Influence of the Perianeurysmal Environment on Rupture of Cerebral Aneurysms
Preliminary Observation

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Summary

We evaluate the perianeurysmal environment and study parameters potentially influencing rupture of cerebral aneurysms. 101 consecutive aneurysm cases were retrospectively evaluated using radiological observation including imaging documents such as MR, CT and DSA studies. Aneurysm contact with perianeurysmal environment was classified and correlated with aneurysm shape, size, location and likely rupture point. Topographic relation of the aneurysm to the cisternal compartment was studied. Presence of contact with the surrounding structures was evaluated for bone, dura, brain, cranial nerves, arteries, and veins.

The aneurysm shape and likely rupture point was found to be significantly influenced by the aneurysm environment. Depending on aneurysm type, location and size, the growth pattern also exhibited signs of interaction with the environment. Overall, there was no significant difference in the largest average diameter of the dome of ruptured (7.8 mm) and unruptured (6.7 mm) aneurysms. When compared to unruptured aneurysms (6/42), the presence of a bleb was more frequent in ruptured aneurysm (41/59).

The perianeurysmal environment was found to have a significant influence on aneurysmal rupture pattern, whenever direct contact between the aneurysm and the anatomical structures in the perianeurysmal environment was visualized. This influence was independent of aneurysm size. Aneurysm size seems to be a poor indicator for the risk of rupture when compared to shape of the aneurysm and the degree of direct contact with the perianeurysmal environment.

Introduction

Cerebral aneurysms are pathological outgrowths of localized weak parts of the arterial vessel wall and are thought to grow secondarily in areas of weakened wall structures. The primary condition leading to the development of a weakness in the wall at the vessel's bifurcation might be related to a congenital disposition. This could explain the occurrence of the increased number of aneurysms found in conditions such as polycystic kidney disease [1,2]. Cerebral saccular aneurysms are typically found at sites of arterial branching and are most frequently located on main cerebral arteries close to the skull base [3]. The intrathecal location of aneurysms implies a lack of surrounding structures and the subsequent free exposure of the arteries to the subarachnoid space [3].

Aneurysm growth and shape are mainly considered to be influenced by flow dynamics and strength of the wall[3-7]. Rupture of the aneurysm seems to be mainly related to flow and pressure conditions, whereas the presence of areas of thin walls is considered an additional factor for risk of rupture[8]. Such areas of thin aneurysm wall may lead to the formation of daughter aneurysms (blebs) that account for the irregular shape of these aneurysms. Sites of blebs are therefore considered as indicators of increased risk of rupture.

In presence of multiple aneurysms, clinical trials show an association between high bleeding risk and more proximal aneurysm location, increased aneurysm size and irregular aneurysm shape[4,9-14].

These factors seem to govern the risk of rupture and may fit the concept in which blood flow, blood pressure and aneurysm wall thickness are the dominant parameters for the growth and evolution of an aneurysm.

However, as for every pathological situation where physical parameters determine the evolution of the disease, in cases of cerebral aneurysms, the external factors affecting the environment should also be considered. The purpose of this retrospective analysis is to evaluate a series of 101 consecutive cases of cerebral aneurysms to study the potential factors that influence the outside of an aneurysm. The term perianeurysmal environment is introduced to group the anatomical structures and landmarks surrounding and affecting the growth and rupture of cerebral aneurysms.

Material and Methods

A series of 101 consecutive saccular cerebral aneurysms were retrospectively evaluated in 77 patients using radiological observations, including imaging documents produced by MR, CT and DSA studies.

All cases were examined using CT before and after use of intra-venous bolus injection of contrast material.

A vessel reconstruction based on axial CT image acquisition permitting a CT-angiography (CTA) was available in slightly more than half of the cases. In the majority of the cases (89) angiographic (DSA) evaluation was performed.

In our center there is, however, a trend towards reduction in the use of DSA for emergency diagnosis of subarachnoid hemorrhage, and a more widespread use of CTA. In a limited number (18), MRI and MRA data were available as well.

Aneurysms were analyzed on all available radiological documents in regard to their location, size, shape, implantation on the arterial tree, direction of their development and presence of wall irregularities (irregular shape, or bleb, or both).

The presence of irregular shape was opposed to the presence of regular round or oval aneurysm shape. Type of hemorrhage, initial Glasgow coma scale (GCS) rating, WFNS grade, Fisher grade, and presence of concomitant aneurysms was recorded. Contact between aneurysmal wall and brain, dura, bone, vessels and nerves was evaluated in the study of the perianeurysmal environment.

The influence of the perianeurysm environment on an aneurysm was qualified as "balanced" or "unbalanced" according to the symmetry or the asymmetry of the forces exerted by the structures within the perianeurysmal environment on the aneurysm. The likely point of rupture was identified in cases where a bleb was present.

Results

This study of 101 aneurysms included 77 patients (40 females, 37 males) with an average age of 52.6 years (range: 20-81 years). The series is representative of the average two year recruitment of a medical center offering surgical and endovascular treatment modalities under regular and emergency conditions.

Clinical and epidemiological information

Hemorrhage was the presenting symptom in 59 patients (average age 52 years) with presence of subarachnoid hemorrhage (SAH) in 59 patients, presence of intraparenchymous hemorrhage (IPH) in 22 patients, and presence of intraventricular blood in 27 patients, as observed on the initial CT study. Fisher grading of hemorrhage as seen on CT revealed an average of 3.4 (range: 1-4). Initial clinical evaluation of patients presenting with hemorrhage revealed an average Glasgow coma scale value of 12.1 (range: 4-15) and an average WFNS grade of 2.5 (range: 1-5). In these 59 patients (29 fe-

Table 1 **Evaluation of ruptured aneurysms**

Location	number	av. max diam.*	contact with brain	dura	bone	artery	vein	nerve	influence of external environment none	balanced	unbalanced
pericai A	2	5.5	2	0	0	0	0	0	0	0	2
MCA	9	5.8	6	0	0	1	0	0	3	0	6
AcomA	22	6.6	13	3	3	1	0	11	6	0	16
ICA bif	2	3.5	1	0	0	0	0	0	1	0	1
ICA-AchA	1	3	0	0	0	0	0	0	1	0	0
ICA-PcomA	18	9.8	10	14	13	5	3	6	2	0	16
ICA-Ophth	0		0	0	0	0	0	0	0	0	0
ICA-SHP	1	6	0	1	0	0	0	0	0	0	1
ICA-cavern	0		0	0	0	0	0	0	0	0	0
BA bif	4	14	3	0	0	1	1	1	1	0	3
BA-SCA	0		0	0	0	0	0	0	0	0	0
Total	59	7.8	35	18	16	8	4	18	14	0	45

**av.max.diam. = average maximum diameter of the aneurysmal dome; perical A = pericallosal artery; MCA = midle cerebral artery; AcomA = anterior communicating artery; ICA bif = internal carotid artery bifurcation; AchA = anterior choroidal artery;PcomA = posterior communicating artery; Ophth = ophthalmic artery; SHP = superior hypophysial artery; cavern = cavernous sinus; BA bif = basilar artery bifurcation; SCA = superior cerebellar artery*

males, 30 males) imaging revealed 18 additional unruptured aneurysms.

Three patients presented with mass effect and the remaining 21 aneurysms (15 patients) were found either incidentally or during evaluation of patients with polycystic kidney disease. The average age of the 18 patients (11 females, 7 males) without history of hemorrhage was 56 years.

Aneurysm location and sizes

The distribution of the aneurysm location and the frequency of the aneurysms in this location are displayed on table 1 and 2. Ruptured aneurysms exhibited average dome size measurements for the longest aneurysm diameter of 7.8 mm (range: 2-26 mm), and of 6.2 mm and 5.5 mm for the two other axes respectively. The neck dimensions averaged 3.3 x 2.5 mm in ruptured aneurysms.

Accordingly, unruptured aneurysms exhibited average dome size measurements for the longest aneurysm diameter of 6.7 mm (range: 1-30 mm), and of 5.6 mm and 5.0 mm for the two other axes respectively. The neck dimensions averaged 3.3 x 2.6 mm in unruptured aneurysms.

Perianeurysmal environment

The evaluation of the perianeurysmal environment revealed contact with the tissues as defined above (see table 1 and 2) with the highest number of contacts seen with posterior communicating artery (PCOMA) aneurysms.

In the group of 59 ruptured aneurysms interaction between aneurysm and environment was found to be as follows: in 14 cases there was no conflict between aneurysm and environment; in 45 cases the aneurysm was exposed to unbalanced forces coming from the environment; and there were no cases of aneurysms exposed to balanced forces.

In the group of 42 unruptured aneurysms interaction between aneurysm and environment was found to be as follows: in 25 cases there was no conflict between aneurysm and envi-

Table 2 **Evaluation of unruptured aneurysms**

Location	**number**	**av. max diam.***	**contact with** brain	dura	bone	artery	vein	nerve	**influence of external environment** none	balanced	unbalanced
pericalA	1	3	0	0	0	0	0	0	1	0	0
MCA	17	6.5	7	1	0	0	0	0	10	5	2
AcomA	3	5.3	1	0	0	0	0	0	2	1	0
ICA bif	1	4	0	0	0	0	0	0	1	0	0
ICA-AchA	5	3	0	0	0	0	0	0	5	0	0
ICA-PcomA	2	13.5	1	1	1	1	0	0	1	0	1
ICA-Ophth	5	5	2	2	0	0	0	1	2	2	1
ICA-SHP	3	5	0	2	0	0	0	0	1	2	0
ICA-cavern	2	16	0	2	1	1	0	1	0	2	0
BA bif	2	14.5	1	0	0	0	0	0	1	1	0
BA-SCA	1	3	0	0	0	0	0	0	1	0	0
Total	42	6.7	12	8	2	2	0	2	25	13	4

**av.max.diam. = average maximum diameter of the aneurysmal dome; perical A = pericallosal artery; MCA = midle cerebral artery; AcomA = anterior communicating artery; ICA bif = internal carotid artery bifurcation; AchA = anterior choroidal artery;PcomA = posterior communicating artery; Ophth = ophthalmic artery; SHP = superior hypophysial artery; cavern = cavernous sinus; BA bif = basilar artery bifurcation; SCA = superior cerebellar artery*

ronment; in 4 cases the aneurysm was exposed to unbalanced forces coming from the environment; and in 13 cases the aneurysm was exposed to balanced forces.

Aneurysm shape and rupture point

In the 59 ruptured aneurysms, the aneurysm shapes were found regular in 25 cases (round: 3, oval: 22) and irregular in 34 cases.

In the 42 unruptured aneurysms, the aneurysm shapes were found regular in 37 cases (round: 7, oval: 30) and irregular in 5 cases.

Presence of a bleb (daughter aneurysm) was found in 42 of the 59 ruptured aneurysm cases. Blebs were present in 6 of the 42 unruptured aneurysms.

Discussion

A recent publication on the average size of unruptured aneurysms and evaluation of risks of aneurysm rupture revealed the difficulty of accepting aneurysm size as the only or dominant parameter [15]. This mainly because of the high frequency of aneurysmal rupture that is reported to occur at a similar size range [3,4,8]. This is concordant with the findings in our series. The goal of our evaluation was to investigate whether morphological factors other than aneurysm dome size could play a role in the assessment of the risk of aneurysm rupture, and what these factors could be.

The reported series is a retrospective analysis of consecutive patients. We believe, that it is based on the average recruitment of an unbiased referral pattern for an average university hospital that provides the currently available standard treatment options for aneurysms.

Although we are aware of the small sample size and the difficulty to provide statistical evidence, we would like to make some remarks pertinent to the morphological parameters influencing aneurysm growth, shape and rupture pattern based on our material.

Aneurysm location and sizes

The distribution of the aneurysm location and the frequency of the aneurysms in this location as displayed on table 1 and 2 reflect a sampling corresponding to the average distribution of cerebral saccular aneurysms. Accordingly, the aneurysm dome sizes matched published data [4,8,14] with an average longest aneurysm diameter of 7.8 mm (range: 2-26 mm) for ruptured aneurysms and of 6.7 mm (range: 1-30 mm) for unruptured aneurysms.

Perianeurysmal environment

The 14 out of the 59 ruptured aneurysms, that ruptured free of any contact with the environment exhibited an average size of 3.9 mm. There were also 25 out of the 42 unruptured aneurysm that were small enough to avoid any conflict with the environment.

We would like to conclude from these observations, that if small aneurysms (without contact with the environment) do rupture, then they are likely to rupture due to reasons mainly related to wall quality [8]. If the aneurysm wall quality is sufficient to withhold the stress inflicted by the circulation, then no rupture will occur. Since it is certainly difficult to judge upon the wall quality based on imaging data, it seems, in our opinion, that to wait and see if the rupture of an aneurysm wall occurs (due to incidental irregularities) is relying on a random choice.

The recently published international study on unruptured intracranial aneurysms puts this risk of rupture below the risk of a surgical intervention [15], a notion that might be challenged, when the ruptured aneurysms of the same size range are considered as being part of the whole pool of aneurysms.

Unbalanced influence by environment

Contact with the environment was possible for 45 out of 59 ruptured cases and for 17 out of the 42 unruptured cases. Unbalanced environmental stress was thought to exist in all ruptured aneurysms and in 4 of the unruptured aneurysms. The average maximal diameter of the ruptured aneurysms with signs of environmental influence was 9.0 mm.

We would like to conclude from these observations, that in the presence of an aneurysm size that is large enough to get into contact with the environment, additional parameters influencing growth, shape and rupture pattern come into play. Indeed, our current impression is that asymmetrical contact of an aneurysm with the environment might lead the aneurysm to perform asymmetrical pulsations and growth. Irregular wall stress might result and the unbalanced situation may lead to irregular strain of the aneurysm wall and to aneurysm rupture.

The aneurysm shapes were found more frequently to be irregular in ruptured aneurysms (34 of 59) when compared to unruptured aneurysms (5 of 42). The presence of a bleb (daughter aneurysm) was found to indicate the existence of weak aneurysmal wall segments and was the likely rupture site in the ruptured aneurysms (42 of 59). Blebs were much less frequently observed in unruptured aneurysms (6 of 42). Presence of bleb formation was mainly found in aneurysm wall segments without direct contact with bone or dura. Blebs were mostly directed towards the free subarachnoid space.

In cases with associated IPH, the parenchymal bleed was considered to have developed close to the rupture point, i.e. in areas where the aneurysm surface would have exhibited contact with the brain. Here, we think, that potentially early small bleeds may have induced subarachnoid adhesion [8], thus changing the rupture pattern by an additional, non-evaluated factor, the subarachnoid space.

Balanced influence by environment

A balanced, i.e. symmetrical appearance of the contact was seen in 13 of the unruptured aneurysms. We consider the balanced status as a form of influence, which may favor bleb formation if the upper part of the dome is not involved in this symmetrical surrounding contact. This may typically be seen in cases where the walls of the aneurysm are surrounded on all sides by brain tissue, and the top portion of the dome is exposed to free subarachnoid space. This is the case with MCA aneurysms for example.

However, in most situations, the balanced contact might provide some protective effect, somewhat like a "natural wrapping". Such a surrounding balanced contact could develop with basilar bifurcation aneurysms, if the contact occurs in a symmetrical fashion, and in the presence of a giant aneurysm growth. Another example would include the development of intracavernous aneurysms.

Conclusions

The perianeurysmal environment was found to have a significant impact onto aneurysmal growth, shape, and rupture pattern, whenever direct contact with the perianeurysmal environment was visualized, and this independent of aneurysm size. Depending on aneurysm type, location and size, the growth pattern exhibited signs of interaction with the specific environment. Aneurysm shape irregularity and bleb formation cannot be explained by contact with perianeurysmal environment only, and depend likely from factors mainly influenced by the aneurysm wall quality. Aneurysm size seems to be a poor indicator for evaluating the risk of rupture, when compared to shape and type of direct contact with the perianeurysmal environment.

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