Subarachnoid Hemorrhage

CASE

A middle-aged women with chronic back pain, COPD, and tobacco use presents with altered mental status. She was last known well at 9PM the night prior but was found down on her bathroom floor this morning at 7AM. Her CT head shows a right frontal intracranial hemorrhage. She is at a small community hospital and needs to transfer to your hospital for continued care.

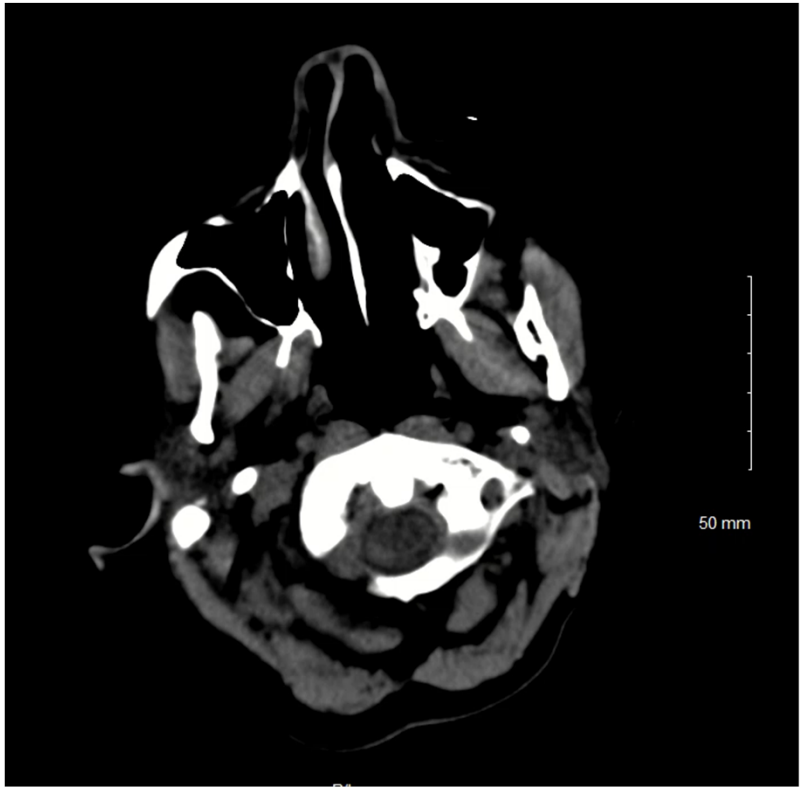
On arrival, she is obtunded, she does not open her eyes to voice or noxious stimuli, her pupils are reactive but sluggish, groans without any clear words, and moves her right side more than her left with withdrawal in the right upper extremity and extension in all others.

What do you do next?

ABCs: airway, breathing, circulation.

She is not protecting her airway and has a GCS of 7. She needs to be intubated for airway protection. She also has a known ICH, so blood pressures should be tightly controlled.

IMAGING

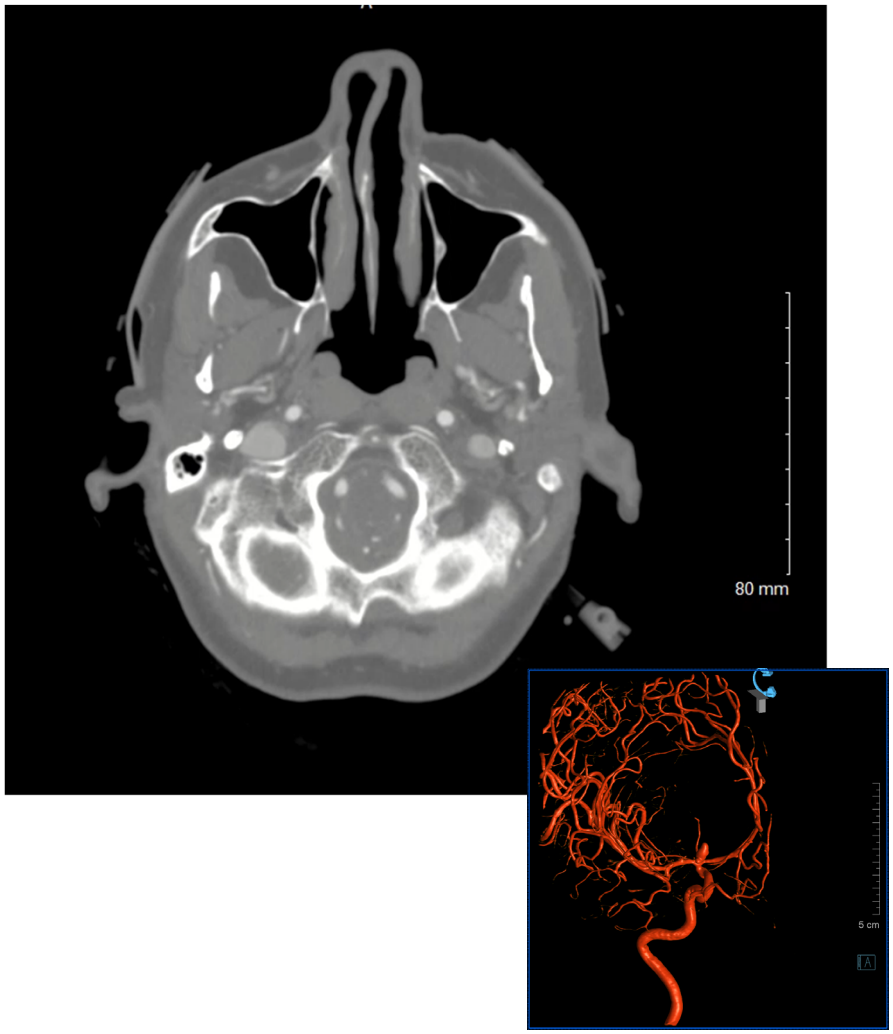


A 5.0 x 4.5 x 3.5cm right frontal hematoma that has ruptured into the right frontal horn with the bodies of the lateral ventricles nearly totally filled. The right lateral ventricle is moderately enlarged, the left to a lesser degree, with marked enlargement of the temporal horns and blood layered in the occipital horns.

How do you calculate the hematoma volume?

$$\frac{A \cdot B \cdot C}{2} = \frac{HEIGH \cdot WIDTH \cdot LENGTH}{2}$$

$$\frac{5.0 \cdot 4.5 \cdot 3.5}{2} = 39\ CC$$



You consult your colleagues in Neurosurgery for an external ventricular drain (EVD) due to developing hydrocephalus. After placement, you repeat the CT head and also obtain at CT angiogram.

On the CTA, there is a R ICA terminus aneurysm. While this may have initially appeared to be a traumatic vs hypertensive ICH, now it is clearly an aneurysmal subarachnoid hemorrhage (aSAH).

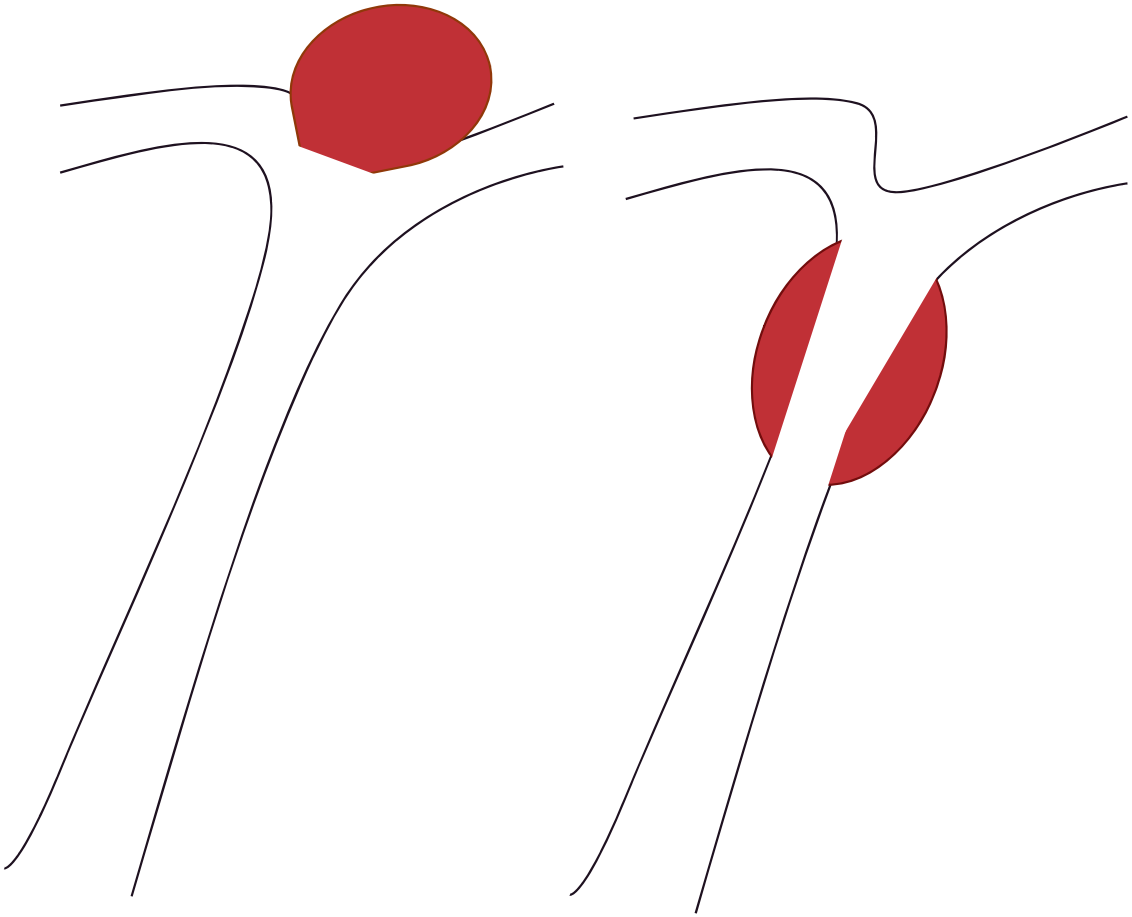
In a suspected aneurysmal rupture, CTA is 77-98% sensitive and 87-100% specific. It is important to note that for aneurysm <33, CTA can be unreliable. In these cases, digital subtraction angiography (DSA) is the gold standard for cerebral vasculature imaging.

PATHOPHYSIOLOGY

Subarachnoid hemorrhages occur due to extravasation of blood into the subarachnoid space (i.e. under the arachnoid mater) due to rupture of an aneurysm (aneurysm SAH) or trauma (traumatic SAH). Approximately 80% of spontaneous, non-traumatic SAH result from aneurysmal rupture.

Aneurysms typically form at vessel bifurcations due to developmental defects in the tunicas media and elastica. Inflammatory processes are also implicated in aneurysm formation and rupture.

There are several types of aneurysms:



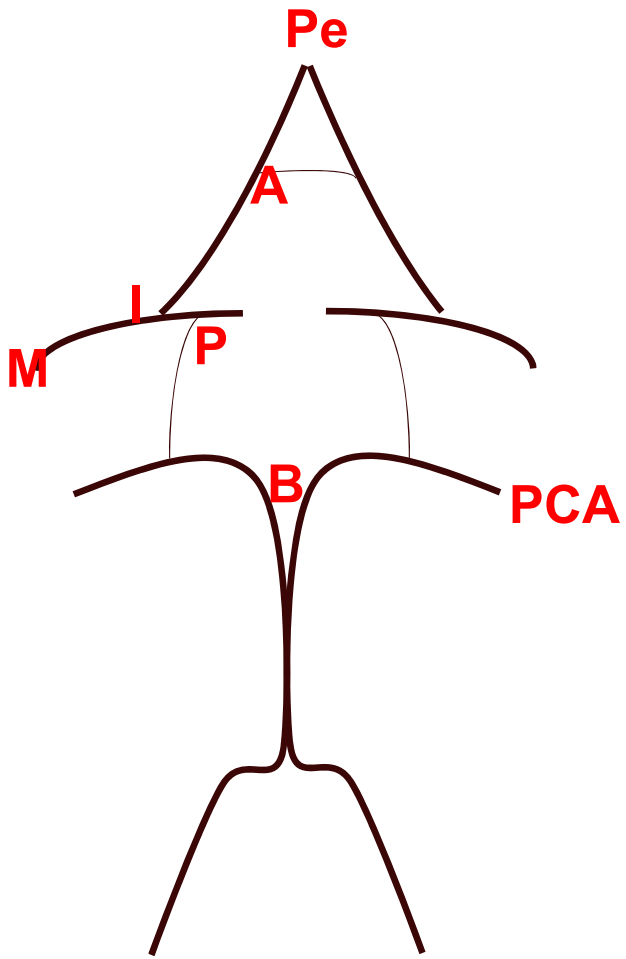
Saccular (berry) aneurysms (left) are located at major arterial branch points, predominately in the anterior circulation. They account for approximately 90% of all intracranial aneurysms and 70-80% of aSAH. They can be considered “giant” if they are >2.5cm.

Fusiform (dolichoectatic) aneurysms (right) are elongated outpouchings, predominately in the vertebrobasilar system and account of approximately 4% of intracranial aneurysms.

There also pseudoaneurysms, in which dissections can rupture through the tunica adventitia, and mycotic aneurysms, which are infectious in etiology where bacteria weakens the vessel.

Aneurysms are most often seen in the anterior circulation.

AComm	30%
PComm	25%
MCA	20%
ICA terminus	7.5%
Basilar tip	7%
Pericollasal artery	4%
PCA	3%



EPIDEMIOLOGY

Based on autopsy studies, the prevalence of unruptured intracranial aneurysms in adults in the US is 1-5%, with 20-30% of with multiple aneurysms. The incidence of ruptured aneurysms in the US is approximately 10-15/100,00 adults, leading to approximately 30,000 adults affected per year.

Risk factors for aneurysms and subsequent rupture include, but are not limited to: autosomal dominant PKD, fibromuscular dysplasia, Marfan syndrome, Ehlers-Danlos syndrome type IV, cerebral AVMs, substance use, tobacco use, and hypertension.

GRADING OF aSAH

WFNS

World Federation of Neurosurgical Societies

- **grade 1**: GCS 15, no motor deficit.
- **grade 2**: GCS 13-14 without deficit
- **grade 3**: GCS 13-14 with focal neurological deficit
- **grade 4**: GCS 7-12, with or without deficit.
- **grade 5**: GCS <7 , with or without deficit.

The WFNS is a communication tool to denote severity of symptoms.

The mFS predicts incidence of symptomatic vasospasm based on radiographic appearance.

The HH score predicts mortality based on symptoms at presentation.

Modified Fisher Scale (mFS)

- **grade 0**: no SAH; no IVH → *incidence of symptomatic vasospasm = 0%*
- **grade 1**: focal or diffuse, thin SAH; no IVH → *the incidence of symptomatic vasospasm: 24%*
- **grade 2**: thin focal or diffuse SAH; IVH present → *the incidence of symptomatic vasospasm: 33%*
- **grade 3**: thick focal or diffuse SAH; no IVH → *the incidence of symptomatic vasospasm: 33%*
- **grade 4**: thick focal or diffuse SAH; IVH present → *the incidence of symptomatic vasospasm: 40%*

Hunt-Hess Score (HH)

- **grade 1**: asymptomatic or minimal headache and slight neck stiffness *(70% survival)*
- **grade 2:** moderate to severe headache; neck stiffness; no neurologic deficit except cranial nerve palsy *(60% survival)*
- **grade 3**: drowsy; minimal neurologic deficit *(50% survival)*
- **grade 4**: stuporous; moderate to severe hemiparesis; possibly early decerebrate rigidity and vegetative disturbances *(20% survival)*
- **grade 5**: deep coma; decerebrate rigidity; moribund *(10% survival)*

How would you grade the aneurysm of the patient presented in the case?

WFNS

Grade 4: GCS 7-12

HH

Grade 4: stuporous moderate to severe hemiparesis, possible early decerebrate rigidity and vegetative disturbances

Carries a 20% survival likelihood

mFS

Grade 4: thick focal or diffuse SAH with IVH present

Carries a risk of 40% incidence of symptomatic vasospasm

ACUTE COMPLICATIONS

Rebleeding of an unsecured aneurysms is a significant risk, the occurrence of which is associated with high mortality. This occurs in 4% of patients in the first 24rs, 8% within 72hrs, and 20% within 2 weeks if the aneurysm is not secured. Risk factors for re-bleeding include low GCS, large aneurysm, high blood pressure, intracranial hemorrhage, and acute hydrocephalus. It is imperative that the blood pressure is tightly controlled until the aneurysm is secured.

Hydrocephalus occurs in 15-85% of aSAH patients due to casting of the ventricles when intraventricular hemorrhage is present. When symptomatic, it leads to elevated ICP due to increased CSF pressure, necessitating an EVD for drainage. Of those with symptomatic hydrocephalus, 8.9-48% become shunt dependent.

SUBACUTE COMPLICATIONS

Seizures are reported in 6-18% and are more common in MCA aneurysms, when thick clots are present, with rebleeding, infarctions, and clipping (vs coiling). Seizures can increase mortality if they occur before an aneurysm is secured as they may lead to elevated pressures and subsequent rebleeding. It is a COR IIB, LOE B recommendation to prophylactically give an anti-seizure medication.

Cardiac abnormalities such as cerebral T-wave inversions and Takotsubo (stress) cardiomyopathy can been seen after aSAH.

Hyponatremia can occur due to hypothalamic injury leading the the release of naturetic peptides, promoting cerebral salt wasting. Patient are kept eunatremic with hypertonic fluids and/or salt tabs.

Vasospasm typically occurs 3-10 days, although it has been reported to occur up to 21 days, after the initial hemorrhage. Earlier vasospasm has also been reported in approximately 10% and is predictive of worse outcomes.

Vasospasm can lead to **delayed cerebral ischemic** (DCI) which is the 2nd most common cause of morbidity and morality after the acute effects of the initial rupture. DCI may manifest by worsening mental status and/or focal neurological deficits depending on the vessel territory involved.

INITIAL MANAGEMENT

Prior to and immediately after securing the aneurysm, patients must be monitored in the ICU. With the acute/subacute complications in mind, key points in management are:

- Maintain SBP < 140 until the aneurysm is secured
- Consult for EVD placement if hydrocephalus develops
- Start nimodipine for DCI
  - Nimodipine does not reduce rates of vasospasm
  - It reduces rates of DCI, severe disability, and death
- Monitor for hyponatremia and hypovolemia
  - Maintain eunatremia
  - Replete fluid losses

SECURING THE ANEURYSM

The mainstay treatment is to secure the aneurysm either by surgical ligation (clipping) or endovascular embolization with detachable coils (coiling). Which method is selected depends on the location and shape/size of the aneurysm as well as the expertise of the surgeon.

Clipping

Consider for:

- MCA bifurcation
- Small dome:neck ratios
- Atypical morphology

Pros:

- Can be used in tortuous circulation
- Direct aneurysm visualization
- Can evacuate hematoma during procedure

Cons:

- Requires craniotomy
- Clip can occlude neighboring vessels
- Clip can migrate or erode
- More prone to technical complications

Coiling

Consider for:

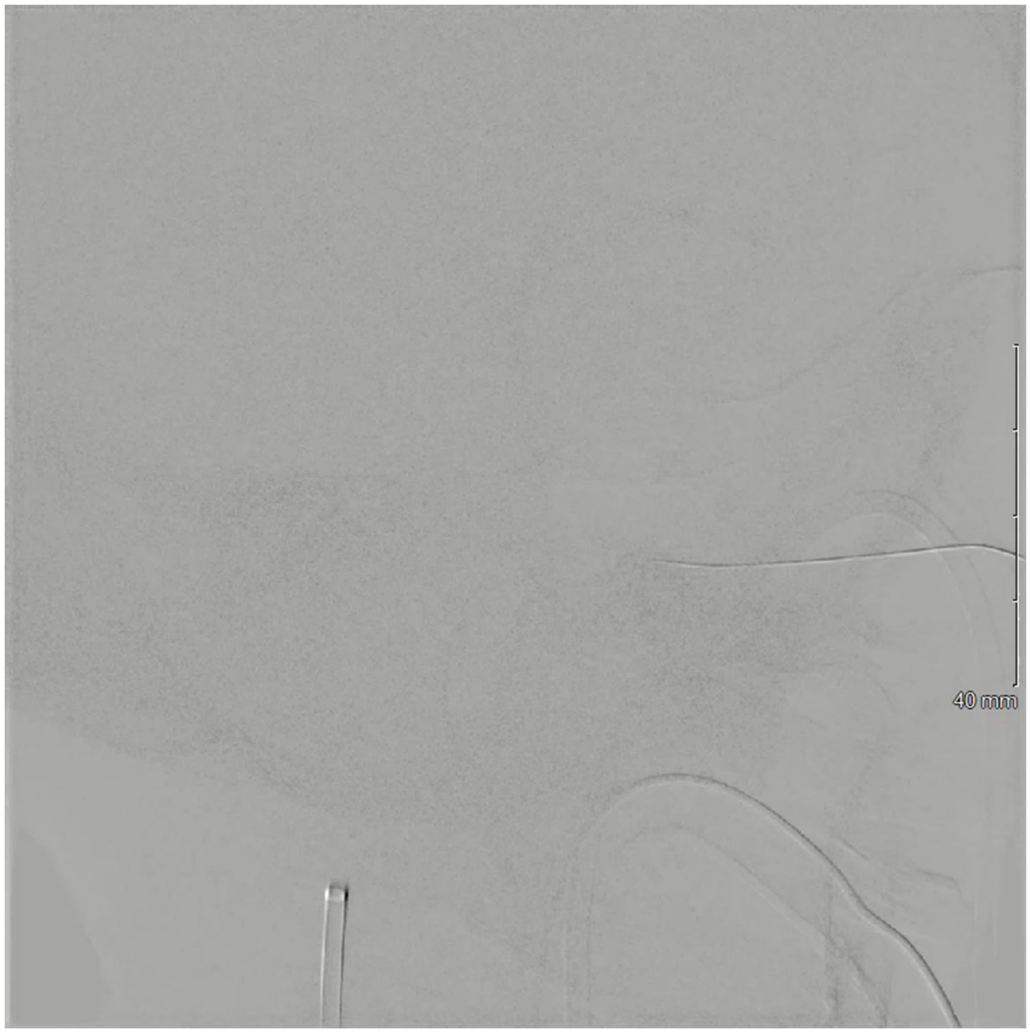
- Favorable dome:neck ratios
- Posterior circulation

Pros:

- Endovascular treatment
- Lower risk of subsequent epilepsy
- New devices and technique can be successful on complex morphology

Cons:

- Coils may perforate aneurysm wall
- Coils may malfunction, leading to incomplete aneurysm blockage
- Higher late re-bleeding rates



Returning to the case, a DSA was performed and the aneurysm dome:neck ratio for favorable for coiling. Endovascular embolization with detachable coils was successfully performed

MONITORING

Post-aneurysm securement, blood pressures may be liberalized to allow for permission hypertension during the vasospasm period. Between days 3 up to 21, monitor for vasospasm and DCI with transcranial dopplers (TCDs), EEG, and angiography as indicated.

TCDs use ultrasound to measure the flow in the intracranial vessels with phase shift proportional to the speed of blood. During vasospasm, there is an increase in flow velocity through the narrowed segment that is proportional to the reduction in vessel diameter. This can be normalized to the ipsilateral ECA to account for hyperemia, called the Lindegaard ratio.

EEG can also be used as a non-invasive method of detecting vasospasm-related DCI. Studies have evaluated using quantitative EEG changes in alpha/delta ratios (ADR) or alpha variability to detect impending cerebral ischemia. Decreasing relative alpha variability, decreased ADR, worsened focal slowing, and late epileptiform abnormalities correlate with DCI. This can be useful in patients with poor windows for TCDs but is limited in that it requires real-time interpretation for maximized intervention.

Vessel imaging (CTA or DSA) can also be used to assess for vasospasm if there are clinical concerns. If DSA is performed and clinically-relevant vasospasm is observed, intra-arterial therapy can be conducted.

Returning to the case, this patient was on nimodipine but it caused hypotension requiring pressor therapy. On TCDs, there was evidence of persistent vasospasm in the L ICA and basilar artery.

How do you treat this vasospasm?

TREATMENT OF DCI

Treatment of DCI can include calcium channel blockers and/or intra-arterial therapy.

Calcium channel blockers (nimodipine) are given as standard of care post-aSAH. They reduce the neurological worsening and infarction but do not change the degree of angiographic vasospasm.

Intra-arterial therapy can include IA drug administration or, less commonly, angioplasty. IA verapamil can be given directly to the site of vasospasm, limiting systemic hypotension which may complicate systemic therapy such as nimodipine, but should not be given if the aneurysm is partially secured.

Permissive hypertension is also allowed to help perfuse through spasmed vessels.

In this case, the patient was on pressors to keep blood pressures at least normotensive and underwent intra-arterial verapamil to the L ICA and L vertebral artery (for basilar spasm) on multiple occasions. This led to improved, but persistent, spasm in those regions. There was also vasospasm in the R MCA territory but no IA therapy was given due to the presence of a large hematoma.

OUTCOMES

The mortality of aSAHs has decreased over the years but it remains a high morbidity and mortality condition:

- 25% die within the first 24 hours
- 36-40% mortality at 30 days
- Permanent disability in 50%

Risk factors for poor outcomes include: poor clinical grade, advanced age, large aneurysm, re-bleeding, DCI, and global cerebral edema. Medical complications such as infections, anemia, fever, and hyperglycemia are also linked to worse outcomes.