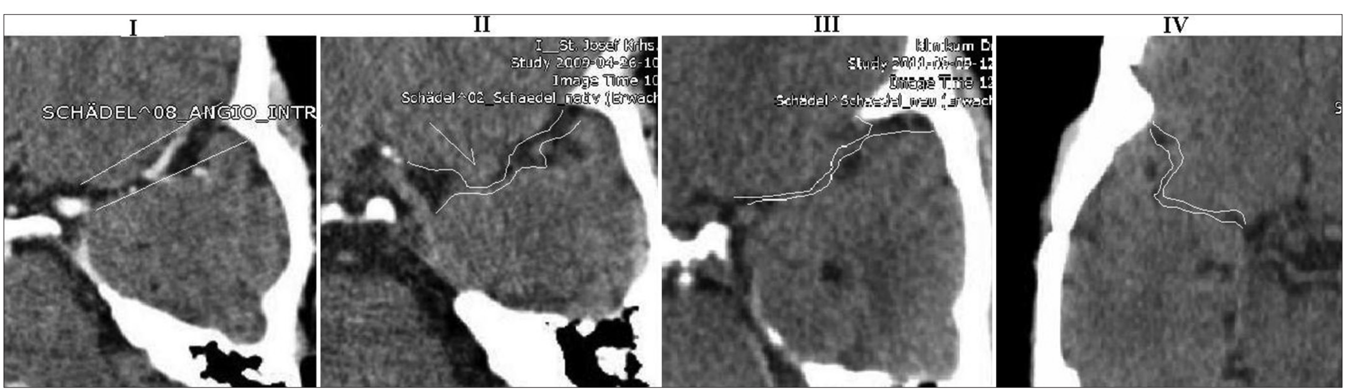


Figure 2: I: Straight and wide or narrow sylvian fissure. II: Wide fissure with herniation of the frontal or temporal lobe. III: Herniation of the frontal or temporal lobe and narrow sylvian fissure. IV: Herniation of the temporal- and frontal-lobe into the fissure

16 hours after surgery in retraction related and remote ischemic lesions. The outcome was evaluated according to the Glasgow Outcome Scale (GOS).[17] A GOS of 1 equals death, 2 apallic state, 3 severe neurological deficit, 4 mild neurological deficit, and 5 no neurological deficits.

The postoperative brain edema was categorized as 0: No edema, 1: Perifocal edema with maximum radius of 2 cm around the SF and 2: Severe edema with midline shift.[14]

The edema formation in patients with aneurysms treated surgically with aneurysm clipping through a pterional approach was evaluated for every SF category separately. Additionally the patients were categorized in patients with unruptured intracranial aneurysms ($N = 98$) (UIA) and those with SAH (HH grade 1 and 2 ($N = 48$), HH grade 3 ($N = 17$), HH grade 4 and 5 ($N = 76$)).

The anatomical variants of the SF were evaluated by considering the defined factors to identify the influence on postoperative imaging changes and clinical outcome.

To evaluate the distribution of patient age and SAH, the patients were categorized into different age groups: <40, 40 to <50, 50 to <60, 60 to <70, and >70 years. Aneurysm size was classified as <1, 1-2.5, and >2.5 cm.

Aneurysm shape was characterized as berry, multilobular, and fusiform.

All the patients were treated in the neuro-intensive care unit (neuro-ICU) and transcranial Doppler sonography has been performed daily for 5-14 days in cases of SAH.

All the aneurysms included in the study were clipped within 72 hours after bleeding.

Statistical analysis has been performed by Fisher's t-test, Chi-square, and analysis of variance (ANOVA). A statistical significant result represents a $P < 0.001$.

RESULTS

Anatomy of the sylvian fissure and edema formation after pterional approach to aneurysms

Patients with UIAs

In patients with UIAs ($N = 98$) 38 (38.8%) had a SF type I, 43 (43.9%) type II, 13 (13.3%) type III, and 5 (5.1%) patients had a type IV SF. In the SF type I group five patients had a mild edema and three suffered of severe brain edema. In SF type II group 10 patients had a mild and 1 a severe edema, in SF type III group 9 patients had a mild and 1 a severe edema, whereas in group IV none of the 5 patients had an edema. As shown in Figure 3a, the edema formation for patients in the category III was significantly higher than in the other groups.

Ischemic lesions occurred in four patients of group I, in nine of group II, in two of group III and zero in group IV [Figure 3b]. Despite the fact that edema

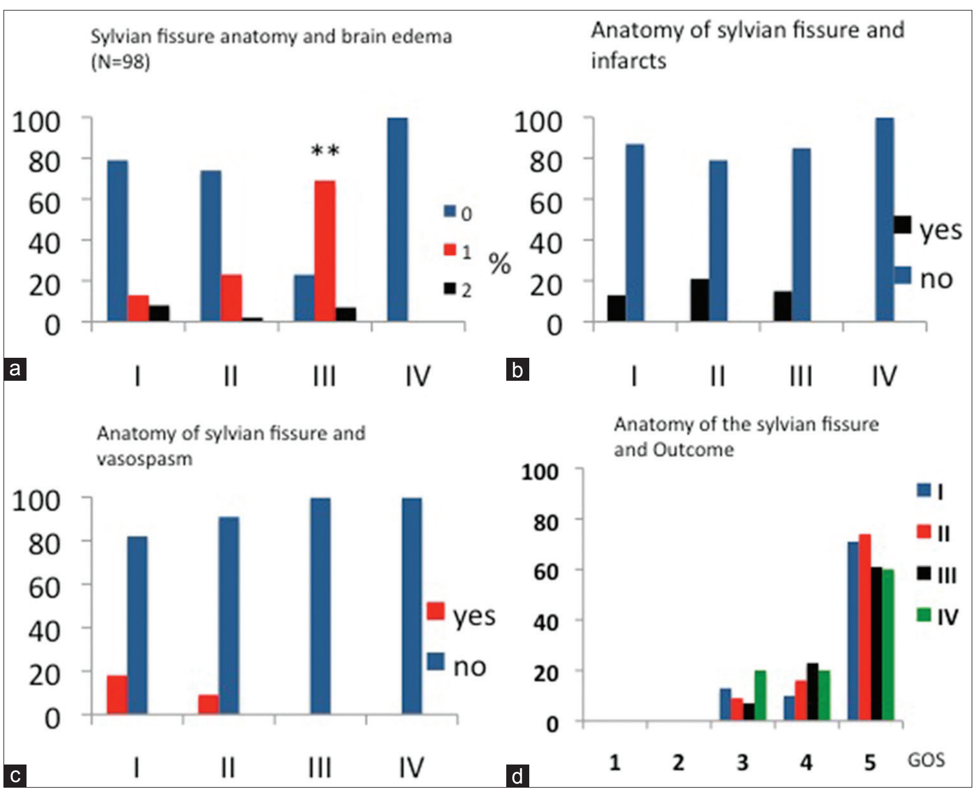


Figure 3: (a) The sylvian fissure category III is significantly correlated with a postsugical brain edema. (b) The categories of the sylvian fissure do not correlate with the infarction rate. (c) The vasospasm rate does not correlate with the sylvian fissure category. (d) The glasgow outcome scale does not correlate with the sylvian fissure category. Numbers are given as percentage(P<0.001)**

formation was statistically significant higher in group III there was no statistical difference in the occurrence of ischemic lesions between the four defined groups.

The rate of transient vasospasm without occurrence of delayed cerebral ischemia (DCI) in patients operated on UIAs was low (N = 11, 11.2%): Seven in group I, four in group II. None of the patients in groups III and IV developed vasospasms. The differences between the groups were not statistically significant [Figure 3c].

The postoperative outcome of the patients was almost similar for all four groups without any statistically significant difference. Thirty-three patients in group I had a good outcome (GOS 4 and 5) and five had a severe neurological deficit. In group II, 39 patients had a GOS of 4 and 5 and 4 a GOS of 3, in group III 12 patients had a GOS of 4 and 5 and 1 a GOS of 3. In group IV one patient had a GOS of 3 and 4 a GOS of 4 and 5 [Figure 3d].

The edema formation was not associated with a higher incidence of ischemic lesions in the studied groups. There was a trend showing an association of severe edema (grade 2) and vasospasm but a statistical significant result could not be proven since the patients with edema and spasms or ischemia or both were very few to allow a reliable statistical analysis.

Table 1 illustrates the characteristics of the 15 patients with ischemic lesions after surgery. As can be seen eight patients after evidence of ischemic lesions on CCT had still a GOS of 4 and 5 indicating clinically silent imaging hypodensity. However, the remaining seven patients with ischemic lesions had a GOS 3. Ischemic lesions occurred beneath the vessel from which the aneurysm originated in nine cases, possibly caused by surgical rupture of small perforating vessels. Remote ischemic lesions occurred in six patients. In this group, five patients belonged to SF group II and one to group I.

Patients with SAH, HH 1 and 2

In patients with SAH HH 1 and 2 (N = 48) 26 had a SF type I, 14 type II,7 type III and only 1 patient had a type IV SF. In the SF group I 1 patient had a mild edema and 4 suffered of severe brain edema. In category II, four patients had a mild and three a severe edema, in category III one patient had a mild, and three a severe edema, whereas in group IV the one patient had no edema. As shown in Figure 4a, the edema formation for patients in the category I was significantly lower than in the other groups.

Four patients of group I, two of group II, two of group III, and 0 of group IV developed an ischemic stroke [Figure 4b]. Despite the fact that edema formation was statistically significant higher in groups II and III there was no statistical difference in the occurrence of brain infarction between the four groups.

The rate of vasospasm in patients operated on ruptured aneurysms in HH 1 and 2 was higher compared with patients with UIAs (31/48 vs. 11/98, P < 0,001). Fifteen patients of group I, 11 of group II, 4 of group III, and 1of group IV had vasospasms. The differences between the groups though were not statistically significant [Figure 4c].

The postoperative outcome of the patients was almost similar for all four groups without any statistically significant difference. Twenty-four patients of group I had a good outcome (GOS 4 and 5) and two had a severe neurological deficit. In group II, 13 patients had a GOS of 4 and 5 and 1 a GOS of 3. In group III, 12 patients had a GOS of 4 and 5 and 1 a GOS of 3 and in group IV the patient had a GOS 5 [Figure 4d].

Similarly, in this group the edema formation was not associated with a higher incidence of ischemic lesions or vasospasms or both in the studied groups.

Table 1: Characteristics of brain infarcts in non SAH patients

Sylvian Fissure category	Edema grade	Aneurysm localisation	Shape (size)	Infarcted artery	Age	GOS
II	2	MCA (R)	Berry (<1cm)	Superior cerebellar artery (R)	49	4
I	0	MCA (L)	Berry (<1-2,5cm)	MCA (L)	49	3
II	2	AcomA (R)	Berry (<1cm)	MCA (R)	55	3
I	2	MCA (R)	Berry (1-2,5 cm)	MCA (R)	66	3
II	0	MCA (L)	Berry (<1cm)	MCA (L)	57	3
I	0	MCA (R)	Berry (<1 cm)	MCA perf (R)	57	5
II	0	MCA (L)	Berry (<1cm)	MCA (L)	54	5
I	1	MCA (L)	Berry (<1cm)	MCA perf (L)	49	3
II	1	PcomA (R)	Berry (<1cm)	MCA (R)	34	5
II	1	MCA (R)	Berry (<1cm)	MCA perf (R)	26	5
II	1	AcomA (L)	Berry (<1cm)	MCA perf (L)	52	5
I	1	MCA (L)	Berry (<1cm)	ACA (L)	52	3
III	1	MCA (R)	Berry (<1cm)	MCA perf (R)	56	4
II	0	ICA (L)	Berry (>2,5 cm)	MCA perf (L)	56	4
III	2	MCA (L)	Berry (<1cm)	MCA perf (L)	56	4

MCA: Medial cerebral artery, ACA: Anterior cerebral artery, AcomA: anterior communicating artery, PcomA: Posterior communicating artery, (R): Right, (L): Left, Perf.: Perforating artery, GOS: Glasgow outcome scale, SAH: Subarachnoid hemorrhage

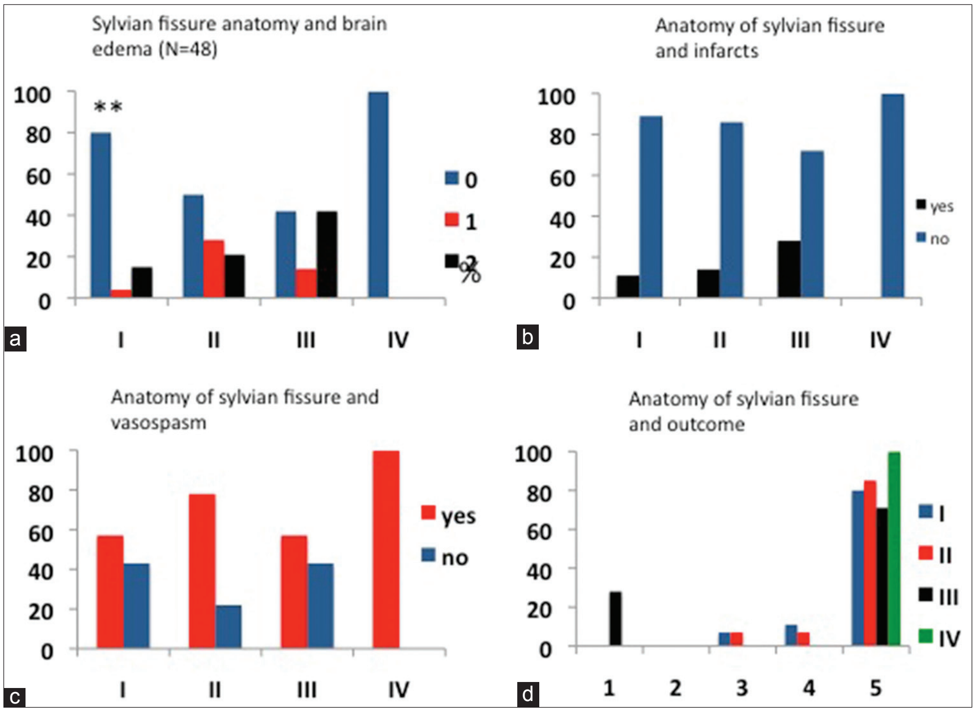


Figure 4: (a) The sylvian fissure categories II and III are significantly correlated with a postsugical brain edema. (b) The categories of the sylvian fissure do not correlate with the infarction rate. (c) The vasospasm rate does not correlate with the sylvian fissure category. (d) The glasgow outcome scale does not correlate with the sylvian fissure category.Numbers are given as percentage (P<0.001)**

Table 2 illustrates the characteristics of the eight patients with ischemic lesions after surgery. As can be seen, four of eight patients after ischemic lesions had still a GOS of 4 and 5 indicating that the hypodensity on CT scanning was asymptomatic. Two of eight patients had a GOS 3 and the remaining two patients died, as result of SAH and its complications and not related to the opening of the SF. In this group we observed five local hypodensities on CT scanning and three remote ischemic lesions. In the latter subgroup the patients belonged to the SF group II or III. The remaining ischemic lesions were possibly caused by surgical rupture of small perforating vessels.

Patients with SAH HH 3-5

An association between the SF anatomy and edema formation, as well as ischemic and vasospasm rate could not be seen in patients with SAH HH3 (N = 17) or HH 4 and 5 (N = 76). The rate of brain edema in HH3 was 6/9 in SF group I patients, 1/2 in group II, 2/3 in group III and 1/1in group IV.

In the HH 4 and 5 group, the edema rate was high through all the SF groups indicating the severity of the initial bleeding as a crucial factor masking the anatomical variants of the SF. Twenty-one of thirty-six patients had a severe edema in SF group I, 20/24 in group II, 6/9 in group III and 5/7 in group IV. No statistical correlation between SF category and edema could be seen. Similarly, in SF category I 16/36 patients, 15/24 in category II, 4/9 in category III and 4/7 in category IV developed ischemic lesions, being statistically insignificant.

Table 2: Characteristics of brain infarcts in SAH HH 1 and 2 patients

Sylvian Fissure category	Edema grade	Aneurysm localisation	Shape (size)	Infarcted artery	Age	GOS
I	0	MCA (L)	Berry (<1 cm)	MCA perf (L)	52	5
I	0	AcomA (R)	Berry (<1cm)	ACA(R)	71	3 (edema pre-surgically)
I	2	MCA (R)	Berry (<1cm)	MCA (R)	52	4
I	0	MCA (R)	Berry (<1 cm)	MCA perf (R)	73	4
II	2	MCA (R)	Berry (<1cm)	MCA (R)	60	5
II	2	MCA (R)	Berry (<1cm)	MCA (L)	55	3
III	0	ICA (R)	Berry (<1cm)	MCA (R)	79	1
III	2	MCA (L)	Berry (<1cm)	ACA, MCA (R) and (L)	52	1

MCA: Medial cerebral artery, ACA: Anterior cerebral artery, ICA: Internal cerebral artery, AcomA: Anterior communicating artery, PcomA: Posterior communicating artery, (R): Right, (L): Left, Perf.: Perforating artery, GOS: Glasgow outcome scale, SAH: Subarachnoid hemorrhage

General characteristics of the patient groups UIAs, HH 1 and 2, HH 3-5

Patient's age

The highest incidence of diagnosed UIAs was in the age group 50 to <60 years (40/98) (P < 0.001, Suppl. Figure 1). The youngest patient was a child of 5 years. For SAH HH 1 and 2 (14/48) and HH 3 (6/17) this age group was also the one with the highest number of patients. Only in HH 4 and 5 more patients were in the age group of 40 to <50years (24/76) but the difference to the group of 50 to <60 (21/76) was not statistically significant [Suppl. Figure 1].

Aneurysm shape and size

In all groups berry aneurysm shape was the most common (P < 0.001) [Suppl. Figure 2]. Of the 98 patients, the size of the aneurysm in the UIA group was <1 cm in 80 patients, 1-2.5 cm in 15 patients, and >2.5 cm in 3 patients. In SAH HH 1 and 2 47 aneurysms were <1 cm and only one was >2.5 cm. In SAH HH 3 87% had an aneurysm <1 cm. In SAH HH 4 and 5 90% of patients had an aneurysm <1 cm. There was a statistically significant number of small aneurysms (<1 cm) in the studied patient population. The shape and size of the treated aneurysms was similar in all the patient groups irrespective of the HH grade or in UIAs.

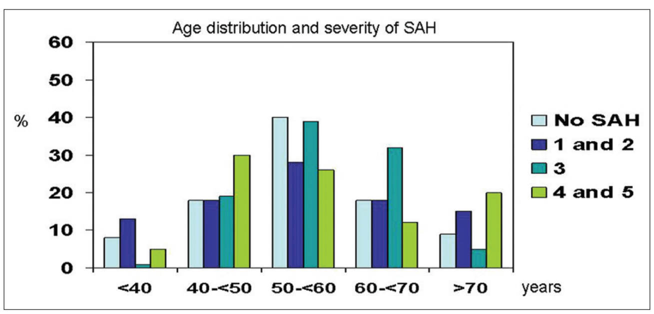
Aneurysm location

As shown in Suppl. Figure 3, most of the surgically treated aneurysms were medial cerebral artery aneurysms (P < 0.001). There is conformity of the aneurysm localization of surgically treated aneurysms through all the studied groups.

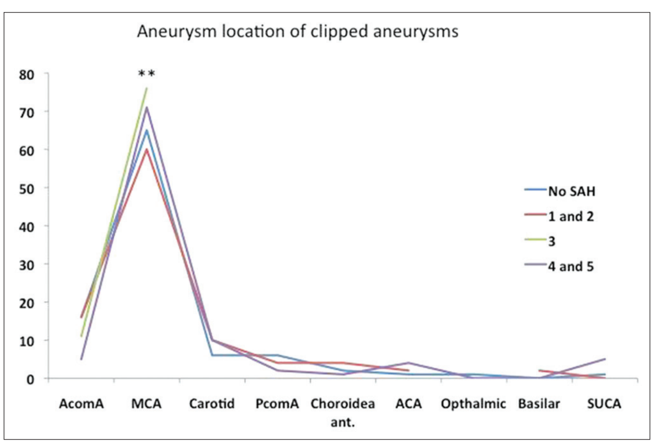
Vasospasms and ischemic lesions

After surgical treatment of patients with UIAs, 11.2% had vasospasms on transcranial doppler. In HH 1 and 2 the vasospasm incidence increased to 67% (P < 0.001 HH 1 and 2 vs. UIAs). In HH 3 66% of patients had vasospasms, in HH 4 81% and in HH 5 the incidence was likewise 81%. The vasospasm rate was as expected the highest in HH 4 and 5. There was a statistically significant higher number of ischemic lesions in the HH 5 patients compared with all other groups (49%, P < 0.001) [Suppl. Figure 4].

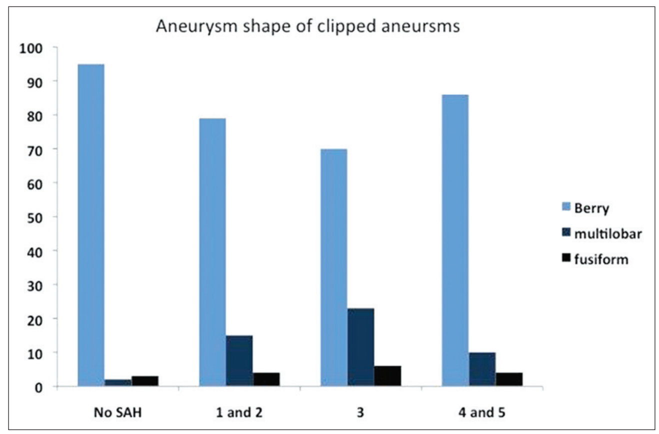
In HH group 1 and 2, 22/98 patients had Fisher 3 and 4



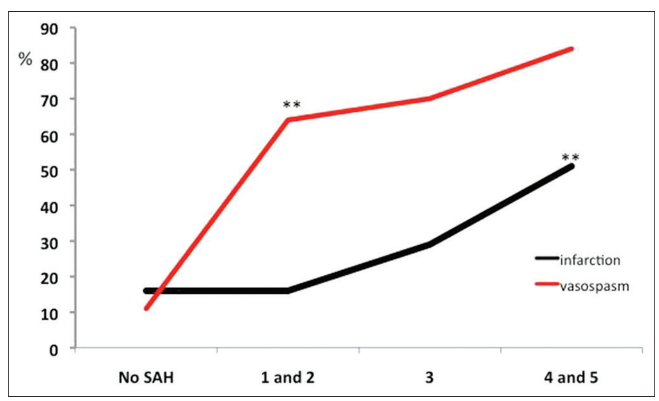
Suppl. Figure 1: Age distribution and SAH. **Patient age of 50 to <60 years is significantly higher represented in all the patient groups with slight exception of HH 4 and 5 where the age of 40 to <50 and 50 to <60 years is equally distributed. Numbers are given as percentage**



Suppl. Figure 3: Location of surgically treated aneurysms. Most of the treated aneurysms were media cerebral artery aneurysms (P**<0.001).Numbers are given as percentage**



Suppl. Figure 2: Aneurysm shape in the studied group. **The aneurysm shape is equally distributed through all the groups. Berry aneurysms are represented at significantly higher number.Numbers are given as percentage**



Suppl. Figure 4: Association of SAH severity, vasospasm and infarction. **The rate of vasospasm (red line) is increasing significantly when bleeding occurs. Even when vasospasm rate increases significantly in HH 1 and 2 the infarction rate in this group is similar to incidental aneurysms without bleeding which has a low number of patients with spasms. The vasospasm rate is not rising significantly from H 1 and 2 to HH 4 and 5 but the infarction rate rises significantly in HH 4 and 5 (**P**<0.001).Numbers are given as percentage**

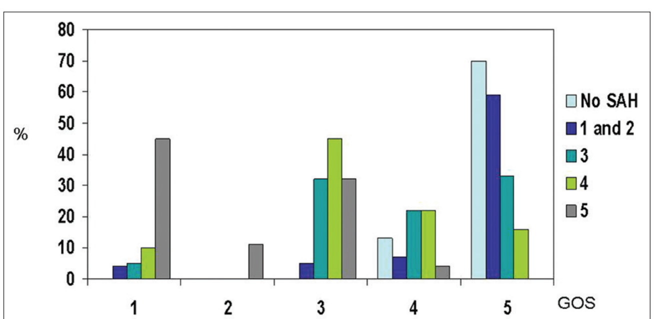
bleeding, the remaining patients (67/98) had Fisher 1 and 2 bleeding. In HH 4 and 5 74/76 patients had Fisher 4 and 2/76 had a Fisher 3 bleeding. None had Fisher 1 or 2 bleeding ($P < 0.001$ for more severe bleedings and higher Fisher grade in HH 4 and 5).

Outcome

Suppl. Figure 5 illustrates the outcome of the treated patients in the different patient groups. Patients with UIAs had a very good outcome with a high number of patients in GOS 4 and 5. In HH 5 patients the mortality rate was almost 50% (27/57) and significantly higher than in any other patient groups. Even patients in HH 4 had a much lower mortality rate (2/17). In the HH4 group there were 7/17 patients with a GOS of 4 and 5, whereas in the HH5 group only 3/57 patients had a good outcome with a GOS of 4 and none had a GOS of 5.

DISCUSSION

Yasargil described four anatomical variants of the SF.[20] The different anatomy of the SF could be a factor for obstacles during the pterional approach to aneurysms. In the present study, the anatomical variants of the SF were determined on preoperative CCTs and correlations of the different anatomical categories with the patients postoperative outcome had been studied. In patients with UIAs or in patients with an SAH HH 1 or 2 the anatomy of the SF played a significant role in the formation of postoperative brain edema. We observed formation of brain edema more frequently in the categories II and III. The rate of ischemic stroke, however, or occurrence of DCI did not seem to correlate with the SF variants, rendering other factors responsible for DCI like vasospasms, injury of veins during surgery, or injury of perforating arteries.[10] DCI has a huge number of factors that can be responsible for its occurrence, but the SF anatomy seems to be excluded of list of triggers.[18,19] Additionally, the outcome of patients based on the GOS does not seem to correlate with the SF anatomy. Nevertheless, the clear correlation of more complex SF anatomical variants with brain edema cannot exclude the logical implication of such an edema in worsening the formation of a delayed neurological deficit in collaboration with other cofactors. Since different approaches to aneurysms are described, which are based on the pterional approach and use the SF as their pathway, the anatomical variants of the SF as seen on the preoperative CCTs should be taken into consideration when the extend of the pterional approach is planned. In a complex anatomical variant of the SF, a sphenoid ridge keyhole approach as described by Nathal *et al.*,[12] should be avoided and in these cases maybe a more extended orbito-cranial or the supraorbital-pterional approach should be considered as a more suitable approach to avoid brain retraction.[2,4,11]



Suppl. Figure 5: Severity of SAH and patient outcome. The outcome in HH 5 is significantly worse compared with all other groups of patients with SAH (P<0.001). Numbers are given as percentage**

In contrast, the role of neuroanesthesia helps tremendously in reducing brain tension and promoting a slack brain.[15] Keyhole approaches like the lateral supraorbital approach, which is extensively and successfully used by Hernesniemi,[6,9,16] avoids the approach through the SF and irrespective of the SF anatomy approaches the aneurysms immediately subfrontally. The SF is only partially open. Projecting the CTAs in the direction of the approach can also be of substantial help for the preoperative planning.[13]

In the present study we did not focus on the implication of SF anatomy/edema formation and different surgical approach strategies, although this is a subject, which would be interesting to study.

Another interesting point considering the anatomy of the SF is the preoperative knowledge of the anatomical variant for neurovascular surgeons in training. SF category 3 and 4 requires more brain retraction to reach the aneurysm lying in a complex SF. Hence, complex SF anatomy should not be the first surgical experience for the neurovascular rookie. SF category I is the easiest anatomical variant to approach an aneurysm and can be more suitable for a neurosurgeon who just started clipping procedures. The preoperative examination of the CCTs allows a safe identification of the SF anatomy and this anatomical variant should be always taken into consideration when planning the approach to the aneurysm in order to avoid complications.

As already shown in the pioneering reports of Fisher[5] and Hunt and Hess[7,8] and confirmed by many others, the Fisher grade of an SAH as well as the HH grade are negative prognostic factors. In the analysis of our patients treated on SAH we also showed, in accordance to the well-known literature, that the amount of blood as well as the HH grade significantly increase the rate of vasospasm and DCI, as well as the mortality rate. It is interesting that HH 4 has a much less mortality rate than HH grade 5.

Other factors like patient age, aneurysm location, shape, and size were similar between the studied groups showing a satisfying conformity of the studied groups.

CONCLUSION

The classification of the SF as proposed by Yasargil is more than a pure anatomical observation. In this retrospective study, we show that the anatomical variants of the SF can be associated to postoperative complications like formation of brain edema or ischemic lesions. Preoperative knowledge of the SF anatomy and possibly consecutive adapted extend of the surgical approach can decrease procedure-related morbidity.

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