Intracranial Aneurysms Types, How to Differentiate Stable from Unstable Ones and When to Intervene?

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Abstract

Background: Intracranial aneurysms (IA) are often asymptomatic and have a prevalence of 3 to 5% in the adult population. The risk of IA rupture is low, however when it occurs half of the patients dies from subarachnoid hemorrhage (SAH). To avoid this fatal evolution, the main treatment is an invasive surgical procedure, which is considered to be at high risk of rupture. This risk score of IA rupture is evaluated mainly according to its size and location. Therefore, angiography and anatomic imaging of the intracranial aneurysm are crucial for its diagnosis. Moreover, it has become obvious in recent years that several other factors are implied in this complication, such as the blood flow complexity or inflammation. These recent findings lead to the development of new IA imaging tools such as vessel wall imaging which gives very useful additional information about the characters of the aneurysms and their stability.

Keywords: Aneurysm, intracranial, stable, vessel wall imaging

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Introduction:

Aneurysms of the cerebral vasculature are relatively common. A recent systematic review collecting data from many countries reported a prevalence of 0.4% and 3.6% in retrospective and prospective autopsy studies, respectively, and 3.7% and 6.0% in retrospective and prospective angiographic studies, respectively (1). The angiographic studies likely overestimate the true prevalence due to a selection bias, whereas the retrospective autopsy studies likely underestimate the true prevalence due to an inability to review the original material. Eighty-five percent of saccular aneurysms of the cerebral vasculature occur in the circle of Willis (2). Multiple aneurysms are seen in 30% of patients. Most are

small and asymptomatic, but each year, approximately 30,000 people in the United States suffer a rupture, peaking in the sixth decade.

Unruptured intracranial aneurysms occur in 4% of adults, usually remaining silent unless rupture occurs.(3) Determining individual criteria for predicting instability is important for therapeutic decision making.(4-6)Histopathologic evidence from human and animal studies has lent support to the concept that inflammation plays a major role in aneurysm formation, growth, and rupture.(7) To target in vivo inflammation of the aneurysm wall, some authors proposed ultrasmall superparamagnetic particles of iron oxide (ferumoxytol) as a contrast agent for MRI. They demonstrated that circumferential uptake in aneurysm walls obtained 24 to 72 hours after infusion was highly predictive of rupture within 6 months. (8) Using 3T gadolinium-enhanced vessel wall MRI (VW-MRI), a preliminary report also described circumferential aneurysmal wall enhancement (CAWE) on 5 ruptured aneurysms.

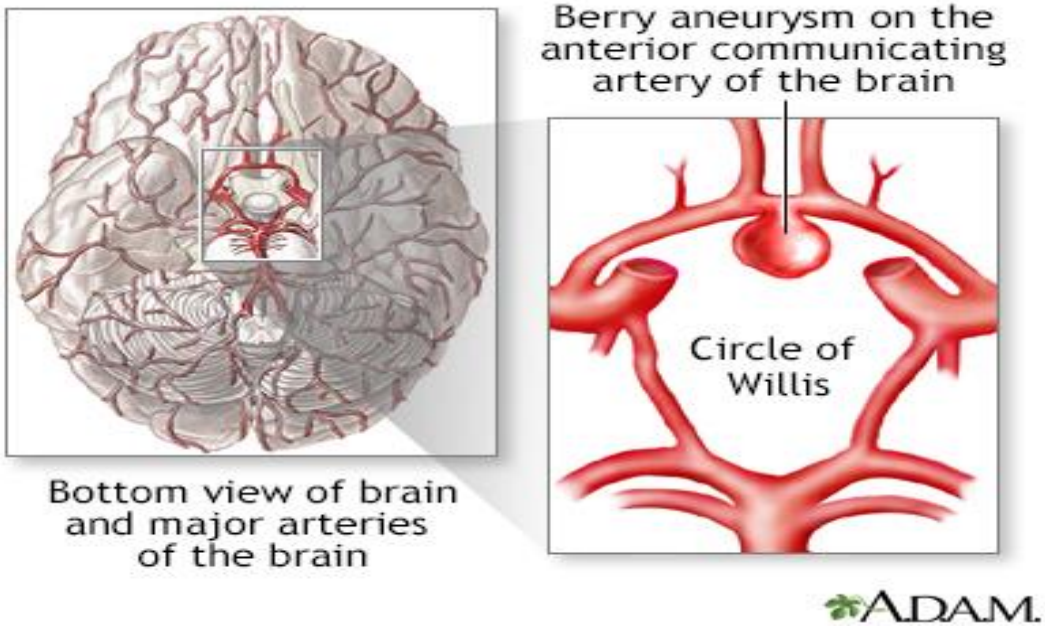

Figure (1) Circle of willis showing saccular aneurysm in the Anterior communicating artery

RISK FACTORS:

There are many risk factors for the development of intracranial aneurysms, both inherited and acquired. Females are more prone to aneurysm rupture, with SAH 1.6 times more common in women. The prevalence of aneurysms is increased in certain genetic diseases; the classic example is autosomal dominant polycystic kidney disease (ADPKD), but other diseases such as Ehlers-Danlos syndrome, neurofibromatosis, and a1- antitrypsin deficiency also demonstrate a link. In ADPKD, 10% to 15% of patients develop intracranial aneurysms. Marfan's Syndrome was once thought to be linked to intracranial aneurysm formation, but recent evidence suggests that this may not be true. Aneurysms also run in families in the absence of an identified genetic disorder, with a prevalence of 7% to 20% in first or second degree relatives of patients who have suffered a SAH.(9)

PATHOGENESIS:

There are four main types of intracranial aneurysms: saccular, fusiform, dissecting, and micotic type. The saccular type accounts for 90% of intracranial aneurysms. Saccular aneurysms are a result of abberations to the normal arterial structure, which consists of the tunica intima adjacent to the lumen of the vessel, the tunica media (the muscular middle layer), and the tunica adventitia (the outer layer composed mainly of connective tissue). The internal elastic lamina delimits the tunica intima from the tunica media, and the external elastic lamina delimits the tunica media from the tunica adventitia. Saccular aneurysms occur when there is collagen deficiency in the internal elastic lamina and breakdown of the tunica media. An outpouching, consisting of only tunica intima and adventitia, protrudes through the defect in the internal elastic lamina and tunica media to produce the aneurismal sac (10,11). The impaired integrity of the wall may be due to congenital weakness or absence of the tunica media or adventitia, degenerative alterations of the internal elastic lamina (from hypertension, turbulent flow, or atherosclerotic deposits in the wall), or both of these factors combined (11). Low collagen and elevated plasma elastase has been observed in patients with aneurysms, suggesting that vascular remodeling involving collagen and elastin plays an important role.

Eighty-five percent of saccular aneurysms arise from the arteries of the circle of Willis. The most frequent location is the anterior communicating artery (35%), followed by the internal carotid artery (30%-including the carotid artery itself, the posterior communicating artery, and the ophthalmic artery), the middle cerebral artery (22%), and finally, the posterior circulation sites, most commonly the basilar artery tip. See Figure 1 for a scheme of the circle of Willis. Multiple aneurysms are found in approximately 30% of patients (11).

CLINICAL PRESENTATION:

The symptoms of SAH result from blood spilling into the cerebrospinal fluid (CSF) and the subsequent increased intracranial pressure and breakdown of blood products. Characteristic symptoms include: "the worst headache of my life," nausea and vomiting, loss of consciousness, neck stiffness, and seizures (12,13). The clinical manifestations of unruptured aneurysms, however, are much more subtle. Only 10-15% of intracranial aneurysms are symptomatic (14, 15), with the majority being identified incidentally during evaluation for other conditions. When present, the symptoms are primarily due to the mass effect of a large aneurysm, or possibly from minimal leakage of blood which irritates the meninges, though not enough to be classified as a hemorrhage. These symptoms include headache, unilateral third cranial nerve palsy (from a posterior communicating artery aneurysm), bilateral temporal hemianopsia (from an anterior communication artery aneurysm impinging on the optic chiasm) ischemic cerebrovascular disease, poorly defined spells, and seizures (16). These symptoms may be a warning sign of an impending rupture, as 10% to 43% of patients with SAH report experiencing a sentinel headache in the 2 months preceding the rupture (17)

DIAGNOSIS AND IMAGING FINDINGS:

There are currently three imaging modalities widely used in the diagnosis of intracranial aneurysms: intraarterial digital subtraction angiography (IADSA), computed tomography angiography (CTA) and magnetic resonance angiography (MRA). IADSA is similar to conventional angiography in that a catheter is advanced in the arterial system to the point of interest, and radio-opaque contrast material is injected while images are acquired. The contrast fills the lumen of the arteries; thus, the vessel anatomy is visualized on the image. In conventional angiography, serial x-ray films are captured, while

in IADSA, serial digital images are obtained and stored on a computer. An initial image acquired before contrast injection is subtracted from the post-contrast images. The resultant image displays dark vessels against a blank background . This technique allows greater contrast resolution (the areas with contrast are more obvious), but decreased spatial resolution (because digitally acquired images have a lower resolution than films) when compared with conventional angiography. CTA is another technique of vascular imaging which involves obtaining a normal CT scan while intravenous contrast material is injected. The contrast material is radio-opaque, so it appears white on the CT image. The serial axial slices enhanced with contrast are analyzed by a computer program that forms a three-dimensional reconstruction of the vascular anatomy. The resultant image is a dynamic model that can be rotated in order to view the image from multiple perspectives. (18)

Similar to CTA, MRA is a technique which uses serial axial MRI images to form a three-dimensional representation of the vascular anatomy. Unlike CTA, however, MRA does not require the use of intravenous contrast material. This is because the signal obtained in magnetic resonance imaging depends on the magnetic properties of the area being imaged. A magnetic pulse aligns all the protons in a certain area and measuring the amount of time necessary for those protons to return to their pre-magnetization state generates the signal which produces the MR image. With a moving substance such as blood, the protons are aligned during the magnetic pulse, but by the time the signal is collected, the aligned protons have moved out of the area which is being imaged, and new 'non-magnetized' protons have taken their place. Because these new protons have not been magnetized, a signal is not generated and the blood vessel lumen appears as a 'signal void' on the image (this is an oversimplified explanation). The lack of signal distinguishes the vessels from the surroundings. In some cases, a gadolinium contrast material may be used to provide better imaging of the vessels. The advantage of MRA is that it can be used in patients who cannot tolerate the iodine based contrast used in IADSA and CTA, such as patients with allergic reactions or with renal failure. The gold standard for diagnosis of intracranial aneurysms is currently IADSA, but a diagnosis can also be provided by CTA and MRA. The contrast provided during IADSA causes the aneurysm to appear on fluoroscopy as a radio opaque, smooth margined, saccular out-pouching of the cerebral vasculature.(19)

Vessel wall imaging (VWI) has recently emerged as a promising diagnostic tool to image intracranial vessel wall inflammation through MRI. This technique, also known as black blood MRI, provides only signals from the vessel wall thanks to the suppression of both blood and cerebrospinal fluid signal (CSF). The acquisition of VWI demands high resolution, therefore a 3T or higher magnet strength is required. Briefly, VWI generally consist in T1-weighted pre- and post- contrast sequences along with blood and CSF suppression obtained with a 3D turbo spin-echo sequence with variable flip angle refocusing pulses (20). Thanks to blood signal suppression, VWI has been used to study aneurysm wall structure, thickness and wall enhancement. Aneurysm wall enhancement (AWE) is mainly qualitatively assessed and can be classified as focal or circumferential. Radiohistological correlation studies revealed that focal AWE (FAWE) is associated with fresh intraluminal thrombus at the rupture site (21). This finding can provide useful information for the surgical treatment of ruptured IA before treating the patient by microsurgical clipping or endovascular coiling. FAWE can also be observed in unruptured IA and colocalized with hemodynamic factors in favor to a higher rupture risk (22). Moreover, FAWE is observed in areas of morphological changes in the IA vessel wall, supporting the hypothesis that FAWE could be a marker of instability (22). On the other hand, circumferential AWE

(CAWE) is thought to be due to wall thickening with abundant inflammatory cell infiltration and neovascularization (23). In cases of subarachnoid hemorrhage and multiple aneurysms, several criteria are used to determine which one underwent rupture (i.e. hemorrhage localization, IA size, location, shape, aspect ratio). As vessel wall inflammation is a risk factor of IA rupture, AWE is nearly always observed in ruptured IAs (24). Along with this observation, some studies performed on patients presenting multiple IAs, demonstrated that VWI can identify the ruptured IA which is characterized by a thick vessel wall enhancement (25,26). Thus, VWI can be a useful diagnostic tool in identifying ruptured IA and its site of rupture (25).

Different observations support that arterial wall enhancement can be used as an indirect marker of vessel wall inflammation, and therefore as a potential marker of aneurysm instability. First, mural artery contrast uptake was described in intracranial vessel wall inflammation, eg, in active cerebral inflammatory vasculitis (27) and is thought to be linked to vasa vasorum density. This is of major interest, because increase of density of vasa vasorum was also associated with morphological modification and rupture risk of intracranial aneurysms (27).

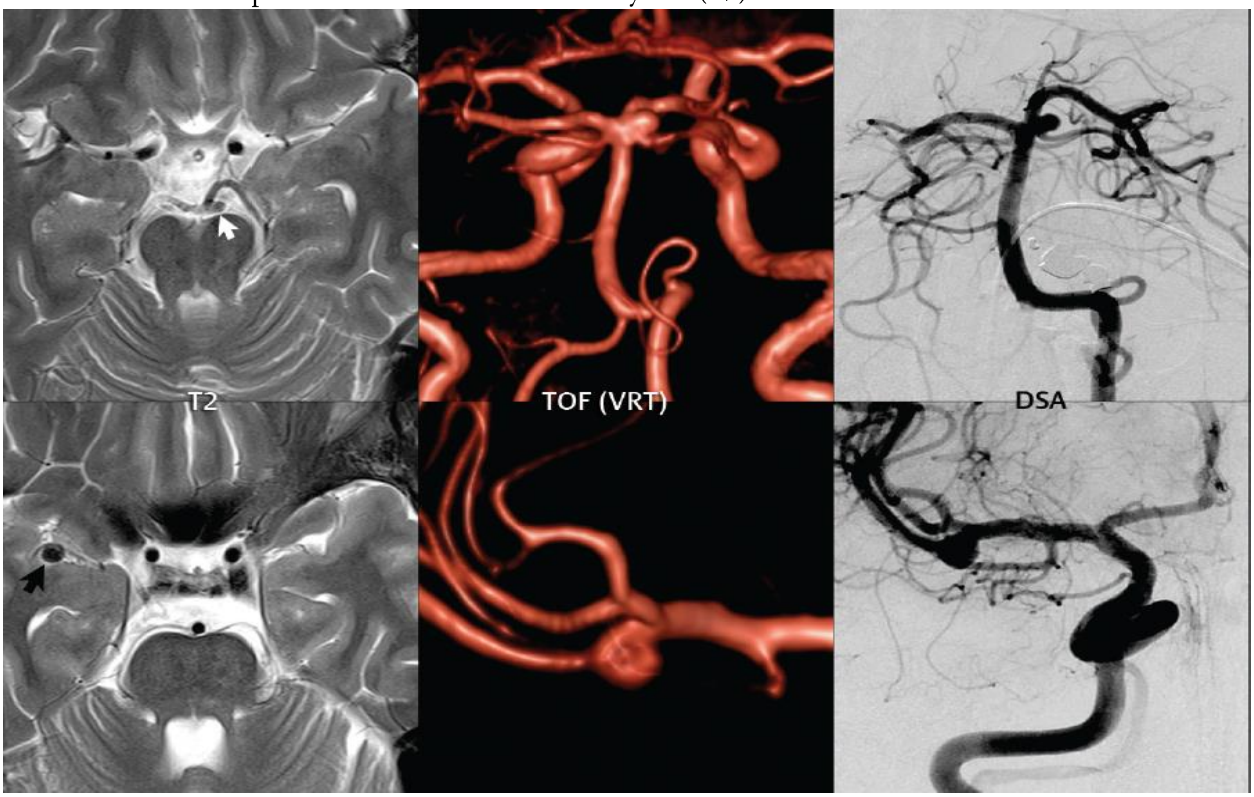

Figure (2) *Small unruptured aneurysms of the middle cerebral and basilar arteries. This case points to the importance of close inspection of high-resolution, thin section axial T2weighted scans for detection of small aneurysms, and the critical role that TOF MRA plays both for detection and in depiction of brain aneurysms. The latter scan technique has markedly improved in recent years with routine imaging at 3 T and attention to setup (spatial resolution). In this instance, although the right MCA aneurysm is easily visualized (black arrow), as a flow void, on the axial screening T2weighted exam, that involving the distal basilar artery (white arrow) is more subtle.. Frontal views from the DSA exam are presented for comparison, with both aneurysms subsequently coiled. (27)*

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