# Neuroradiology

# 1. Anatomy and physiology - quick reminder

a. Brain arteries
b. Dural Covers
c. Sub-arachnoid Space
- » Anatomy
- » Function + CSF

# 2. Neuroimaging

**a.** Plain x-ray of skull

**b.** Computed tomography – CT
- » traditional („normal" CT)
- » angio-CT
- » perfusion techniques

**c.** Magnetic resonance – MR
- » standard techniques
- » angio-MR
- » perfusion, dyfusion, spectroskopy
- » functional & molecular MR

**d.** Ultrasounde
- » Doppler US imaging
- » pediatric trans-fontanelle US

e. Diagnostic Catheter Angiography
- » General Guidelines

3. Congenital CNS defects

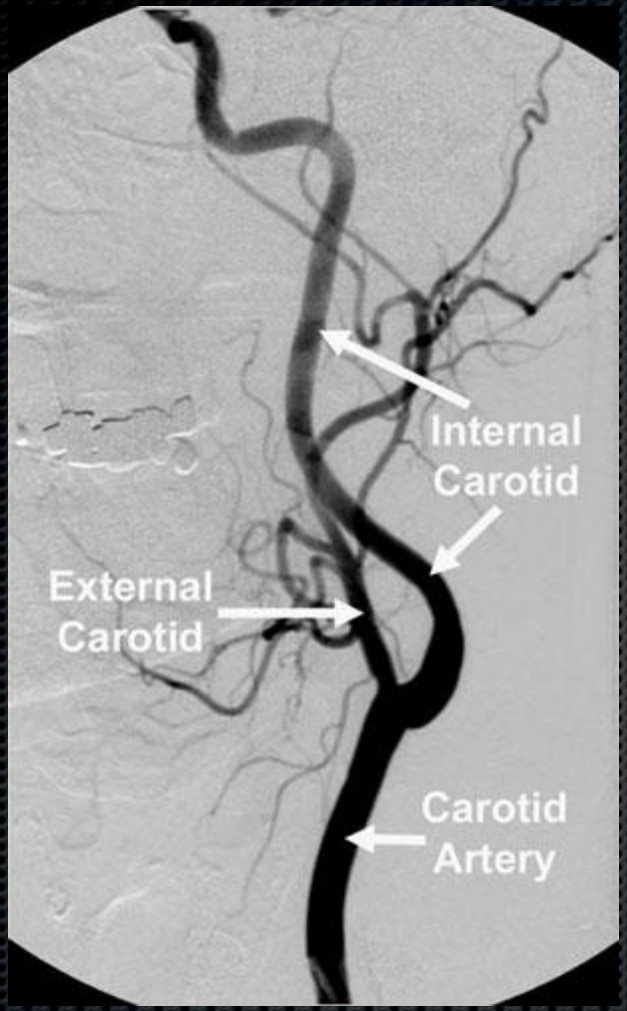
4. Skull and cerebral trauma

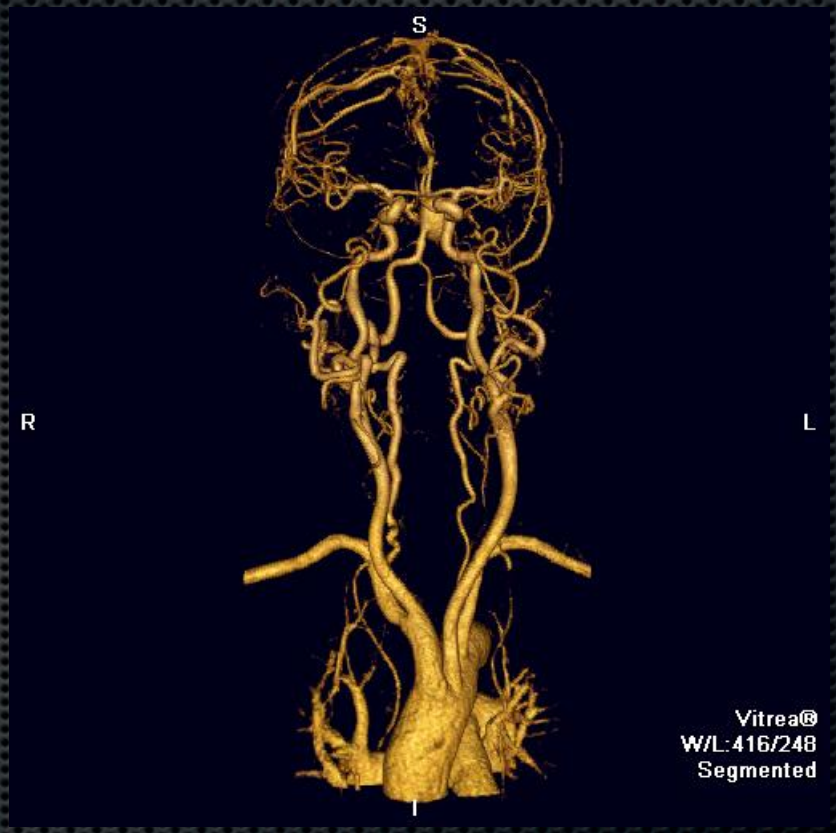
5. Vascular Malformations

a. Aneurysm
- » Ruptured/unruptured, symptomatic/asymptomatic, shape, location, CT
- » Endovascular or Neurosurgical treatment?
- » Coils

b. bAVM - brain Arterio-Venous Malformation
- » What is it?
- » Difference - brain vs peripheral location, size
- » Treatment, risk, Onyx, nBCA (n-butylo-cyanoacrylate), aneurysms (flow-related).
- » Short info on dAVM/dAVF and AVFs

6. Intracranial tumors


Internal
Carotid
External
Carotid
Carotid
Artery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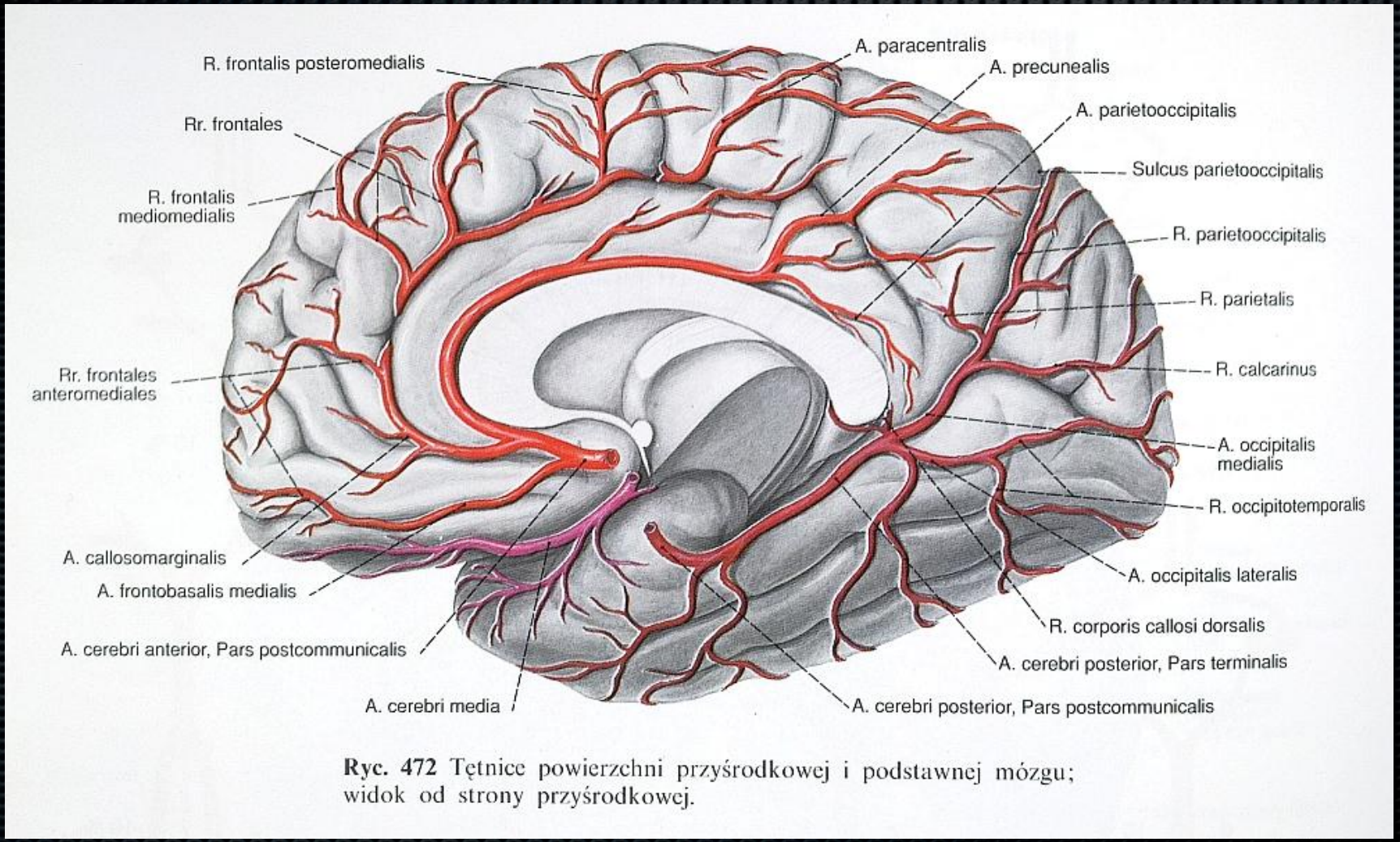
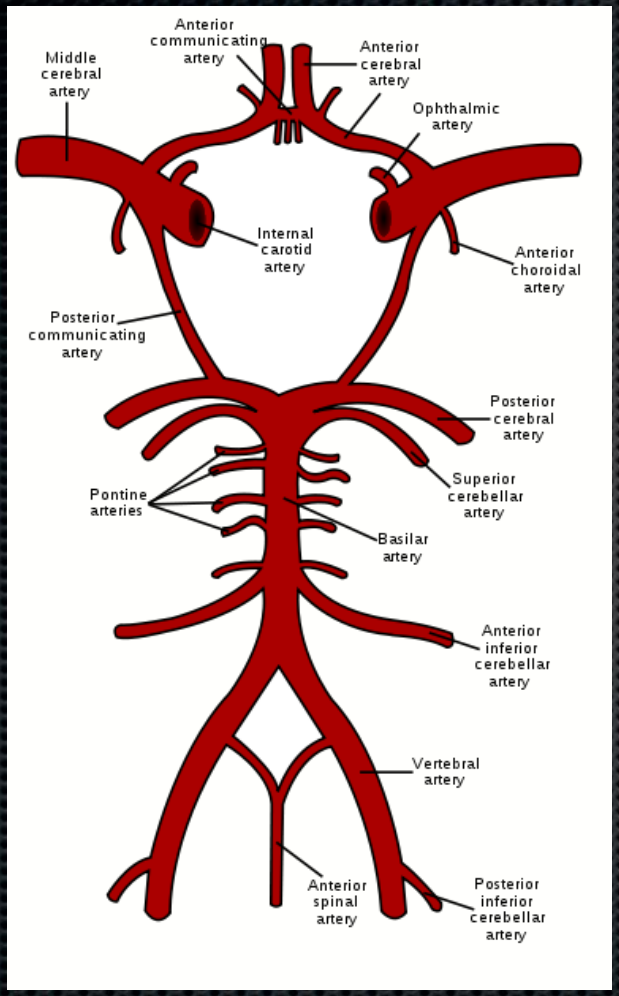
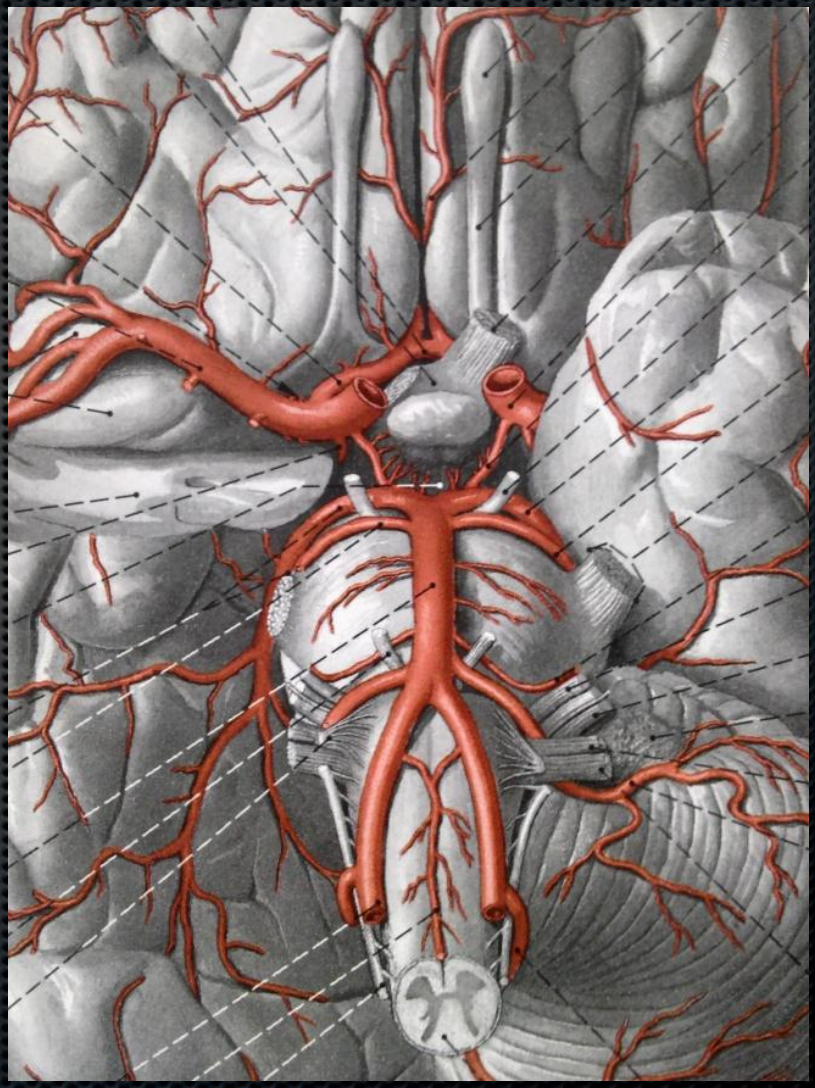



**Ryc. 472** Tętnice powierzchni przyśrodkowej i podstawnej mózgu; widok od strony przyśrodkowej.

# Circle of Willis



# Brain Anatomy and Functions


# Digital subtraction angiography

DSA



# Angio - CT


IP


Volume Rendering No cut
Oct 23 2002
DFOV 10.0 cm
STANDARD
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mA 170
Tilt: 0.0
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I Zd. Radiolog
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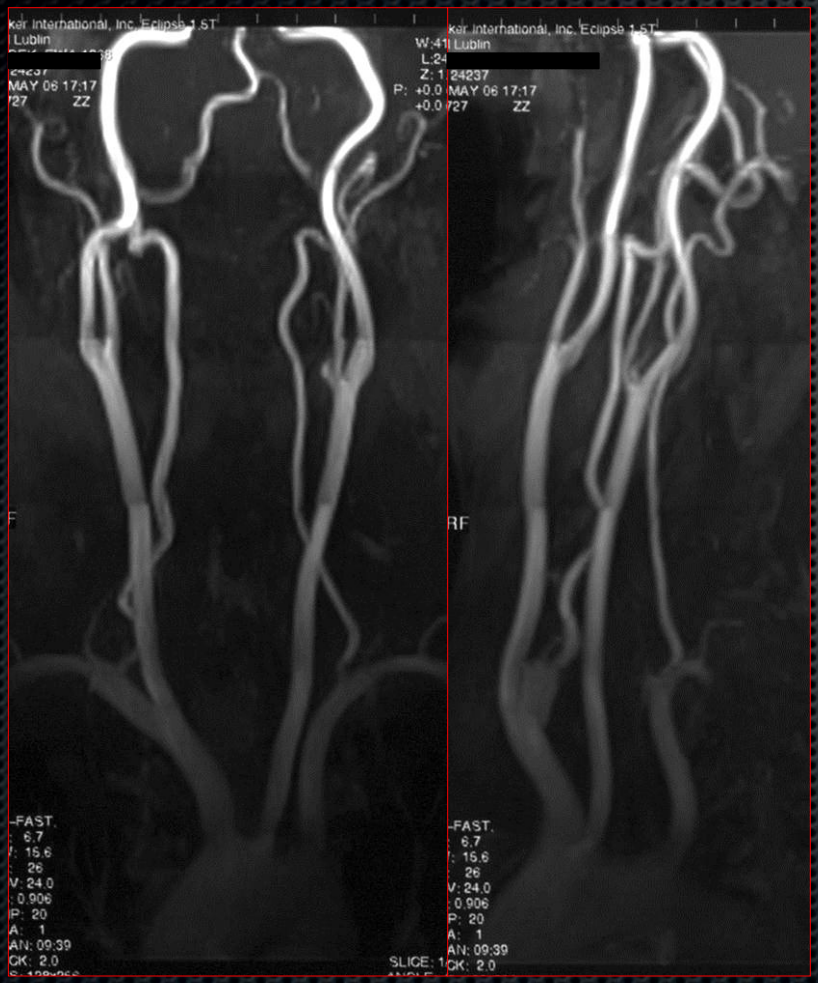
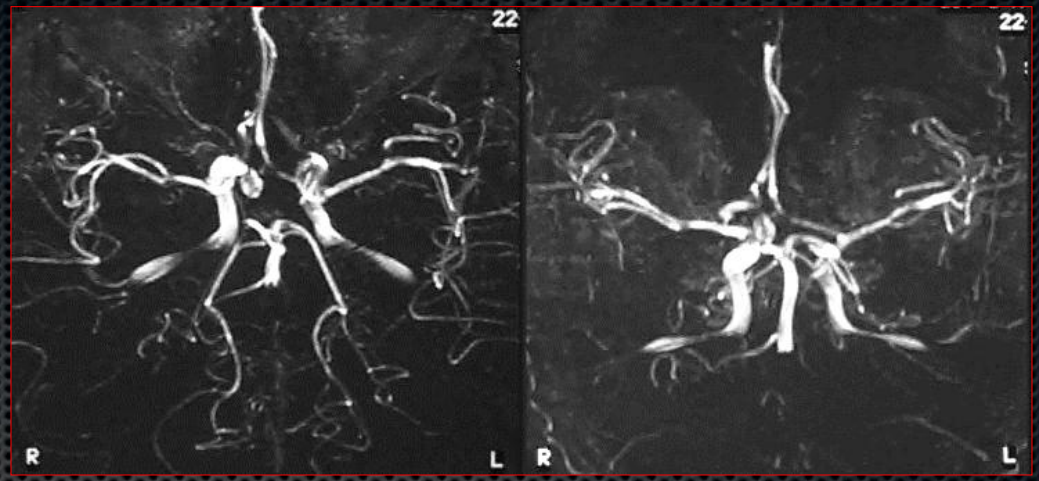
No cut
2mm/rot
6sp
IRP

# Non-invasive angiography

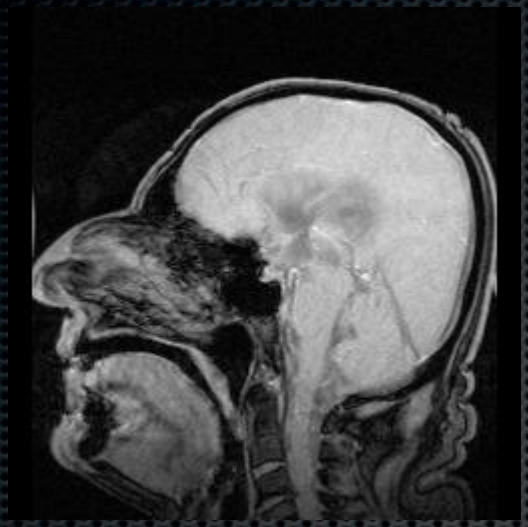
angio-MR




*„ Brain juice "*

# Cerebrospinal fluid

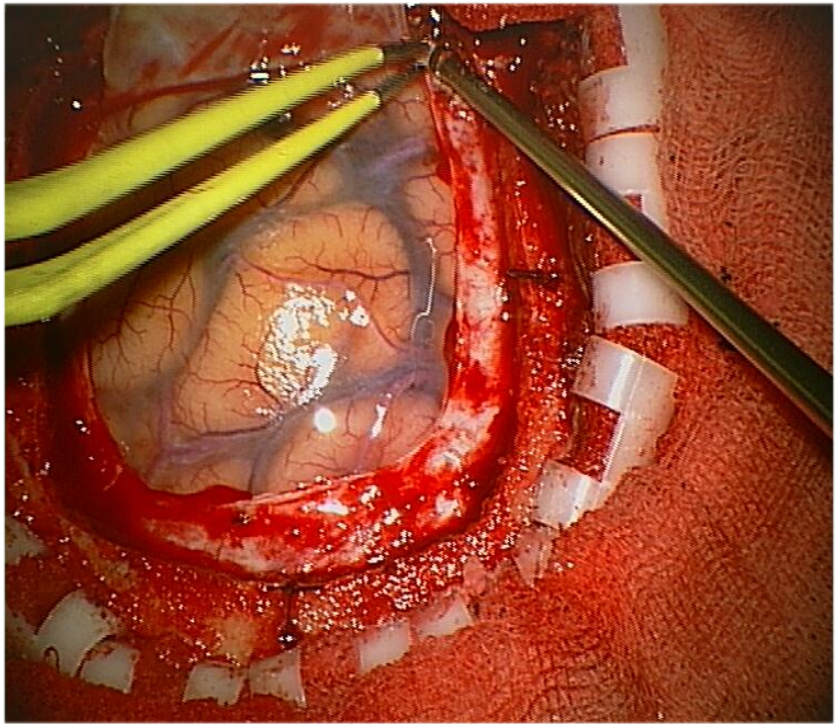


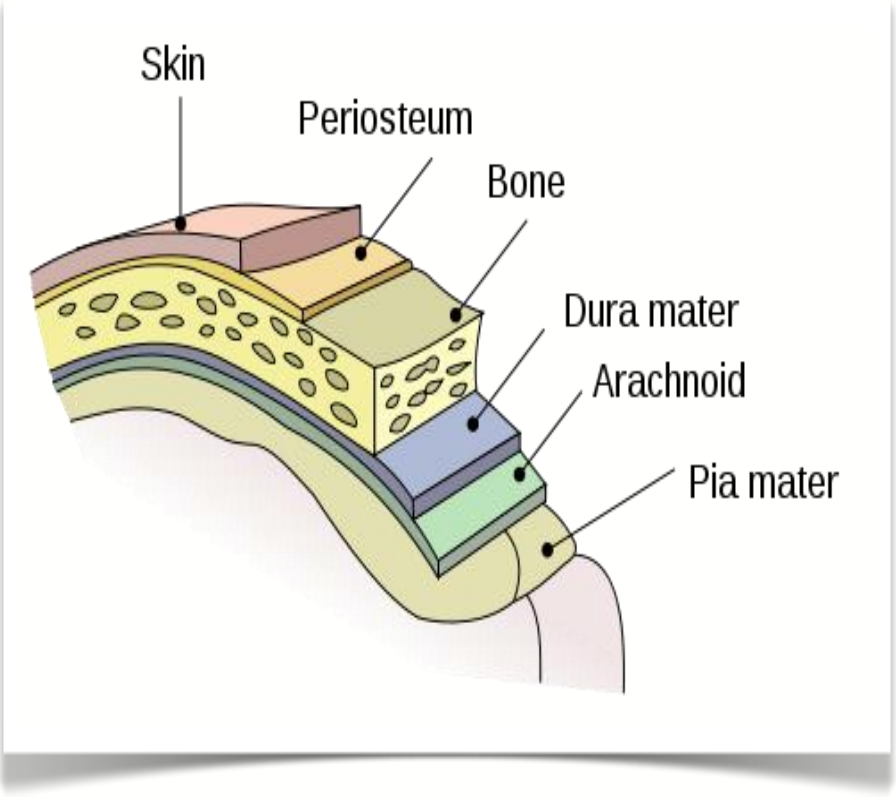
MRI showing pulsation of CSF

CSF is a clear bodily fluid that occupies the subarachnoid space and the ventricular system around and inside the brain and spinal cord. In essence, the brain "floats" in it. It acts as a "cushion" or buffer for the cortex, providing a basic mechanical and imunological protection to the brain inside the skull.

- produced at a rate of 500 ml/day
- brain can contain only 135 to 150 ml
- CSF turns over about 3.7 times a day

F:\ZRZN\
Ilacja\CSF.pptx

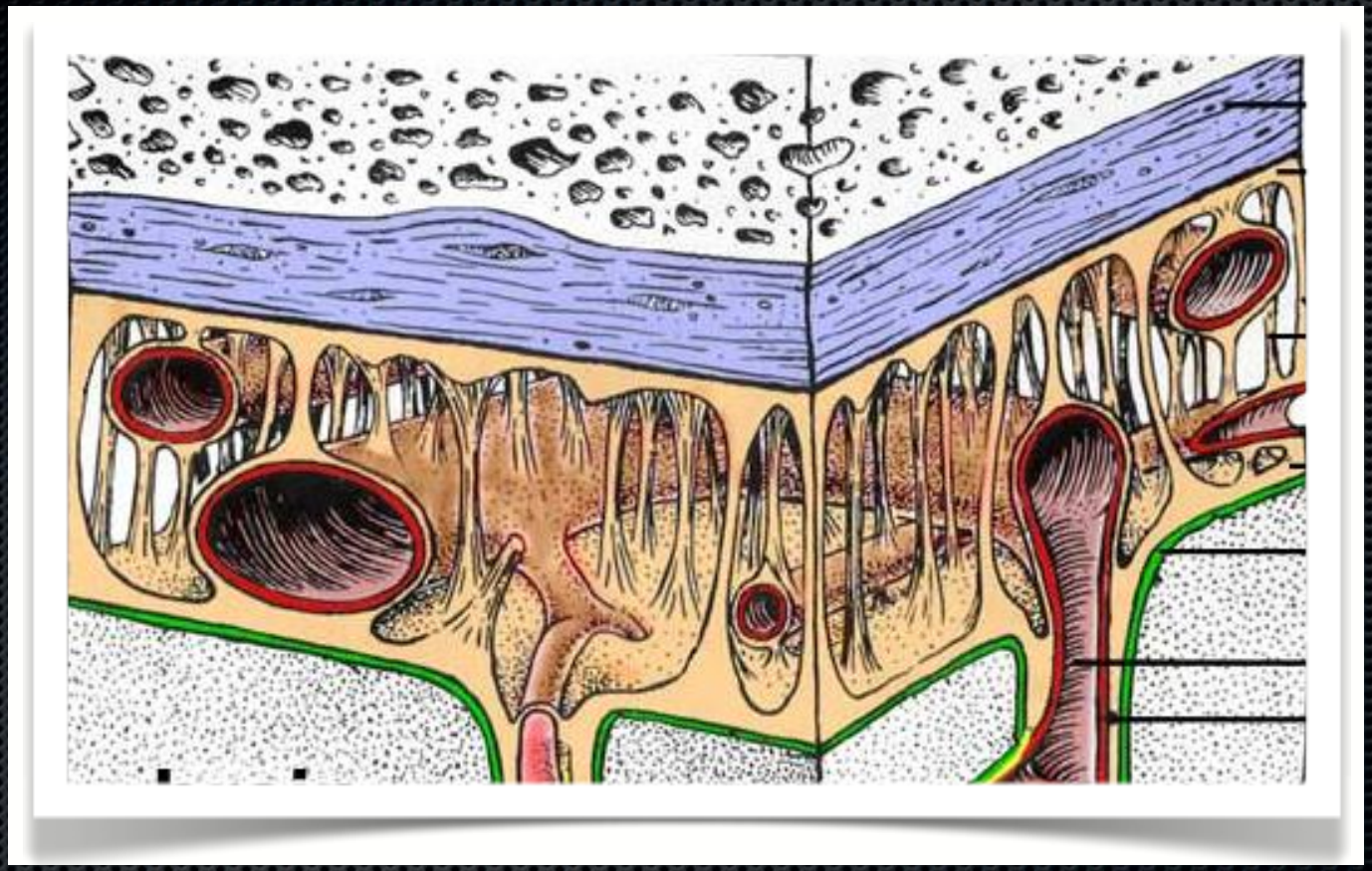




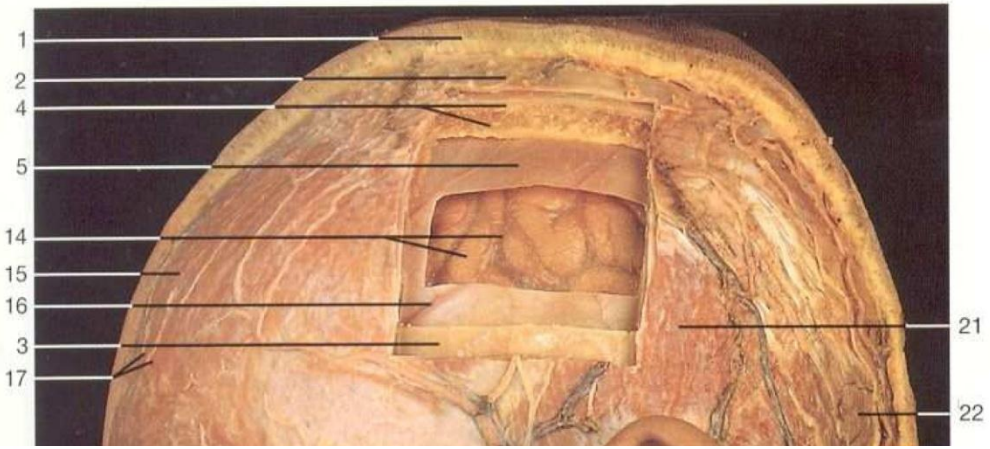

The meninges (system of membranes which envelopes the central nervous system)

Normally, the dura mater is attached to the skull, or to the bones of the vertebral canal in the spinal cord. The arachnoid is **NOT** attached to the dura mater, while the pia mater is attached to the central nervous system tissue. When the dura mater and the arachnoid separate through injury or illness, the space between them is the subdural space.

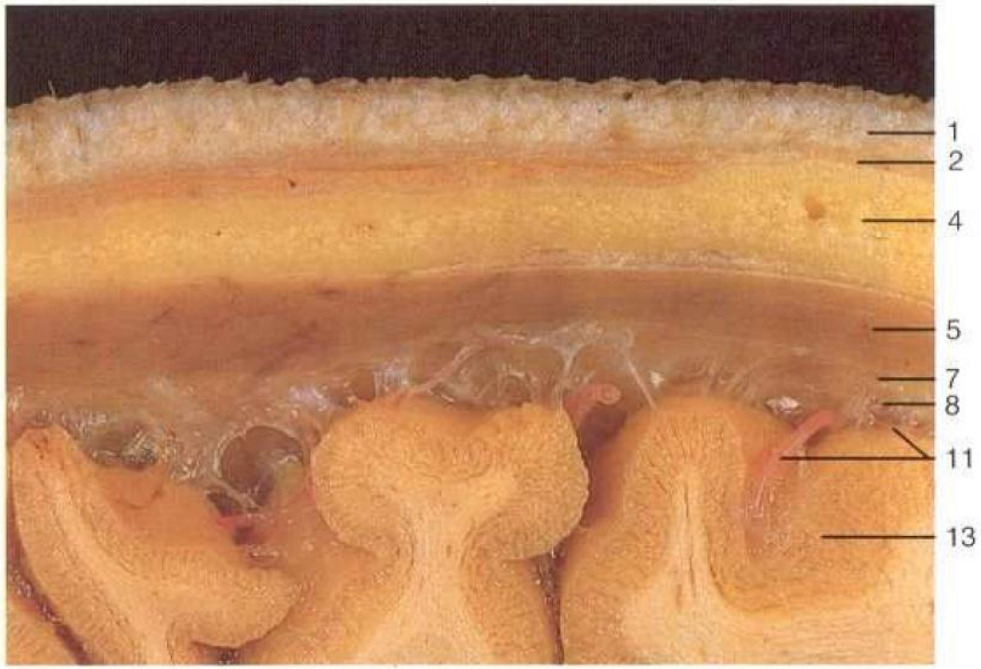
# Subarachnoid space / subarachnoid cavity

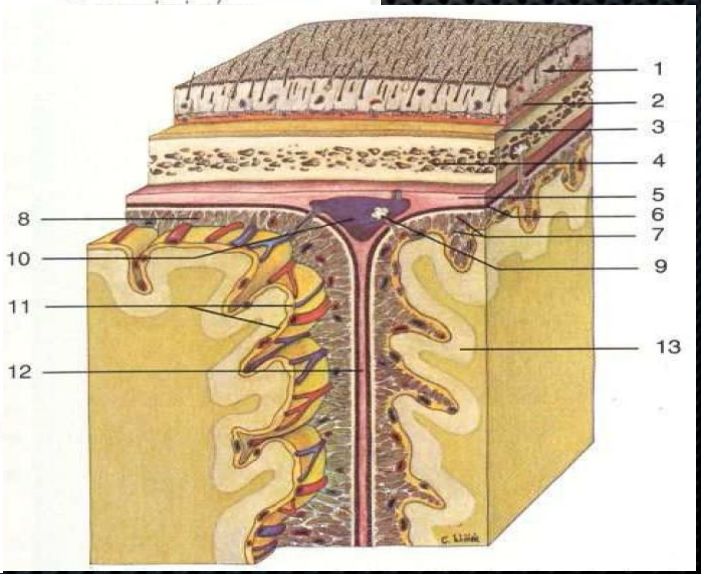


It is occupied by spongy tissue consisting of trabeculae (delicate connective tissue filaments that extend from the arachnoid mater and blend into the pia mater) and intercommunicating channels in which the cerebrospinal fluid is contained.




1 Skóra głowy
2 ***Galea aponeurotica*** **(czepiec ścięg**
3 *Pericranium* (okostna czaszki);
także *periosteum* (okostna)
4 *Calvaria* (sklepienie czaszki)
5 ***Dura mater encephali***
**(opona twarda mózgowia)**
6 *Spatium subdurale*
(przestrzeń podtwardówkowa)
7 ***Arachnoidea*** **(pajęczynówka)**
8 ***Spatium subarachnoideale***
**(przestrzeń podpajęczynówkowa)**
9 *Granulationes arachnoideales*
(ziarnistości pajęczynówki)
10 *Sinus sagittalis sup.*
(zatoka strzałkowa górna)
11 ***Pia mater*** **(opona miękka)**
12 *Falx cerebri* (sierp mózgu)
13 *Cortex cerebri* (kora mózgu)
14 *Arachnoidea* et *pia mater*
(pajęczynówka i opona miękka)




Cross Section

Frontal view of sinus saggitalis.sup.

# Subarachnoid hemorrage a.k.a. S A H

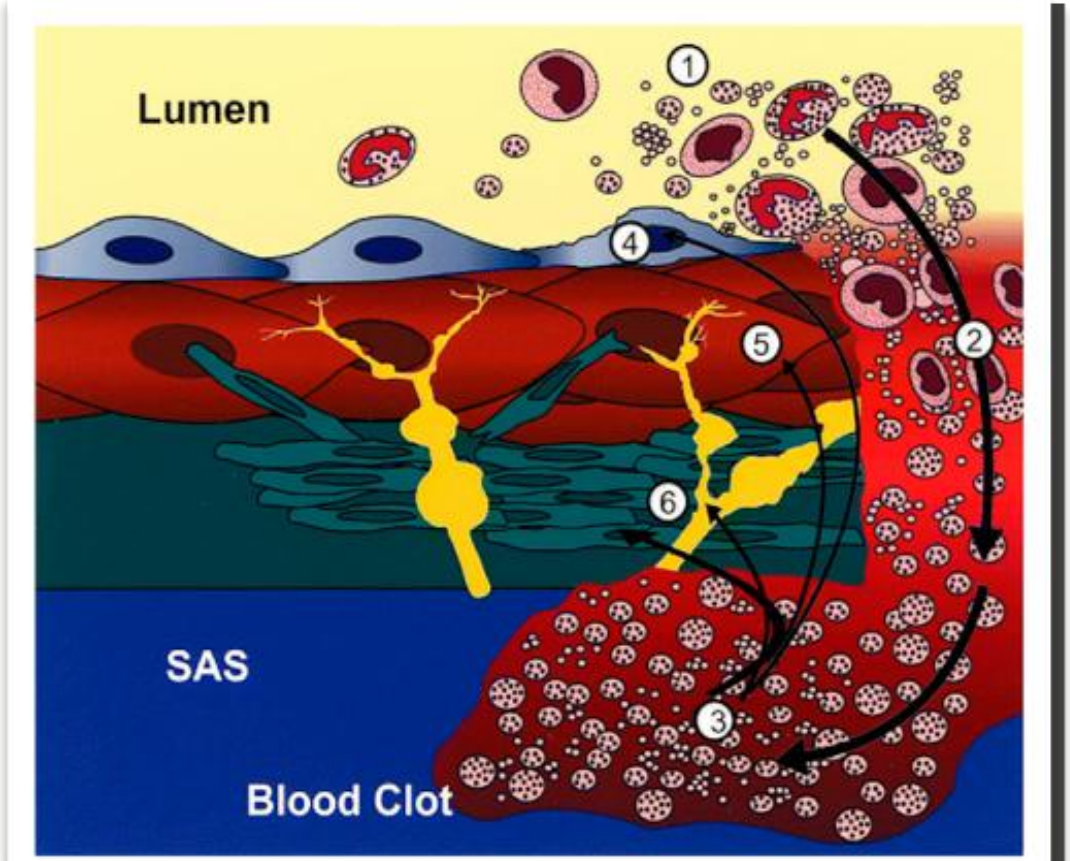
- SAH is a bleeding into the Sspace
- Most common cause - trauma. May also occur spontaneously (usually from a ruptured cerebral aneurysm or AVM – weak points)
- Symptoms of SAH include a severe headache with a rapid onset ("thunderclap headache"), vomiting, confusion or a lowered level of consciousness, and sometimes seizures.
- Complications:

  **Vasospasm**, in which the blood vessels constrict ("vasospasm peak" between 4-12 day) and thus restrict blood flow. It can cause ischemic brain injury 36 % (referred to as "delayed ischemia") and permanent brain damage due to lack of oxygen in parts of the brain.

  **Hydrocephalus** (obstruction – cause by clots - of the flow of cerebrospinal fluid) enlargement of the lateral ventricles

  **Rebleeding** -20 % during the first 2 weaks – with peak in 2 day (clot thrombolysis in aneurysm)

The diagnosis is generally confirmed with a CT scan of the head, or occasionally by lumbar puncture. Fresh blood on CT is marked by bright white (hyperdense)




1. Lumen
2. Ruptured wall
3. Sub-arachnoid space

Chemical reaction> oksyhemoglobin>
patological processys in:

4. Endothelium
5. Smooth muscles
6. Adventitia

vasospasm

# Brain imaging methodology

Prezentacja
w Microsoft PO

Neuroimaging presentation

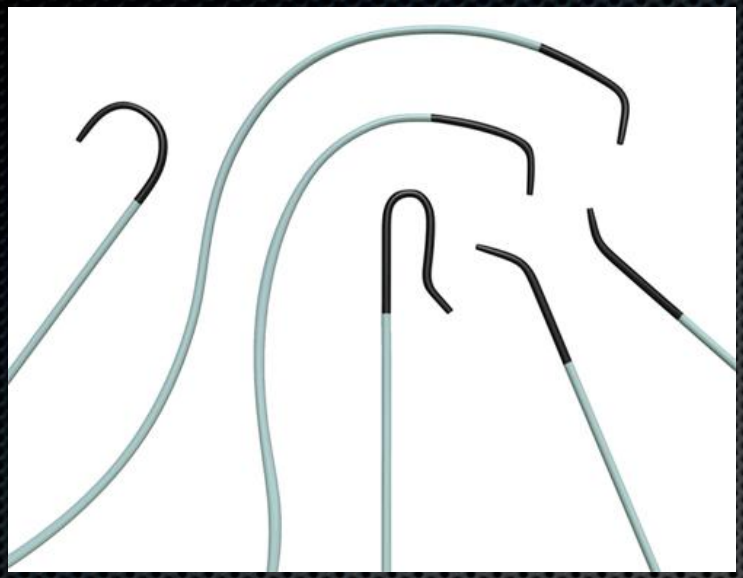
# Diagnostic Catheter Angiography

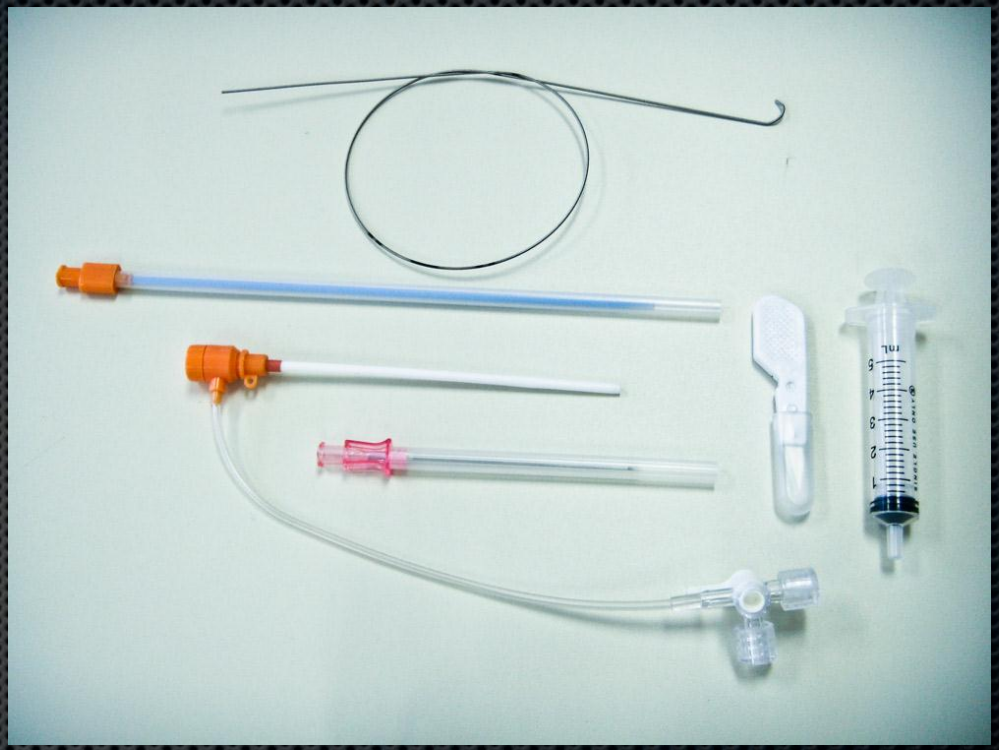
- review the patient's chart
- consent should be obtained (before the patient is brought to the angiography suite, explaine the procedure – risks and benefits )
- should be discontinued:

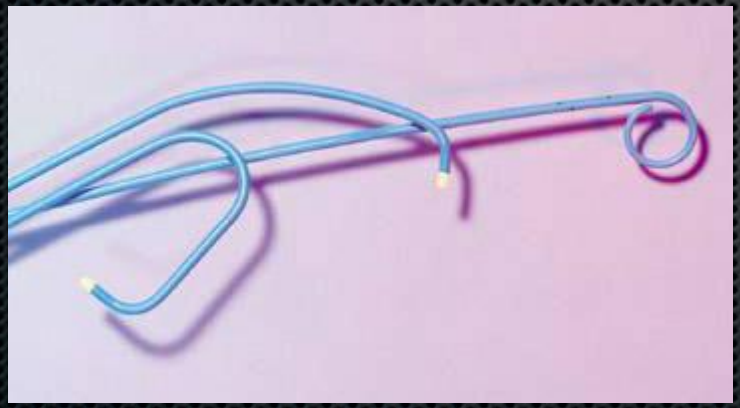
  - heparin drip – approximately 4 hours
  - oral anticoagulants- 7 days, minimum 3 days
  - aspirin 7 to 10 days before the procedure, if possible

- if previous allergic reactions have been severe - anesthesiologist should stand by
- puncture the groin with the strongest pulse
- make sure all patients have the following laboratory tests: blood urea nitrogen (BUN), serum creatinine, PT, PTT, INR, hemoglobin (Hb), hematocrit (HCT), and platelets
- the diastolic blood pressure must be less than 110 mm Hg
- only clear liquids after midnight, nothing by mouth (NPO) 2 hours before procedure
- postangiogram orders: dressing for 4 hours, enforce strict bed rest with leg straight for 6 hours, oral (PO) fluids, normal diet

# Equipment





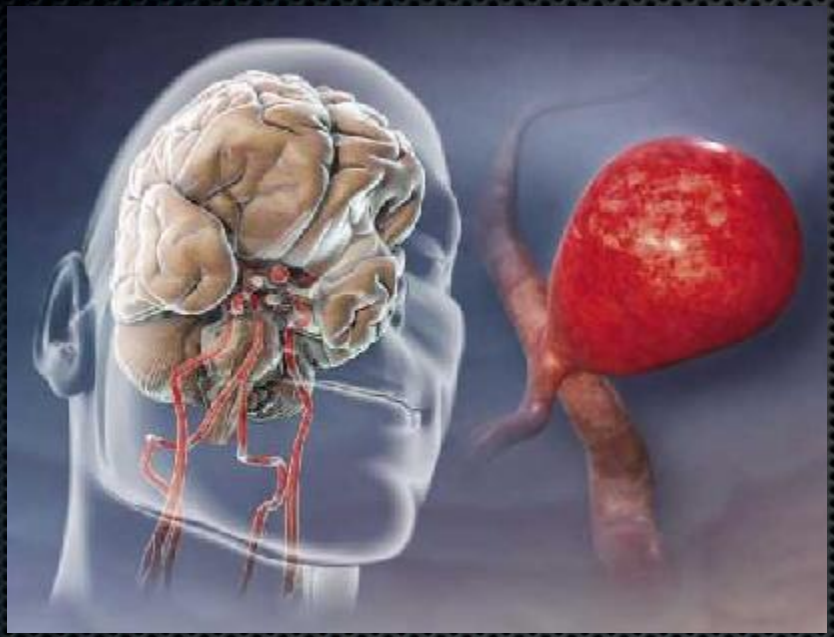


**Introducer set / Femoral sheath**

Digital subtraction angiography is an invasive procedure

What is an

# Aneurysm ?



Approximately 2 million Americans have silent unruptured aneurysms. Most of these people do not know they have an aneurysm and have no symptoms

An aneurysm is a blood-filled dilation of a blood vessel caused by a weakening of the vessel's wall.

Aneurysms typically develop because of the general wear and tear of blood pressure on the arteries' walls, called hemodynamic forces.

A weak spot in the artery wall bulges out, giving way to the pressure of the blood flow, forming a sac.

For this reason, areas of artery or vessel wall which are submitted to higher blood pressures are more susceptible to aneurysm development, such as the branching points of arteries, called bifurcations.

Usually develop as you get older, more prevalent in women

# How common are aneurysms?

2-4% in the general population..

# Are aneurysms hereditary?

In general, aneurysms rarely occur in more than one family member. When aneurysms are present in more than one family member a known hereditary syndrome is often present, such as polycystic kidney disease, Ehler-Danlos syndrome, pseudxanthoma elasticum

# What is the risk of bleeding from aneurysms?

All intracranial aneurysms less than 5 mm in diameter are unlikely to rupture (critical size, 5 to 7 mm); giant aneurysms are also unlikely to rupture. Risk of bleeding is 2% per year in previously nonruptured aneurysms.

## How is an aneurysm diagnosed?

An aneurysm that has not bled is typically discovered on a CT or MRI scan - 'incidental aneurysm.'

## What increases your risk for an aneurysm rupture (SAH)?

Medical family history?
Hypertension (high blood pressure)
Tobacco use
Female (3:2 female to male ratio for aneurismal rupture)
Between the ages of 35 and 60

# What are symptoms of an aneurysm?

## Unruptured Aneurysm Symptoms

Unfortunately, there are few initial symptoms of unruptured aneurysms. In particular, most small aneurysms have none. In fact, most aneurysms are found by accident during routine check-ups or an investigation of another problem.

However, there are symptoms to look out for which often occur in this sequence. The following can occur as the aneurysm enlarges:

Localized headaches

Pain above and behind eye

increases in size > pressure > can cause

Dilated pupils

Loss of sensation, in particular numbness or weakness of an arm or a leg

Double vision, vision impairment or loss of vision (vision impairment may result from an aneurysm located next to and pinching the optic nerve)

Difficulty with memory or speech

Seizures

## Ruptured Aneurysm Symptoms

Aneurysms that rupture can show warning signs. However, only about 40% of all major ruptures are preceded by any combination of the following symptoms.

A sudden and usually severe headache

Nausea

Vomiting

Stiff Neck

Vision impairment: blurred or double vision

Sensitivity to light (photophobia)

Loss of sensation

Loss of consciousness

# Why is a Rupture Extremely Dangerous?

Although the incidence of an aneurysm rupture is relatively low, a subarachnoid hemorrhage is associated with a disastrously high fatality or substantial mental impairment rate as a result of its initial bleed or complications thereafter.

- Mild brain damage or full recovery - 15-30%
- Vasospasm - 15-20%
- Moderate to severe brain damage - 20-35%
- Death - 30-40%

***Percentage of possible outcomes after initial bleeding, according to the American Stroke Association.***

# Rupture Damage

- Blood collects around the base of the brain. This causes an **enlargement of the spaces** within the brain that produce cerebrospinal fluid. This is treated often by inserting a tube into the ventricles (fluid-filled space of the brain) called a ventriculostomy tube, which drains into a bag at the patient's side.

- **Vasospasm** is also a possible complication associated with hemorrhaging in the brain. The onset of vasospasm can be anytime **between 3 to 14 days** after the initial hemorrhage. The blood released into the fluid-filled spaces at the base of the brain can **chemically irritate** the other vessels located there, causing them to **constrict** in response. This constricting could **lead to a stroke or blockage** of a vessel by plaque or some other debris causing it to rupture in a **second hemorrhagic event**. This constriction of normal blood vessels is also likely to interrupt blood flow to healthy brain tissue, leading to even more brain damage.

  The sooner a ruptured aneurysm is treated, the lesser the chance of vasospasm setting in.

- Difficulty breathing which is often treated with a mechanical ventilator

- Infection

- Once blood enters the brain and the surrounding space, there is also **direct damage to the brain tissue and functions**. The amount of damage is proportional to the amount of blood leaked. This damage is caused by the swelling, compression and irritation of the brain tissue by the blood.

- Getting treatment immediately is optimal to avoid additional complications. Other complications and delayed effects of a hemorrhage include **fever, headaches, seizures, and strokes, all of which can be treated with various medicines, or procedures**.

# Aneurysm Structure

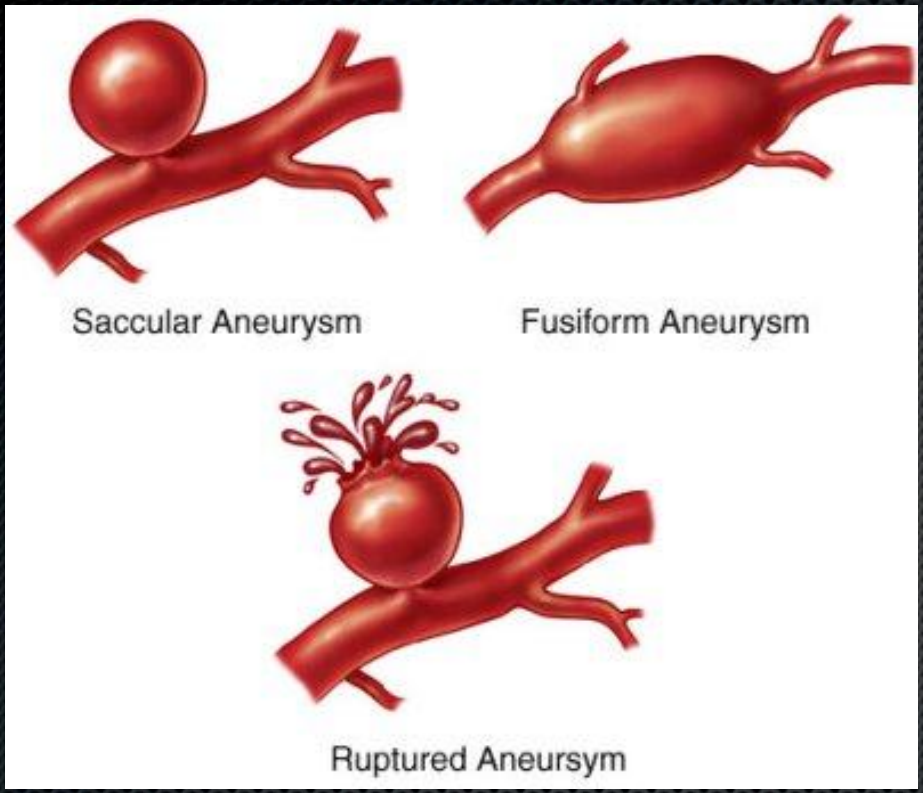
Like people - no two aneurysms are the same.

They vary in size, shape and location. Thus, the appropriate course of treatment is dependent on the particular structure and location of the aneurysm. It is important to familiarize yourself with the indices used to measure aneurysms, such as the neck-to-dome ratio.

| Small | Medium | Large | Giant |
|---|---|---|---|
| <5mm | 6-15mm | 16-25mm | >25mm |
| <1/4inch | _-3/4 inch | _-11/4inch | >11/4inch |

The size of an aneurysm is measured by its diameter in millimeters.

# Shape

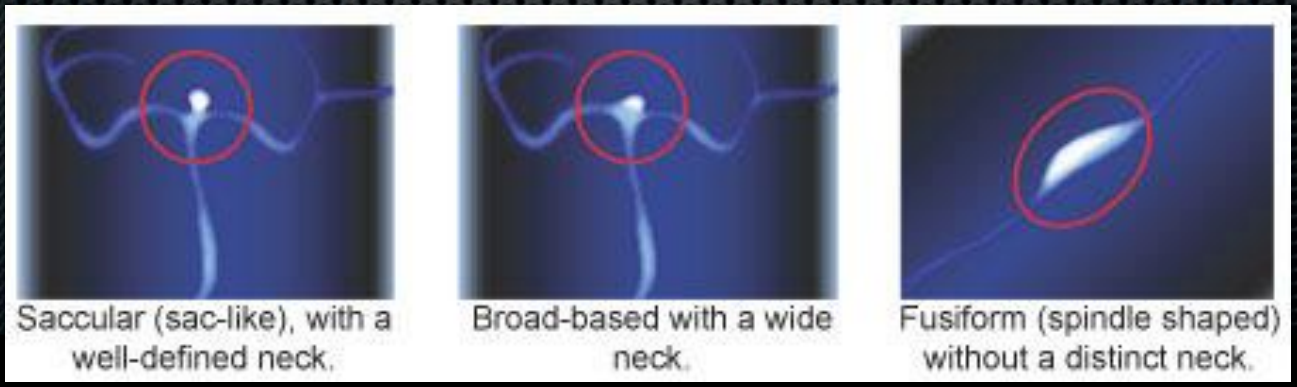



Two main types: saccular and fusiform.

The more common of the two, saccular or "berry" aneurysms, bulge out of one side of the artery wall.

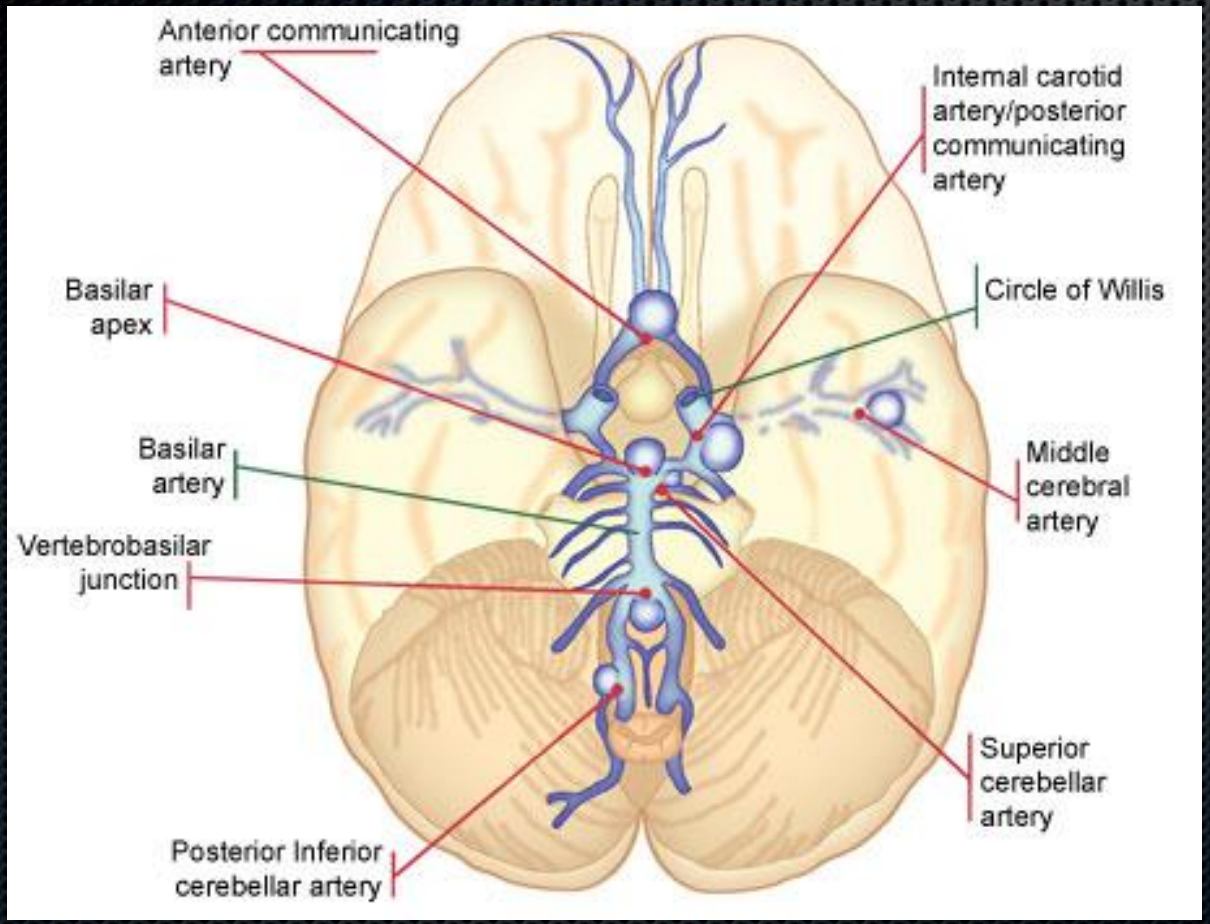
Saccular aneurysms can connect to the artery either with a distinct, well-defined neck or with a wider, broad-based opening to the artery.

Fusiform aneurysms are a swelling of both sides of an artery wall and have no defined neck or stem.




The shape of an aneurysm is a major factor in the choice of treatment.

# Location



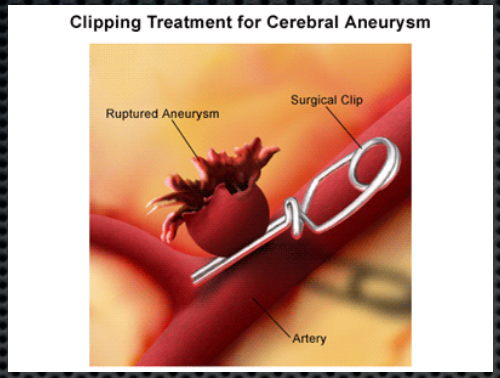

They occur in areas of relatively higher blood pressure such as bifurcations, where one artery splits into two.

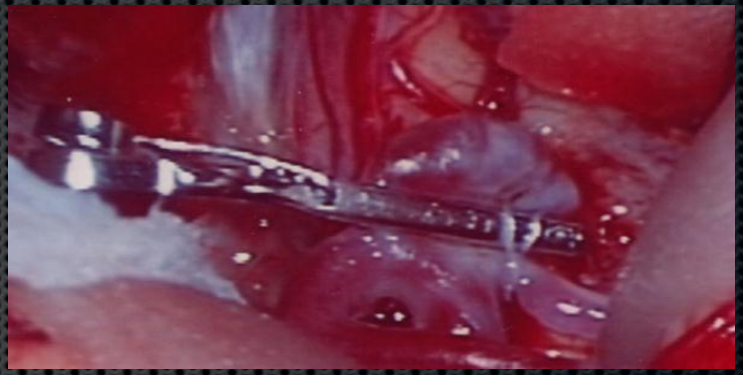
# How are aneurysms treated?

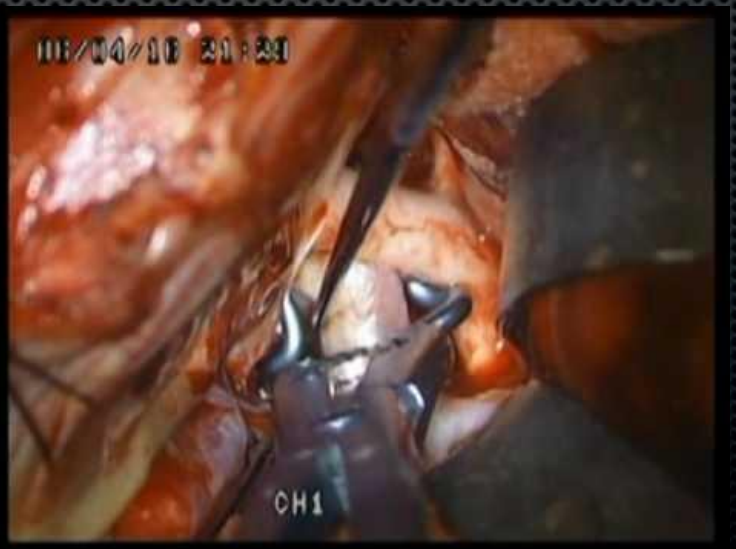
- classical surgical clipping
- coiling (detachable coils)
- coiling with remodeling (stent or baloon)
- Onyx HD for aneurysms (liquid embolic material )

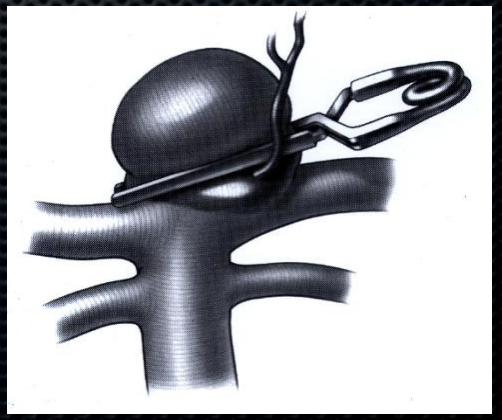
Depends on size, shape, width of base (neck) and location.

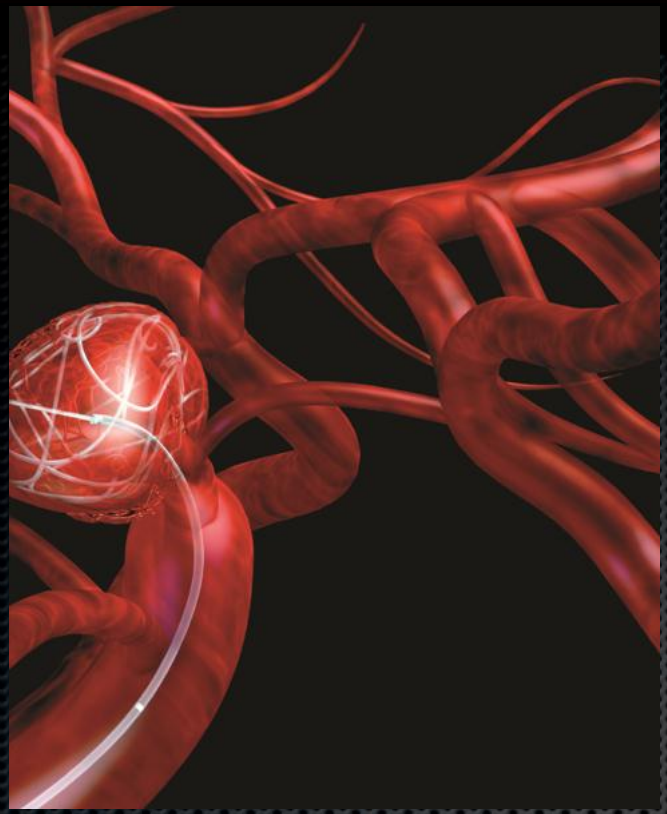
# The modern treatment of aneurysms include classical surgical clipping of the aneurysm



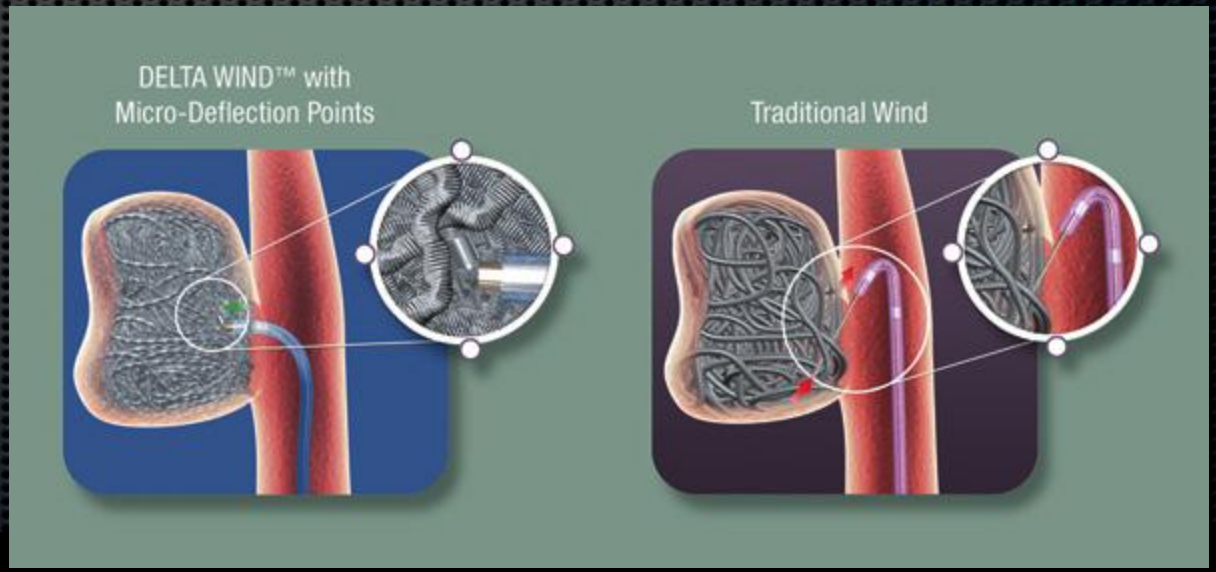







# Coiling

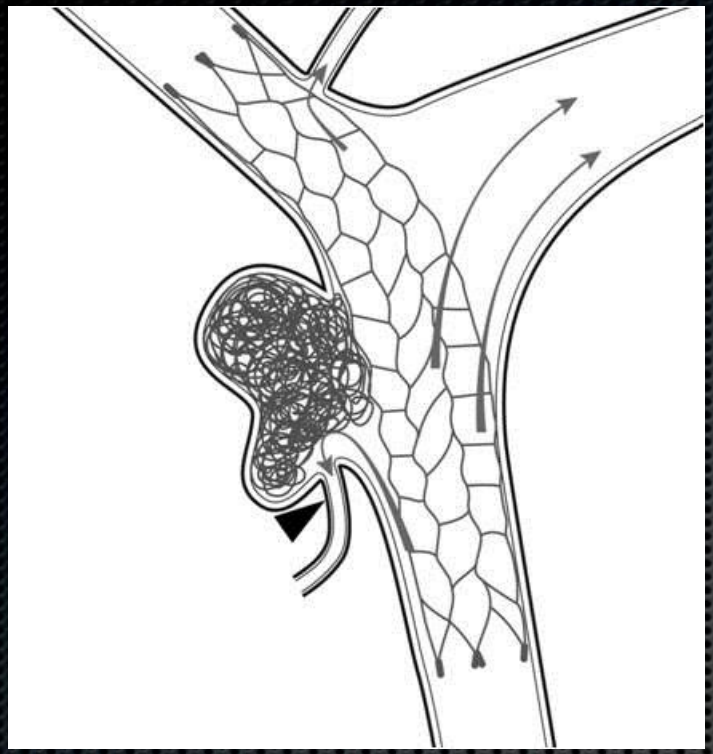


# Coiling - animations





DeltaPaQ



# Remodeling technique with stent

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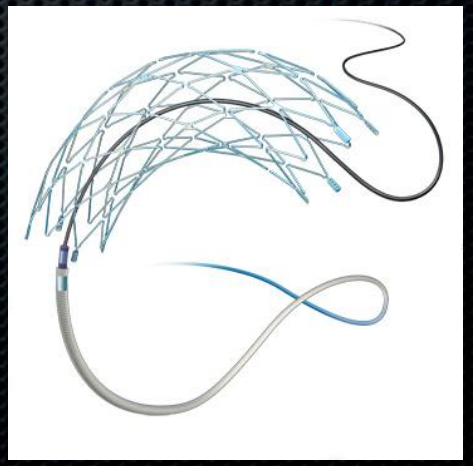
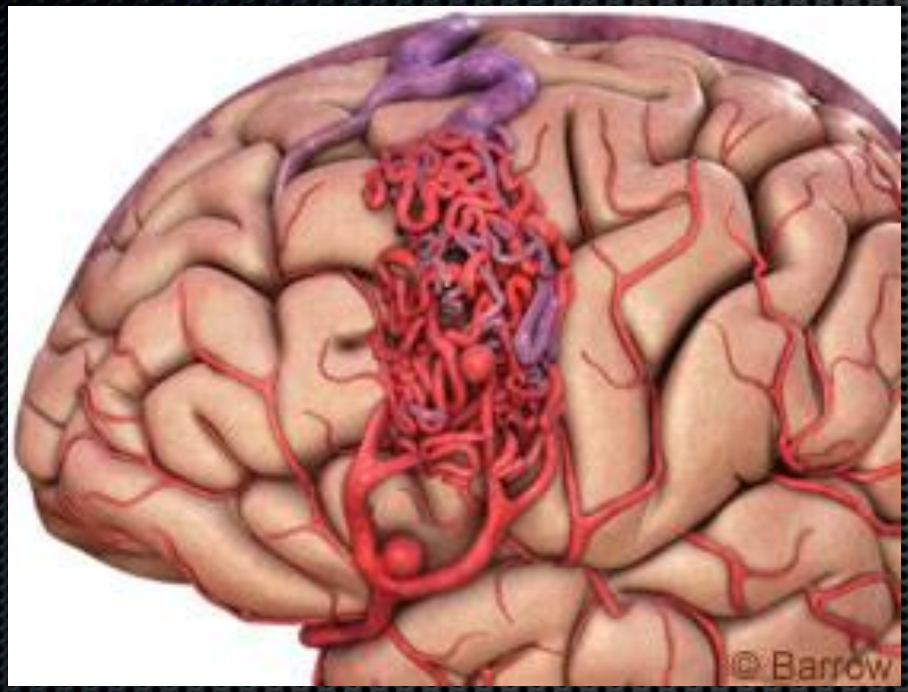


# Onyx

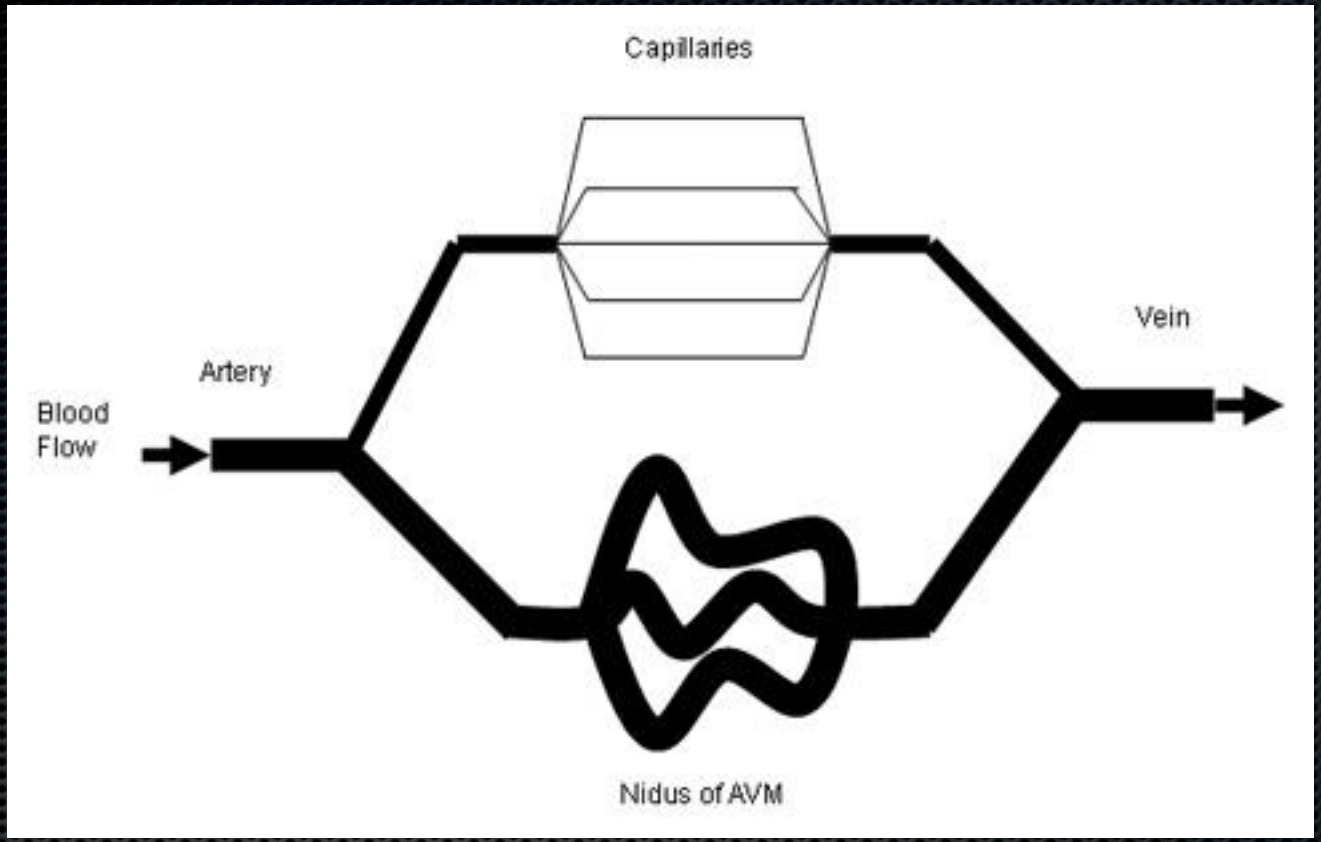
Liquid embolic material
- behaves like lava

+ animation

# Brain Arteriovenous Malformations

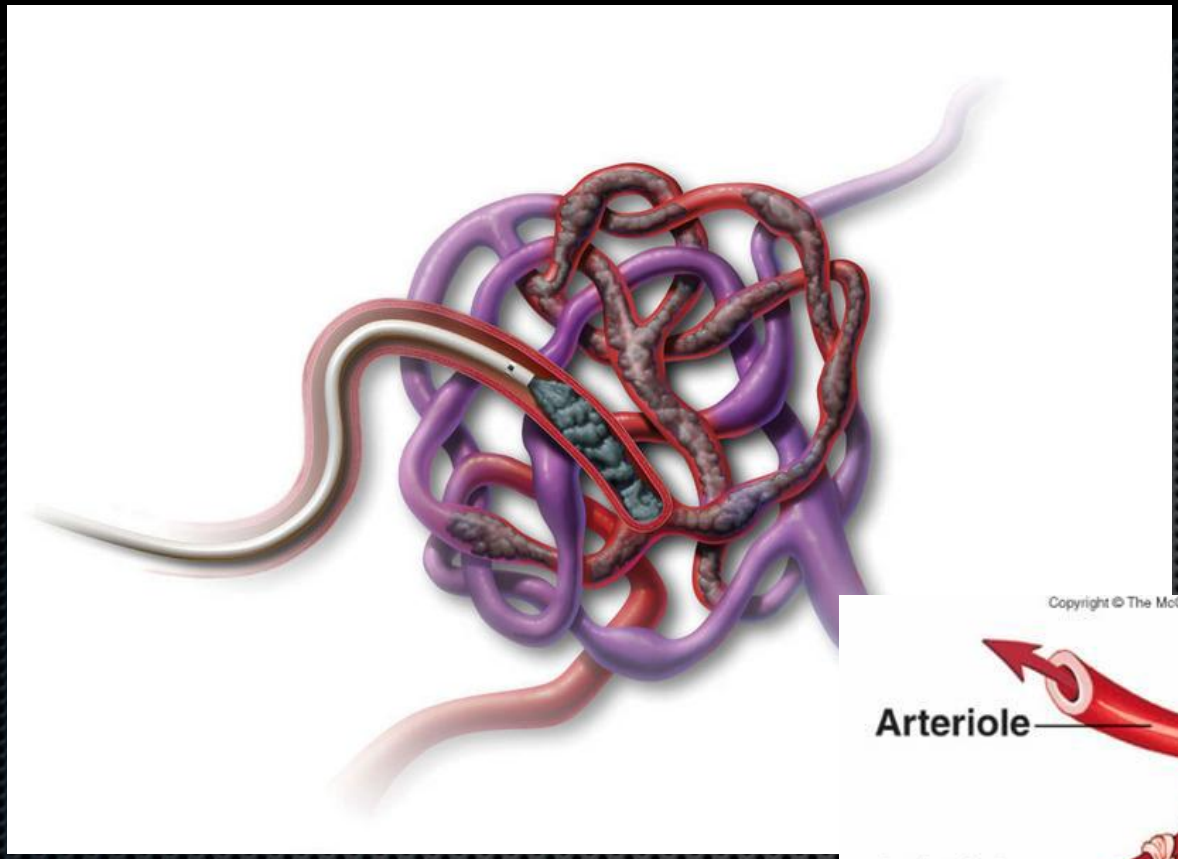



- Arterio-Venous Malformations (AVMs) are abnormal tangles of arteries and veins without an associated capillary bed.
- The mass of the AVM, referred to as the nidus, is devoid of neural tissue.
- Most AVMs are congenital, but they can enlarge over time.
- These lesions can exist anywhere in central nervous system.

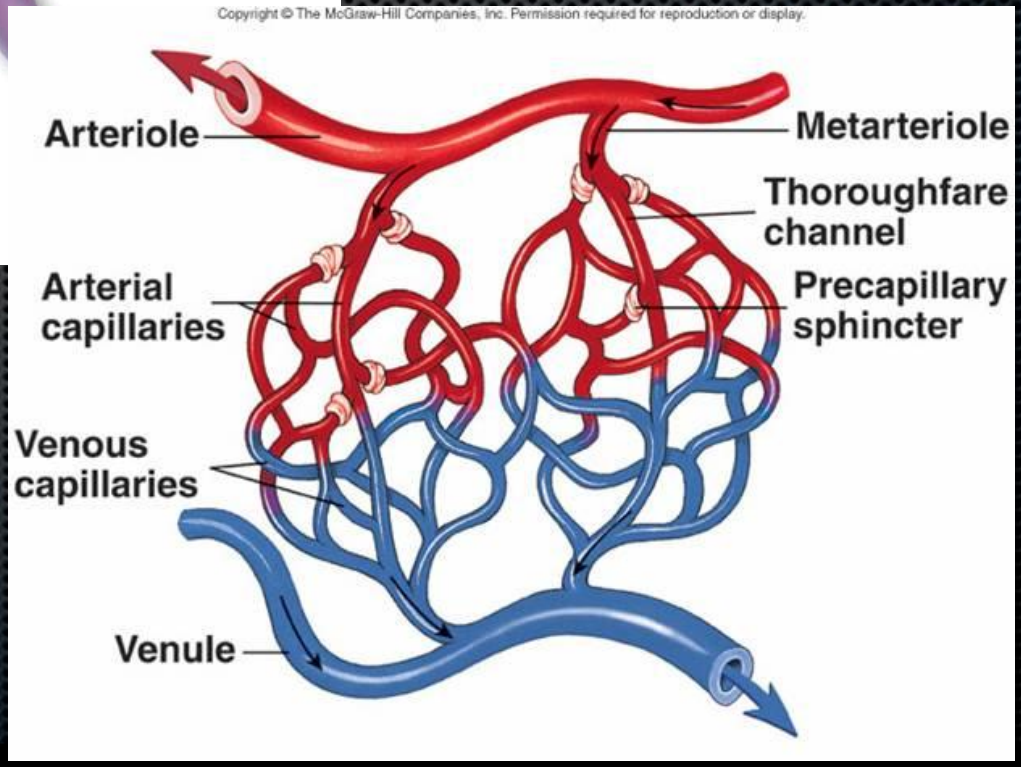



Normal arteriovenous connection is depicted in the figure on top with arteries leading to capillaries then to veins.

On the bottom, an AVM is depicted with **large sized shunts** connecting the artery to the vein. In this diagram three shunts are depicted. The collection of shunts is called the **nidus** of the AVM. In reality, in an AVM, **hundreds of shunts** connect the artery to the vein.







## What causes AVM developement in fetus?

It is not known how AVMs develop in the fetus. About 0.14% of the U.S. population has AVMs

## What are risks associated with AVMs?

Veins are under high pressure and can bleed. Unfortunately most people discover that they have an AVM when they bleed. AVM can cause seizures or neurological symptoms such as weakness, numbness in the body, vision changes or speech problems.

Bleeding has a 1 in 10 chance of causing death and if you survive the bleed there is a 50% chance of causing disability.

This bleeding in the brain causes a **severe headache** that is rather sudden in onset and is typically associated with **nausea and vomiting**. Patients with bleeding in the brain may also lose consciousness

Data on the natural history of AVMs indicate that hemorrhage rate is 2 to 4% per year.

Because these lesions are present from birth, patients tend to develop symptoms at a younger age than patients with aneurysmal hemorrhage.

# How is an AVM diagnosed?

Patient with bleeding is evaluated typically with a **CT scan**.

CT sensitivity depends on: blood volume, hematocrit, and time elapsed after acute event.

24h after SAH 95%

3 days – 80%

5 days - 70%

1 week – 50%

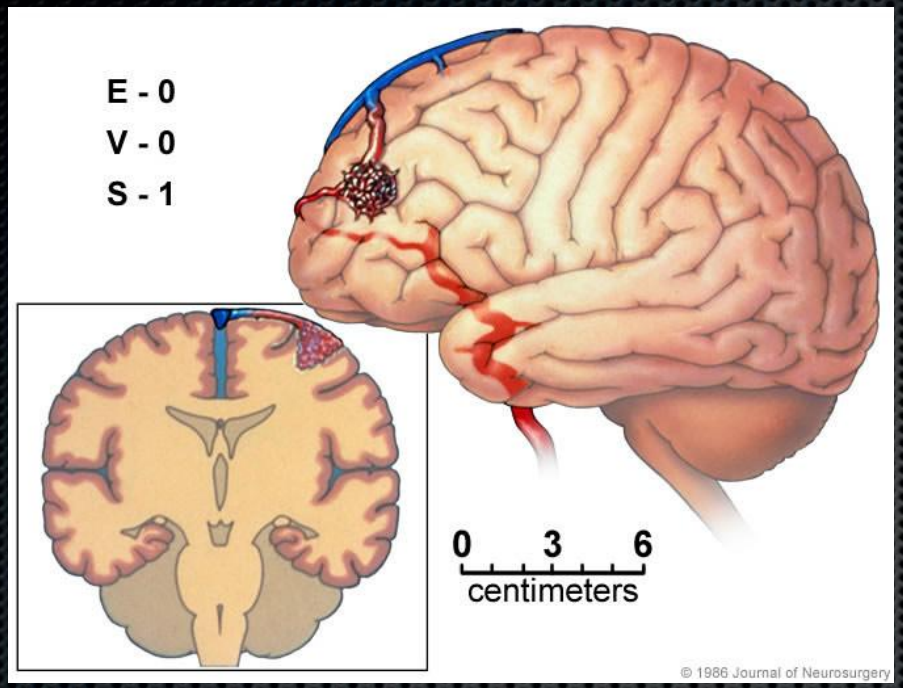
2 weeks – 30% !!!

Once bleeding is confirmed on a CT scan, definitive diagnosis of an AVM is made by **angiography**. **MRI is also very helpful** particularly with localizing the AVM. (*)

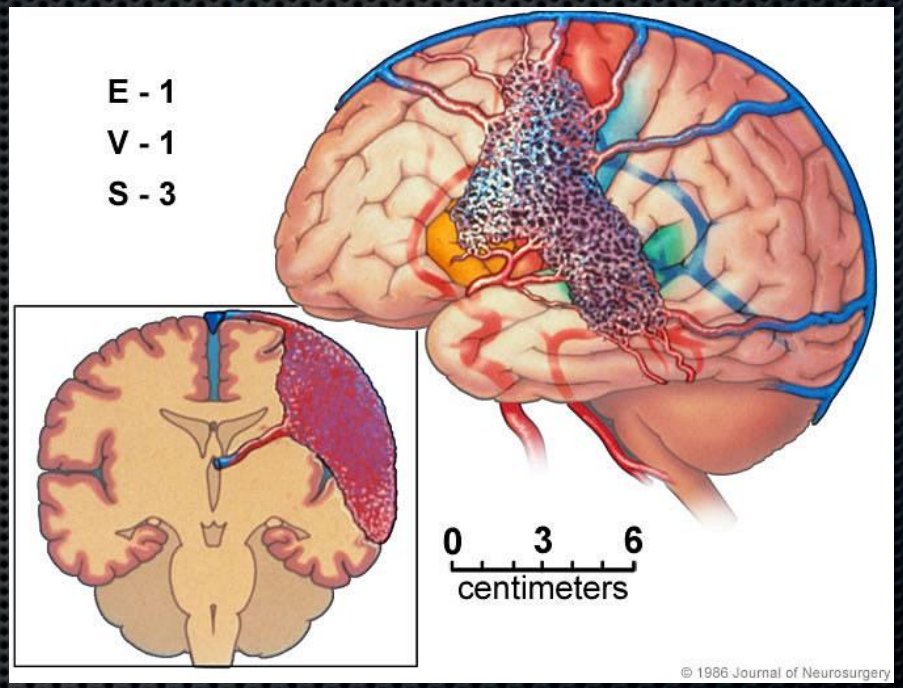

Once the location and appearance of the AVM is decided, definitive plans for treatment are made

Lateral view from catheter angiogram shows AVM nidus (arrow) being fed by branches of the middle cerebral artery (MCA) and immediate filling of a draining vein (arrowhead).

# Grade



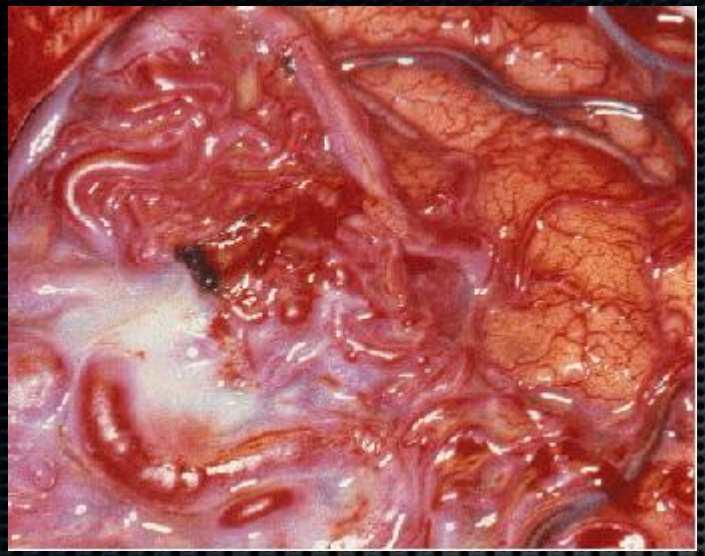

**Grade I**

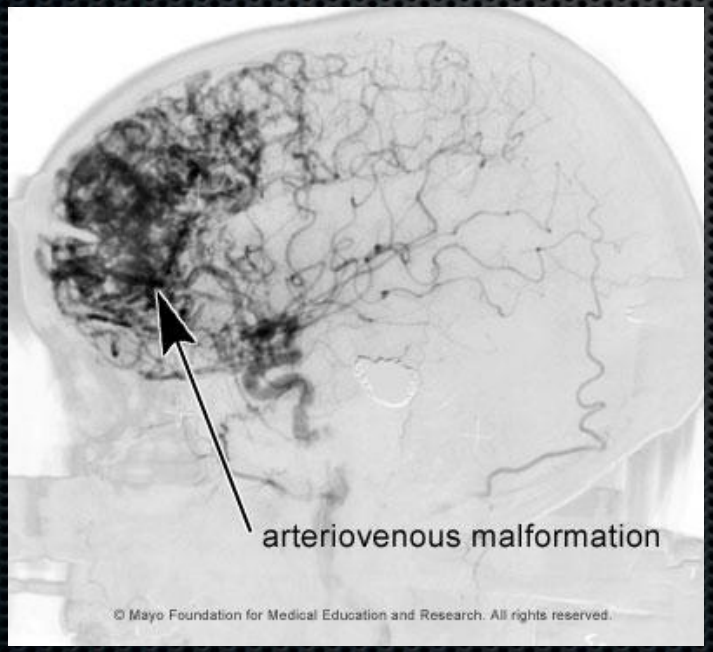



**Grade V**

Arteriovenous malformations are categorized according to the Spetzler-Martin **grading system**. This system considers the **size** of an AVM, its **location** near important cortical tissue, and the presence or absence of deep venous drainage

# Aneurysms Associated with Arteriovenous Malformations







**10 to 20%** of arteriovenous malformations are associated with aneurysms.

These aneurysms can occur along the feeding (flow-related) arteries that lead to the AVM, along dysplastic arteries within the nidus of the AVM itself (nidal aneurysm), or along the circle of Willis.

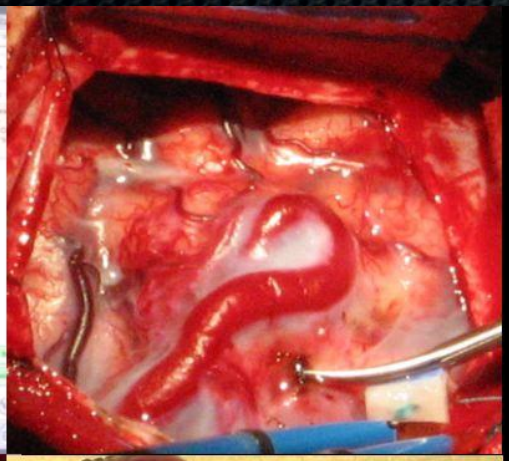
The rupture rate of aneurysms associated with AVMs is thought to be significantly higher than that of patients with an aneurysm and no AVM.

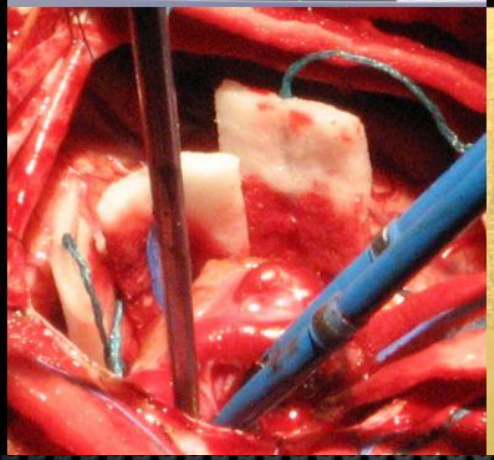
Hence, aggressive treatment of aneurysms associated with an AVM is usually recommended, irrespective of the grade of the AVM.

# Treatment

Treatment options for arteriovenous malformations include:

- endovascular embolization
- microsurgical resection
- stereotactic radiosurgery
- or a combination of these treatments.






Upper-left image: Like GPS navigation in automobiles, during this surgery, a **neuronavigation** system is used to confirm, in real-time, the margins of the AVM as it is being surgically excised. Upper-right image: The AVM is exposed, with a large and abnormal draining vein on its surface. Lower-left image: The AVM is being gradually excised using microsurgical techniques. Lower-right image: The AVM has been removed. At the conclusion of the surgery, the dura mater is surgically closed, and the bone flap restored as described above, followed by closure of the scalp.

Microsurgical resection involves a craniotomy to access the AVM followed by microscopic and stereotactic magnetic resonance (MR) imaging guidance to dissect the lesion

# Neurosurgical AVM operation

(*)

# Endovascular embolization

Requires access to the arterial system via the common femoral artery, followed by guidance of catheters and microcatheters inside of the arteries. The specific arterial branches that feed the AVM are selectively microcatheterized, permitting selective microangiography of the feeding pedicle. Embolic agents (materials that cause clotting) can be deposited into the nidus of the AVM, progressively obliterating the lesion. Metal coils, N-butyl-2-cyanoacrylate (NBCA), and Onyx are materials that can be used to embolize AVMs

# Endovascular Treatment of a Cerebral AVM (*)

(*)


# Stereotactic radiosurgery

Can be performed using Gamma Knife radiosurgery. This method use a focused beam of radiation so that the size and shape of the AVM can be treated precisely while exposure of the adjacent normal structures to radiation is minimized. Ultimately, the mode or modes of AVM treatment are dictated by the patient's clinical history and by the Spetzler-Martin grade and location of the AVM.

(animation)

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