Vascular diseases of the central nervous system

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1.Introduction

2. Vascular anatomy: anterior circulation, posterior circulation

3. Brain ischemia: thrombosis,embolism,systemic hypoperfusion, stroke syndromes(anterior/posterior circulation,lacunes, arterial dissection)

4. Diagnostic evaluation

5. Treatment

6.Transient ischemic attack

7. Intracranial hemorrhage: subarachnoid hemorrhage, intracerebral hemorrhage

8. Vascular malformations

1. Introduction

A stroke is a neurological injury caused by an abnormality of the blood vessels supplying the central nervous system (CNS)

In the USA each year, about 800000 individuals have a stroke and 130000 die from a stroke, i.e a stroke every 40 seconds and death from a stroke every 4 minutes

Fifth leading cause of death in the USA and a very important cause of prolonged disability

Although advances have been made in the prevention and treatment of stroke in the last 25 years, the economic, social and psychological costs of stroke remain huge

Many medical conditions and behaviours predispose to stroke such as HTN,DM, obesity, hyperlipidemia, sedentary lifestyle, smoking, cardiac disease and heavy alcohol use

Prevention of stroke is very important and can be accomplished by physicians attending to these stroke risk factors , advising patients about their lifestyles and habits and prescribing appropriate medications

Primary prevention is prevention of a first stroke, whereas secondary prevention is prevention of stroke recurrence

Second and third strokes are most often due to the same stroke subtypes as the initial stroke

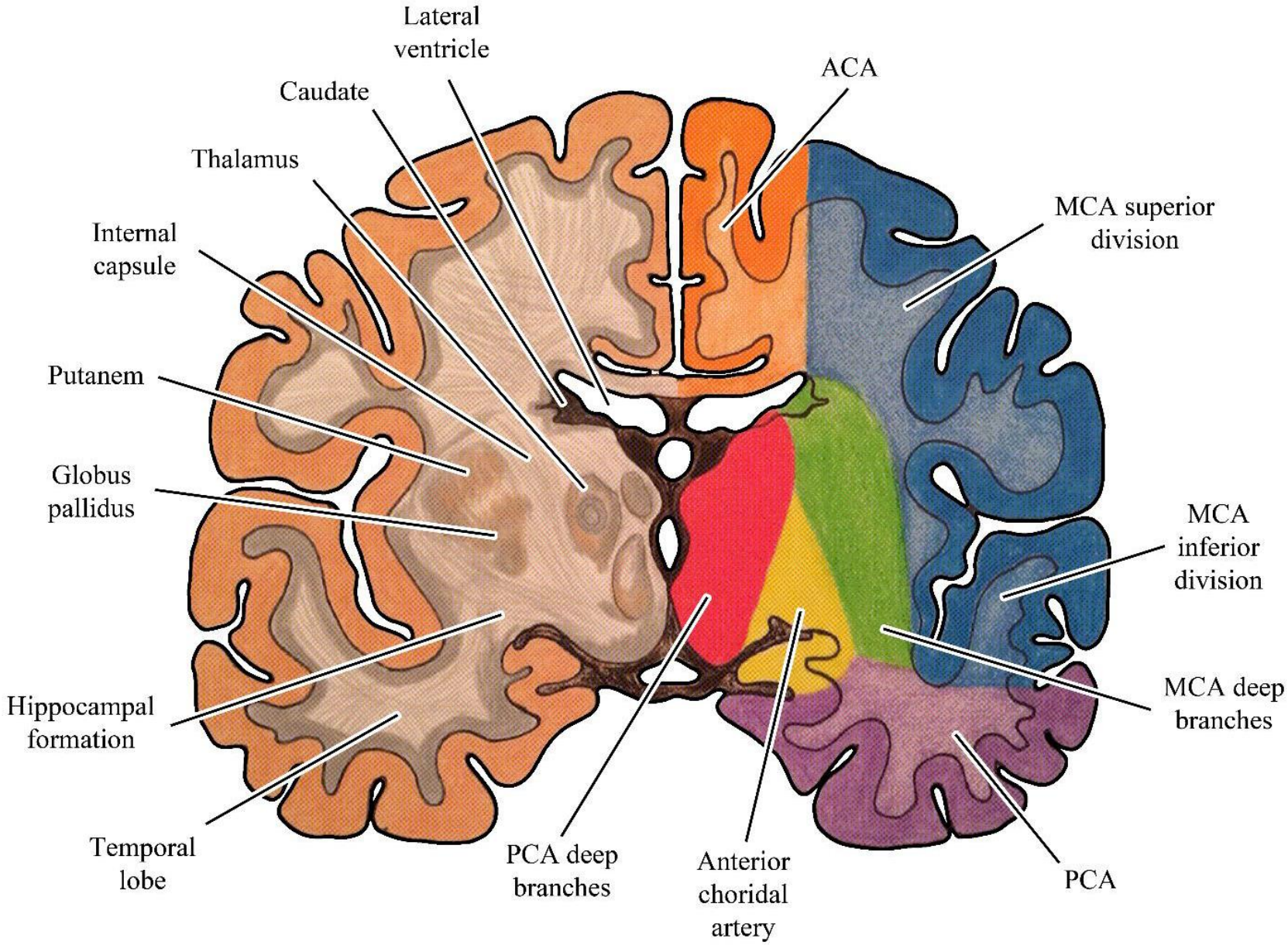
Identification of stroke etiology, therefore, is the most important step in avoiding recurrence

2. Vascular anatomy

The nature of neurologic symptoms and signs helps to localize dysfunction to a particular area of the brain and a particular vascular supply.

Intimate knowledge of the vascular anatomy of the brain , therefore ,is necessary

The cerebral vasculature is divided into the anterior and posterior circulation , with the anterior (carotid) circulation supplying the cerebral hemispheres except the medial temporal lobes and a portion of the occipital lobes, and the posterior (vertebrobasilar) circulation supplying the brainstem, thalami, cerebellum and the posterior portion of the cerebral hemispheres (Figure)


Lateral ventricle
Caudate
Thalamus
Internal capsule
Putanem
Globus pallidus
Hippocampal formation
Temporal lobe
ACA
MCA superior division
MCA inferior division
MCA deep branches
PCA
PCA deep branches
Anterior choridal artery

A) Anterior circulation

The right common carotid artery (CCA) branches from the innominate artery. The left CCA arises directly from the aorta.

The CCA divides in the neck into the internal carotid artery (ICA) and the external carotid artery.

The ICA travels behind the pharynx , entering the skull where it forms an S-shaped curve –the carotid siphon.

This portion of the ICA gives rise to the ophthalmic artery.

The ICA then penetrates the dura and gives off the anterior choroidal and posterior communicating arteries before bifurcating into the anterior cerebral (ACA) and middle cerebral arteries (MCA).

The ACA supplies the anterior medial cerebral hemispheres , the caudate nuclei and the basal frontal lobes.

The anterior communicating artery connects the two ACAs.

The MCA courses laterally , giving off lenticulostriate artery branches to the basal ganglia and internal capsule.

The MCA trifurcates into small anterior temporal branches and large superior and inferior divisions.

The superior division supplies the lateral cerebral hemispheres superior to the sylvian fissure, whereas the inferior division supplies the temporal and inferior parietal lobes.

B) Posterior circulation

The first branch of each subclavian artery is the vertebral artery (VA).

The VA enters the spinal column via the transverse foramina of C5 or C6 and runs within the intervertebral foramina, exiting to course behind the atlas before piercing the dura mater to enter the foramen magnum.

The intracranial VAs join to form the basilar artery at the ponto-medullary junction.

The intracranial VA gives off posterior and anterior spinal artery branches, penetrating arteries to the medulla and the posterior inferior cerebellar artery (PICA).

The basilar artery then runs in the midline along the clivus giving off bilateral anterior inferior cerebellar artery (AICA) and superior cerebellar artery (SCA) branches before dividing at the pontomesencephalic junction into the posterior cerebral arteries (PCA).

Small penetrating arteries arise at the basilar artery bifurcation to supply the medial portions of the midbrain and thalami.

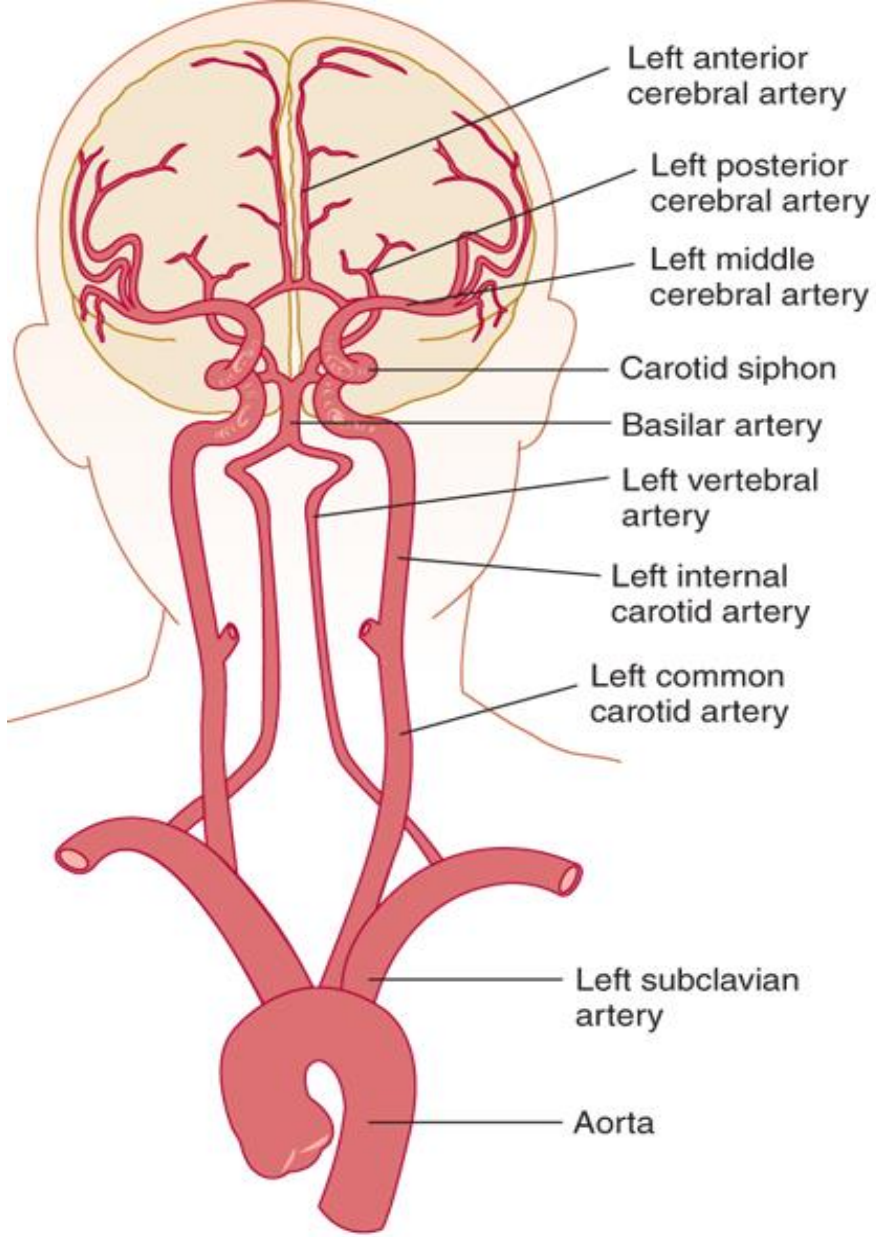
The vascular supply of the brainstem includes large paramedian arteries and smaller, short circumferential arteries that penetrate the basal portion of the brainstem into the tegmentum.

Long circumferential arteries course around the brainstem and give off branches to the lateral tegmentum.

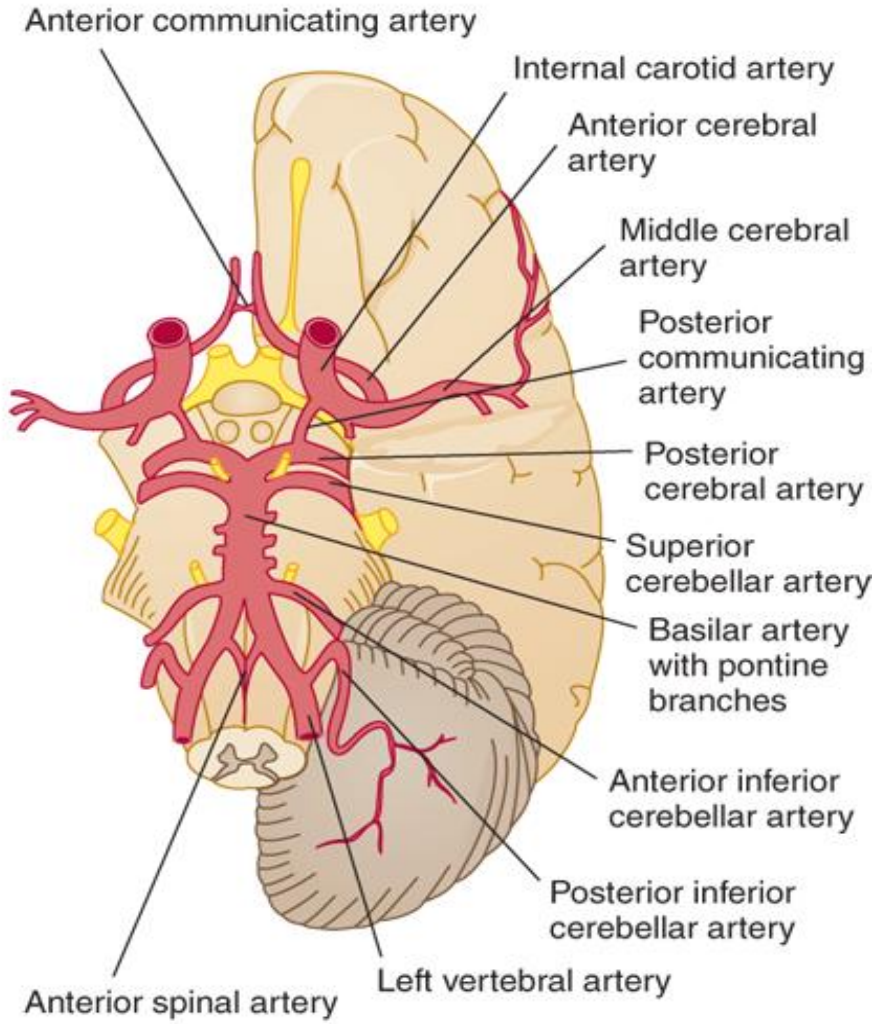
The PCA gives off penetrating arteries to the midbrain and thalamus, courses around the cerebral peduncles and then supplies the occipital lobe and the inferior surface of the temporal lobe.

The circle of Willis connects the anterior circulation of each side through the anterior communicating artery, and the posterior and anterior circulation of each side through the posterior communicating artery (Figure).

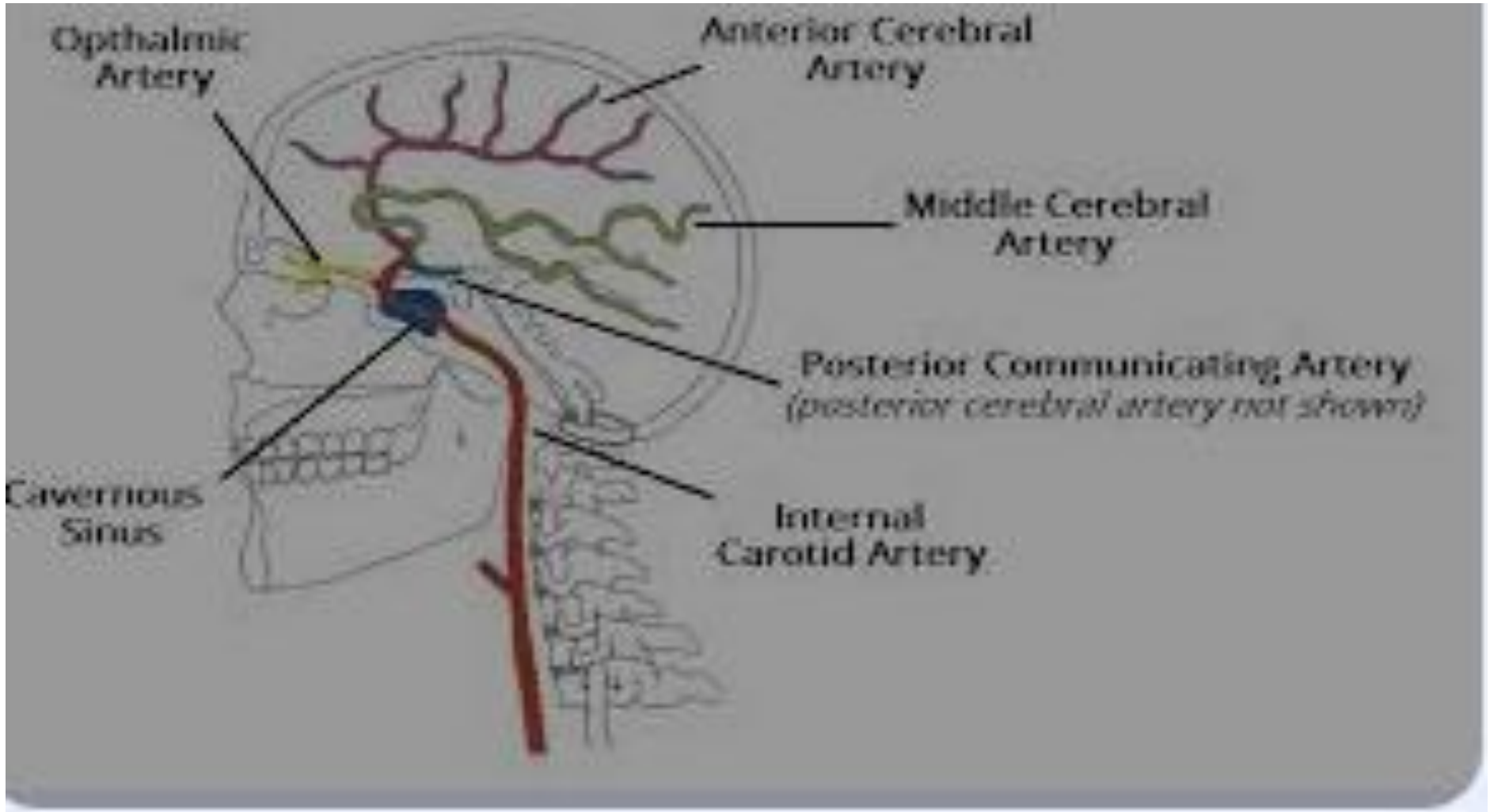
Each carotid artery supplies four-fifths of the brain, the vertebrobasilar circulation, one-fifth

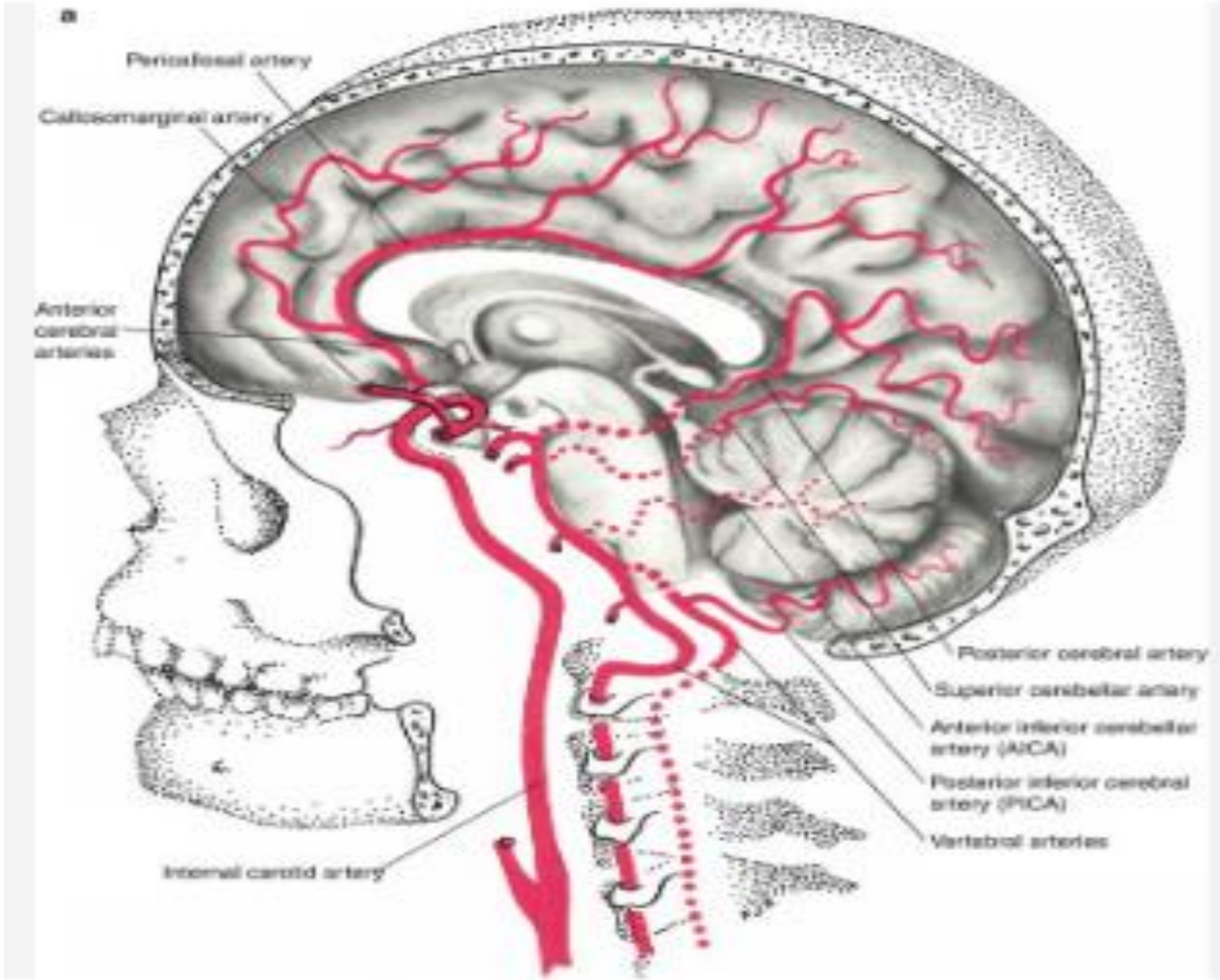


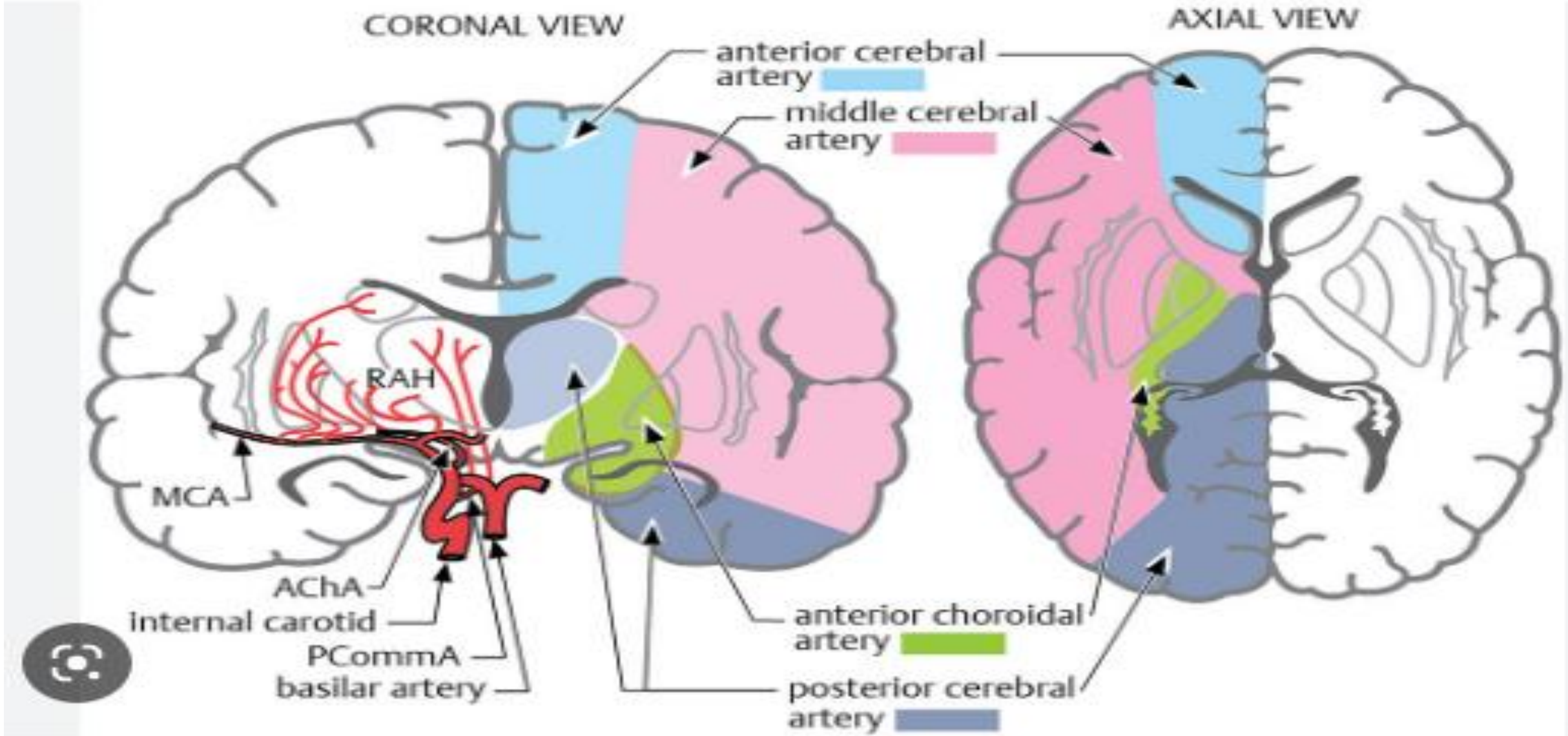
A



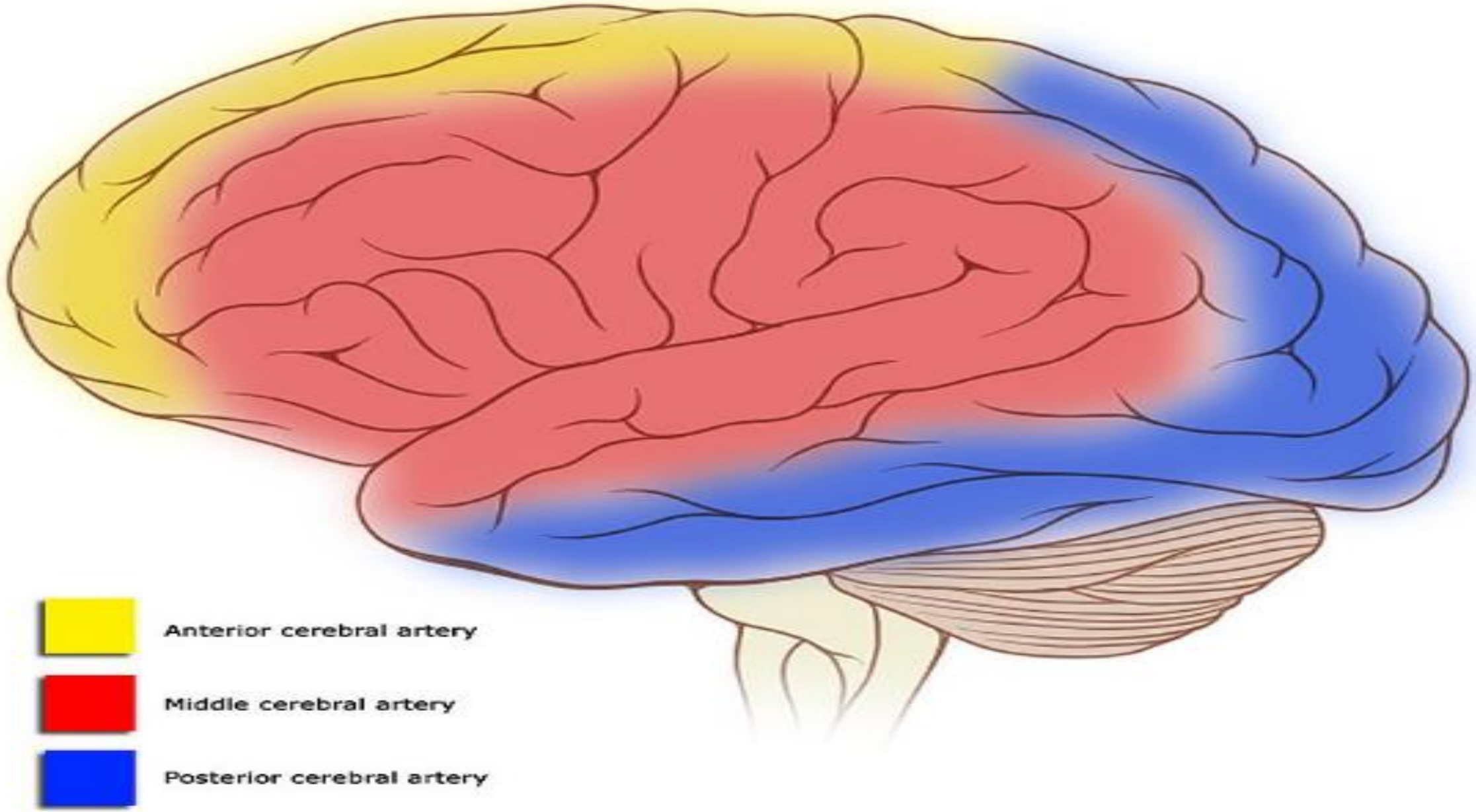
B


Opthalmic Artery
Anterior Cerebral Artery
Middle Cerebral Artery
Posterior Communicating Artery
(posterior cerebral artery not shown)
Cavernous Sinus
Internal Carotid Artery


a
Pericallosal artery
Callosomarginal artery
Anterior cerebral arteries
Posterior cerebral artery
Superior cerebellar artery
Anterior inferior cerebellar artery (AICA)
Posterior inferior cerebral artery (PICA)
Vertebral arteries
Internal carotid artery


CORONAL VIEW
AXIAL VIEW
anterior cerebral artery
middle cerebral artery
RAH
MCA
AChA
internal carotid
PCommA
basilar artery
anterior choroidal artery
posterior cerebral artery

Cortical vascular territories



3. Brain ischemia

About 80 % of strokes are ischemic whereas 10 % each are due to subarachnoid and intracerebral hemorrhages.

Ischemic strokes are divided into thrombotic, embolic and systemic hypoperfusion mechanisms.

A) Thrombosis

Thrombosis refers to obstructed blood flow due to a localized occlusive process within one or more vessels.

The most common vascular pathology is atherosclerosis in which fibrous tissue and lipid materials form plaques that encroach on the lumen.

Atherosclerosis affects mostly the large cervical and intracranial arteries.

Less commonly a clot forms within the lumen due to a primary hematologic problem, for example, polycythemia, thrombocytosis or hypercoagulability.

Vessel wall pathologies leading to thrombosis include vasoconstriction, fibromuscular dysplasia and arterial dissection.

Thrombosis of penetrating intracranial arteries is most often the consequence of hypertension, with hypertrophy of the media and deposition of fibrinoid material(lipohyalinosis) .

Microatheroma can obstruct penetrating artery origins.

B) Embolism

An embolus occurs when clot material formed elsewhere within the vascular system lodges in a vessel and blocks blood flow.

The material arises proximally, mostly from the heart or from major arteries such as the aorta, ICAs and VAs and from systemic veins.

Cardiac sources of embolism include the heart valves, endocardium and clots or tumors within the atrial or ventricular cavities.

High-Risk Sources

- Atrial fibrillation/flutter
- Sick sinus syndrome
- Recent myocardial infarction
- Previous myocardial infarction and akinesia
- Left ventricular thrombus
- Left atrial cavity thrombus
- Left atrial appendage thrombus
- Congenital heart diseases[a]
- Cardiomyopathies[b]

Artery-to-artery emboli are composed of clot, platelet clumps or fragments of plaques.

They may begin in large arteries and occur in the context of arterial dissection.

Thrombi originating in systemic veins travel to the brain through cardiac defects such as an atrial septal defect or a patent foramen ovale, a process termed paradoxical embolism.

Occasionally, air, fat, cholesterol crystals, bacteria and foreign bodies enter the vascular system and embolize to brain vessels.

C) Systemic hypoperfusion

Decreased blood flow to brain tissue may be caused by low systemic perfusion pressure .

The most common causes are cardiac pump failure(most often due to myocardial infarction or arrhythmia) and systemic hypoperfusion (due to blood loss or hypovolemia).

The lack of perfusion is more generalized than in localized thrombosis or embolism and affects brain diffusely and bilaterally.

Poor perfusion is most critical in border zone or so-called watershed regions at the periphery of the major vascular supply territories, for example, between the ACA and MCA or between the MCA and PCA.

Common ischemic stroke syndromes

* Anterior circulation

1. Left cerebral hemisphere strokes lead to:

a) Right hemiparesis: often arm, hand and face more than leg

b) Right hemisensory loss

c) Aphasia

d) In large lesions, conjugate deviation of the eyes to the left; right hemianopia or hemi-inattention

e) When caused by ICA occlusive disease, transient left monocular visual loss may also occur(amaurosis fugax)

2. Right cerebral hemisphere strokes cause:

a) Left hemiparesis, often arm, hand and face more than leg

b) Left hemisensory loss

c) Poor drawing and copying

d) Neglect of the left visual field

e) In large lesions, conjugate deviation of the eyes to the right, left hemianopia

f) When the signs are due to ICA occlusive disease, transient right monocular visual loss(amaurosis fugax) may accompany the brain signs

These cerebral hemisphere lesions are most often caused by carotid artery occlusion, embolism to the MCA or its branches or basal ganglionic intracerebral hemorrhages.

* Posterior circulation

1. Lateral medullary stroke (Wallenberg syndrome, usually due to intracranial VA or posterior inferior cerebellar artery/ PICA occlusion) causes:

a) Ipsilateral facial pain, or reduced pain and temperature sensation on the ipsilateral face or both

b) Loss of pain and temperature in the contralateral limbs and body

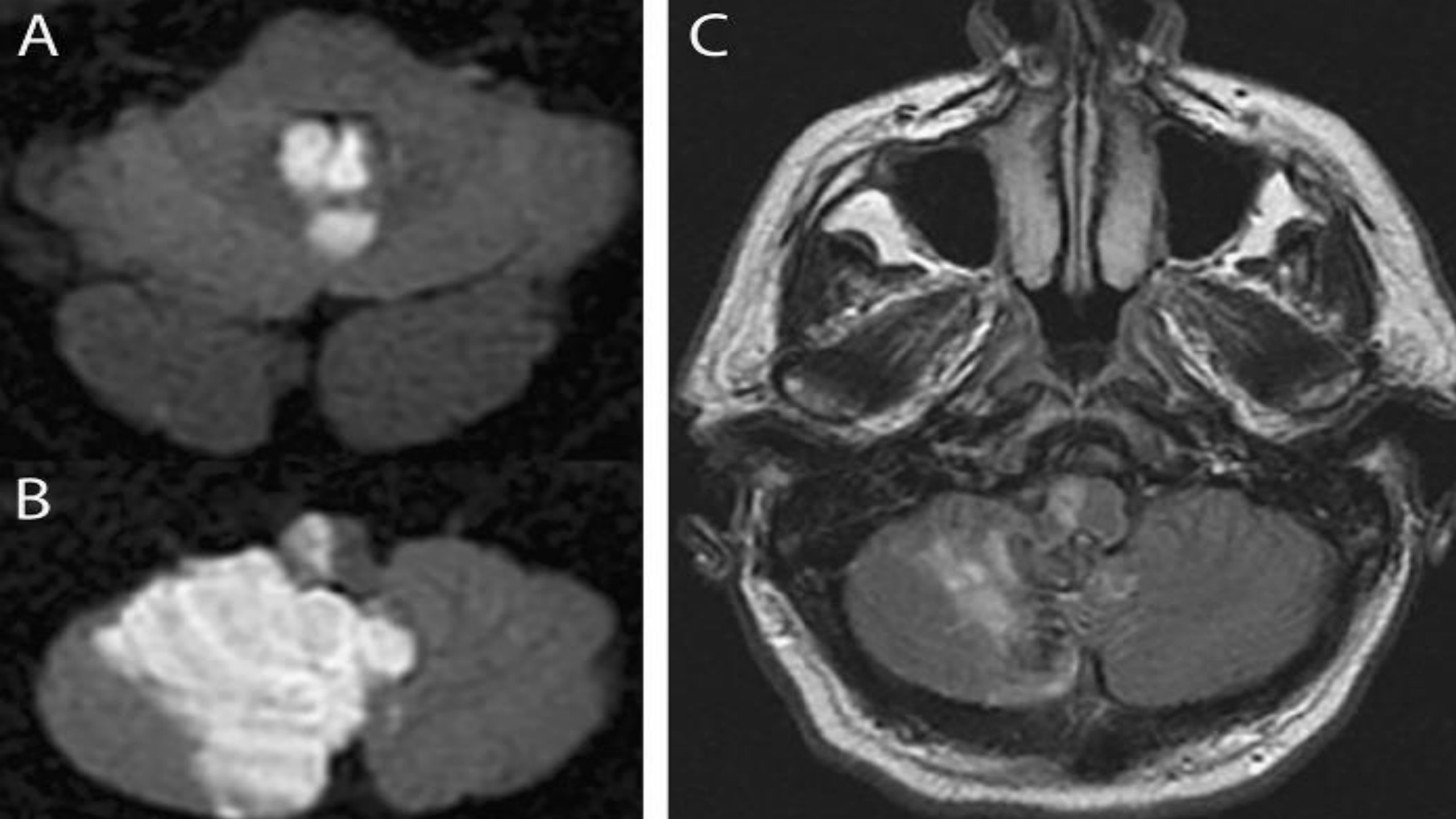
c) Ipsilateral Horner syndrome

d) Nystagmus

e) Incoordination of the ipsilateral arm

f) Leaning and veering while sitting or walking, with gait ataxia

g) In deep lesions, dysphagia and hoarseness


A
B
C

2. Bilateral pontine base and often medial tegmentum stroke(usually due to basilar artery occlusion or pontine hemorrhage) causes:

a) Quadriparesis

b) Unilateral or bilateral conjugate gaze paresis; sometimes internuclear ophthalmoplegia or 6^{th} nerve palsy

c) When the medial tegmentum is involved bilaterally, coma.

3. Cerebellar infarction (usually due to embolism to the PICA or SCA, or cerebellar hemorrhage) causes:

a) Gait ataxia

b) Dysarthria

c) Ipsilateral arm dysmetria

4. Left PCA territory stroke causes:

a) Right homonymous hemianopia

b) At times, amnesia

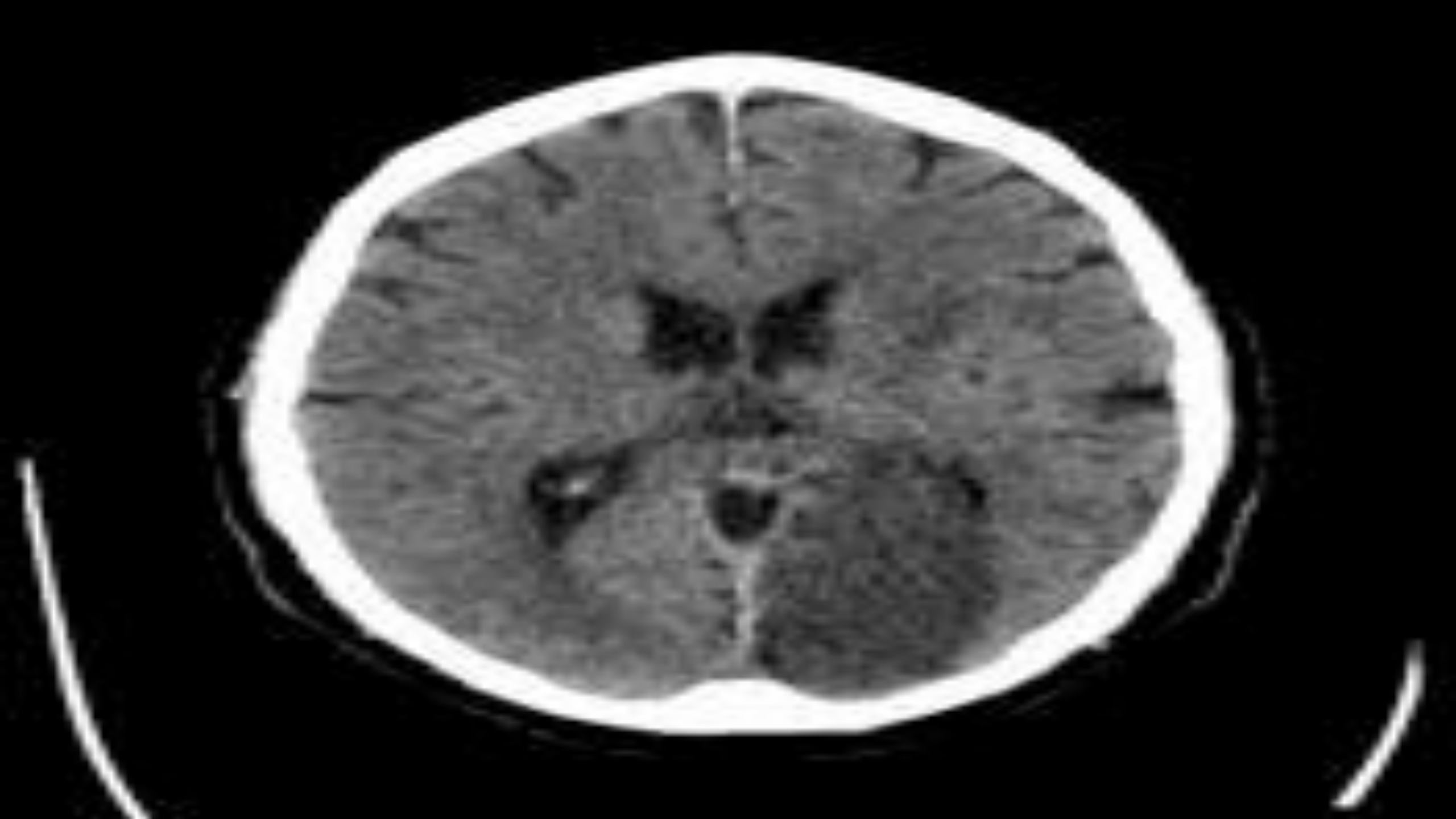
c) Alexia without agraphia when the splenium of the corpus callosum is involved

5. Right PCA territory stroke causes:

a) Left homonymous hemianopia

b) At times, left-sided visual neglect

PCA territory infarcts are most often caused by embolism arising from the heart, aorta or VAs



* Lacunar syndromes

Lacunar strokes are most often due to occlusion of a penetrating artery.

Similar to large-vessel strokes, they produce a fairly limited range of presentations.

Lacunar strokes may occur in either the anterior or the posterior circulations.

Classic lacunar stroke syndromes include the following:

1. Pure motor stroke

Weakness of the contralateral arm, face and leg without sensory, visual or cognitive/behavioural signs.

Common locations include the corona radiata, posterior limb of the internal capsule and pons.

2. Pure sensory stroke

Paresthesiae of the contralateral body, limbs and face without motor, visual or cognitive abnormalities

The most common location is due to infarction in the ventral posterior thalamus .

3. Sensorimotor stroke

Combination of motor and sensory lacunes

Due to infarction in the ventral posterior thalamus and adjacent posterior limb of the internal capsule

4. Dysarthria-clumsy hand syndrome

Slurred speech and clumsiness of the contralateral hand

The most common location is in the base of the pons

5. Ataxic hemiparesis

Weakness and ataxia of the contralateral limbs, often greater in the leg and foot than in the arm and hand.

The most common locations are the base of the pons, posterior limb of the internal capsule and corona radiata

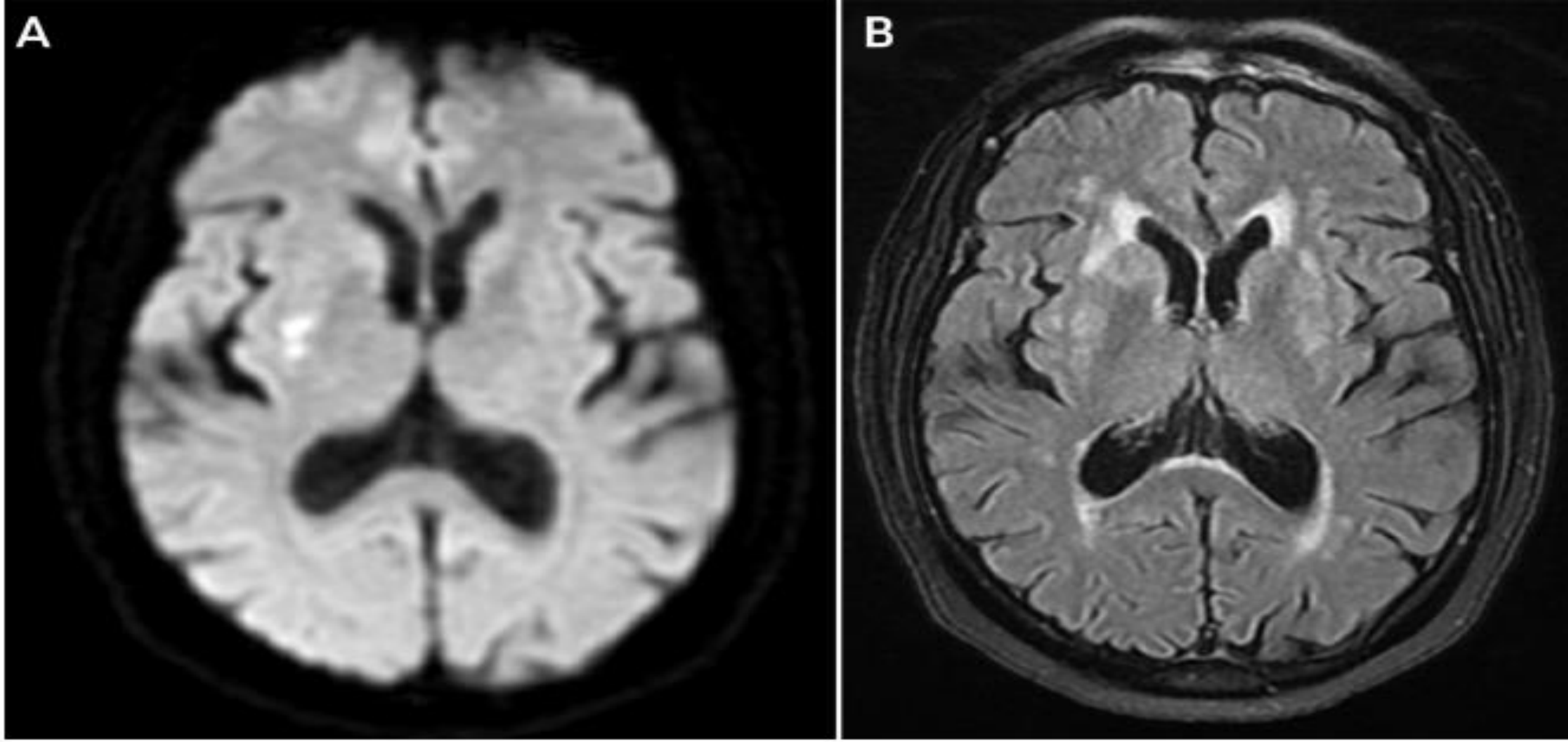
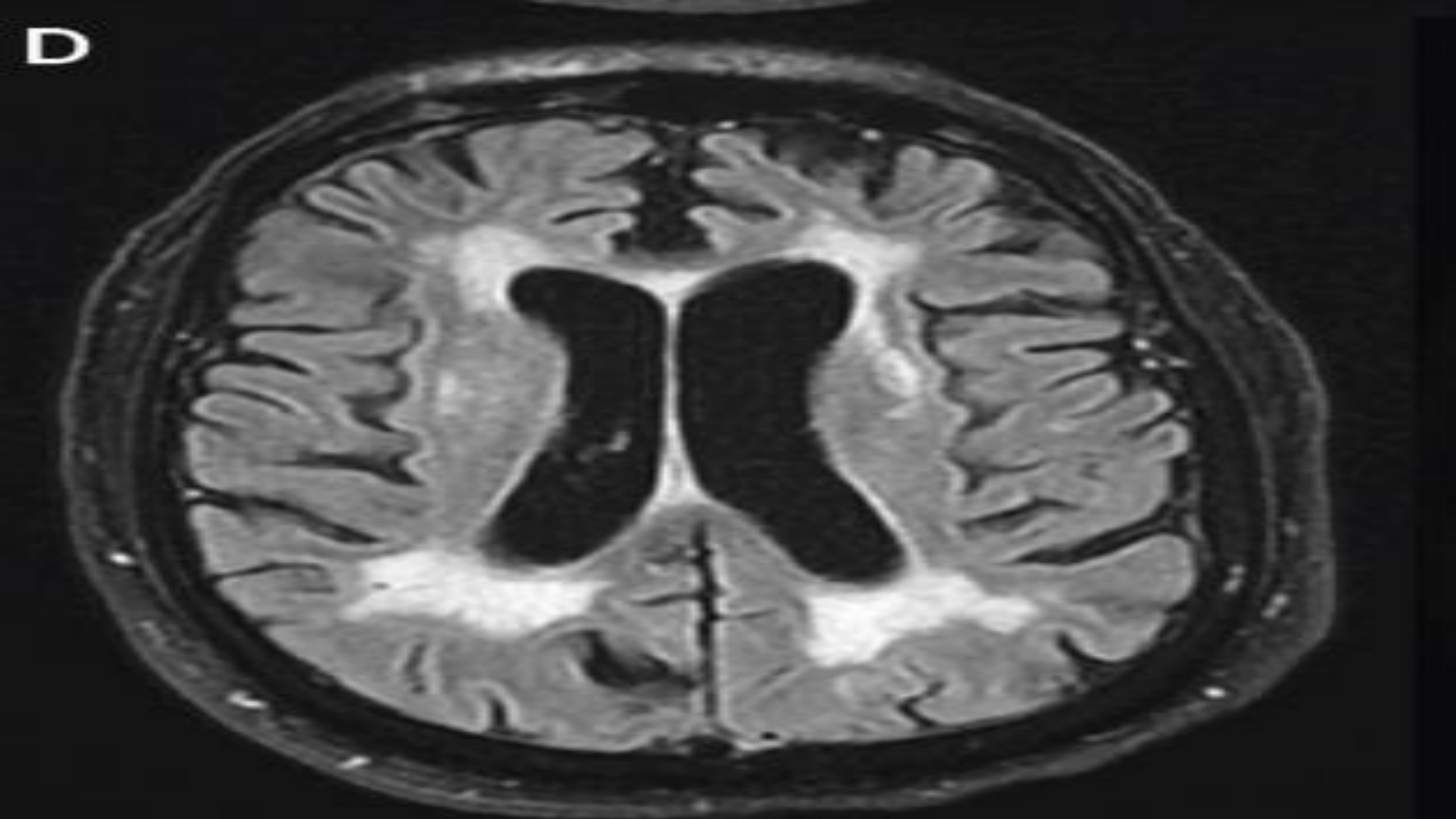


FIGURE 5-2

Imaging of the patient in CASE 5-1. Axial diffusion-weighted MRI (*A*) shows an acute infarct involving the right lentiform nucleus and internal capsule, and axial fluid-attenuated


D

* Arterial dissection

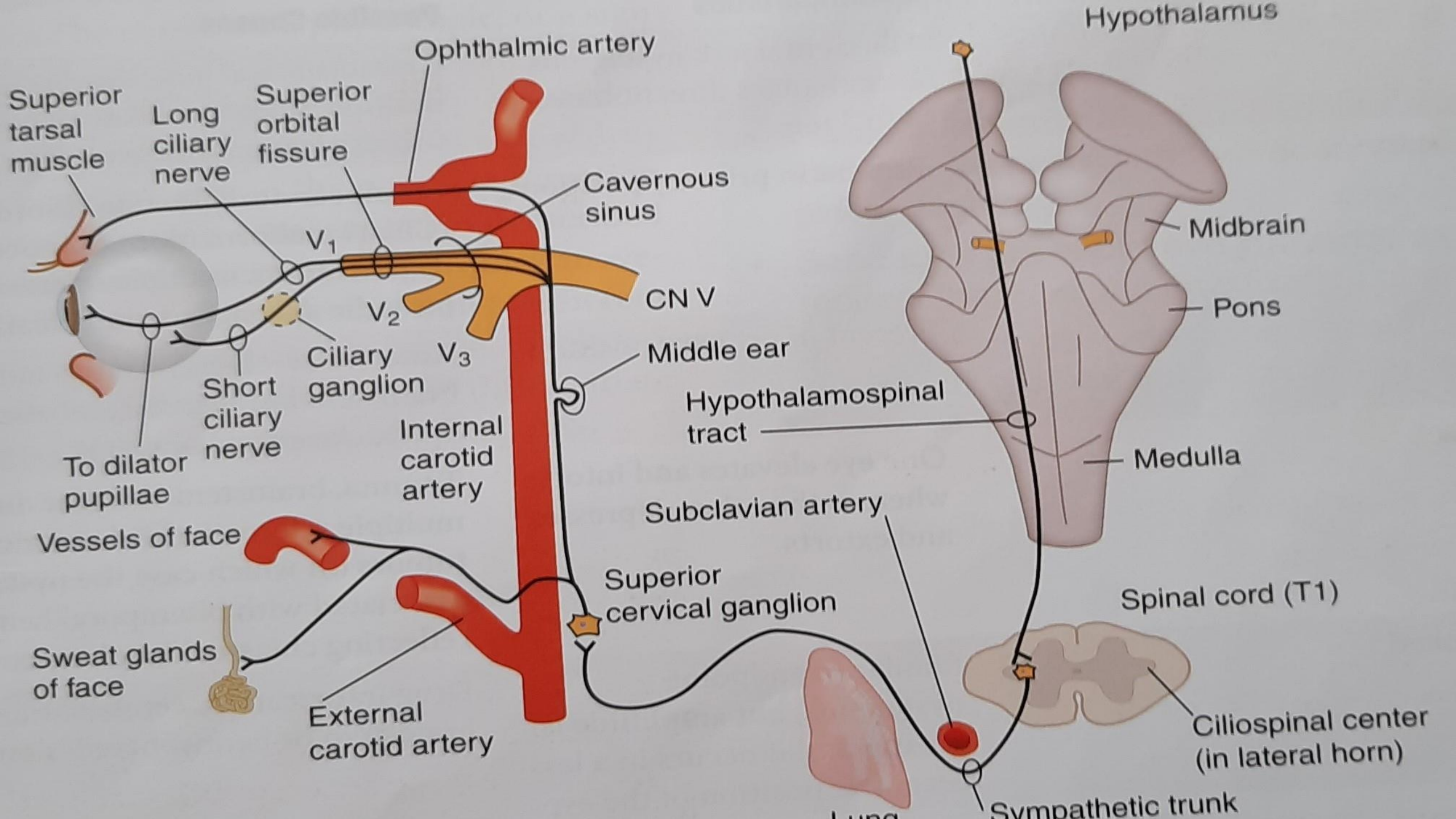
Dissection of the carotid or vertebral arteries may lead to ischemic stroke

a) Carotid dissection:

- Typically presents with severe retro-orbital headache ipsilateral to the lesion

- Strokes involve the anterior circulation and occur either by thrombosis of the ICA or more commonly by an embolus arising from the dissection
- On examination: patients may have an ipsilateral Horner's syndrome due to the involvement of the ascending oculosympathetic tract. Perspiration is preserved because those fibers ascend with the external carotid artery

b) VA dissection may be produced by neck manipulation or trauma and is commonly associated with ipsilateral neck pain and stroke in the posterior circulation.


Hypothalamus
Ophthalmic artery
Superior tarsal muscle
Long ciliary nerve
Superior orbital fissure
Cavernous sinus
V_1
V_2
V_3
CN V
Midbrain
Pons
Ciliary ganglion
Middle ear
Short ciliary nerve
Hypothalamospinal tract
Internal carotid artery
To dilator pupillae
Medulla
Subclavian artery
Vessels of face
Superior cervical ganglion
Spinal cord (T1)
Sweat glands of face
External carotid artery
Ciliospinal center (in lateral horn)
Sympathetic trunk

First-order (or central):
- Hypothalamic infarcts, tumor
- Mesencephalic stroke
- Brainstem: ischemia (Wallenberg syndrome), tumor, hemorrhage
- Spinal cord: syringomyelia, trauma

Second-order (or preganglionic):
- Cervicothoracic cord/spinal root trauma
- Cervical spondylosis
- Pulmonary apical tumor: Pancoast tumor

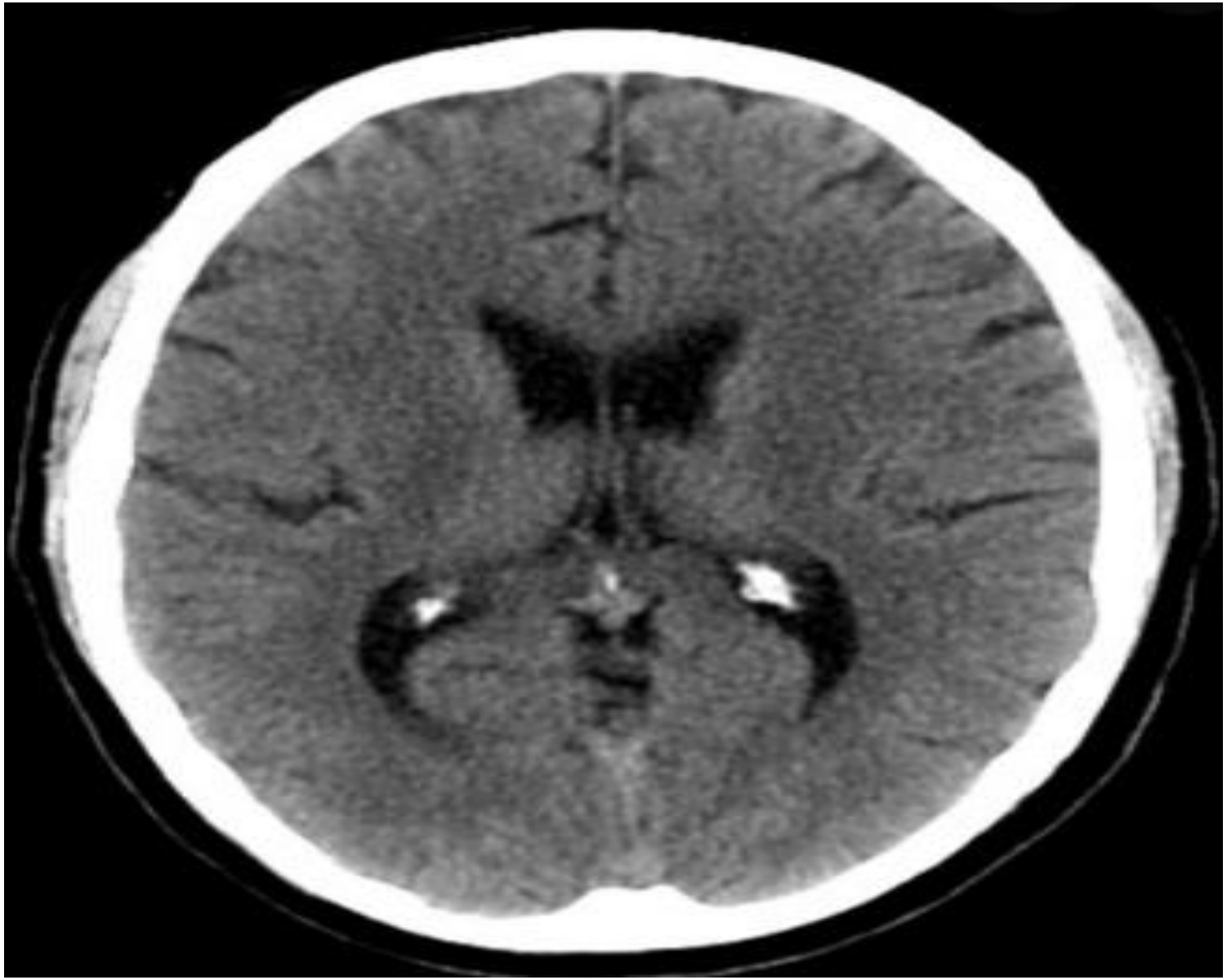
Third-order (or postganglionic):
- Superior cervical ganglion (tumor, iatrogenic)
- Internal carotid artery: dissection, trauma, thrombosis, tumor
- Base of skull: tumor, trauma
- Middle ear problems
- Cavernous sinus: tumor, inflammation (Tolosa–Hunt syndrome), aneurysm, thrombosis, fistula

4. Diagnostic evaluation

After taking a thorough history, performing a general examination emphasizing the heart and blood vessels, and performing a neurologic examination, the next step in a patient with a suspected stroke is a brain image.

CT Brain and MRI Brain are used to separate brain infarction from hemorrhage (Figures) .

MRI Brain with diffusion weighted imaging is more sensitive to acute brain infarction than is CT (Figure).



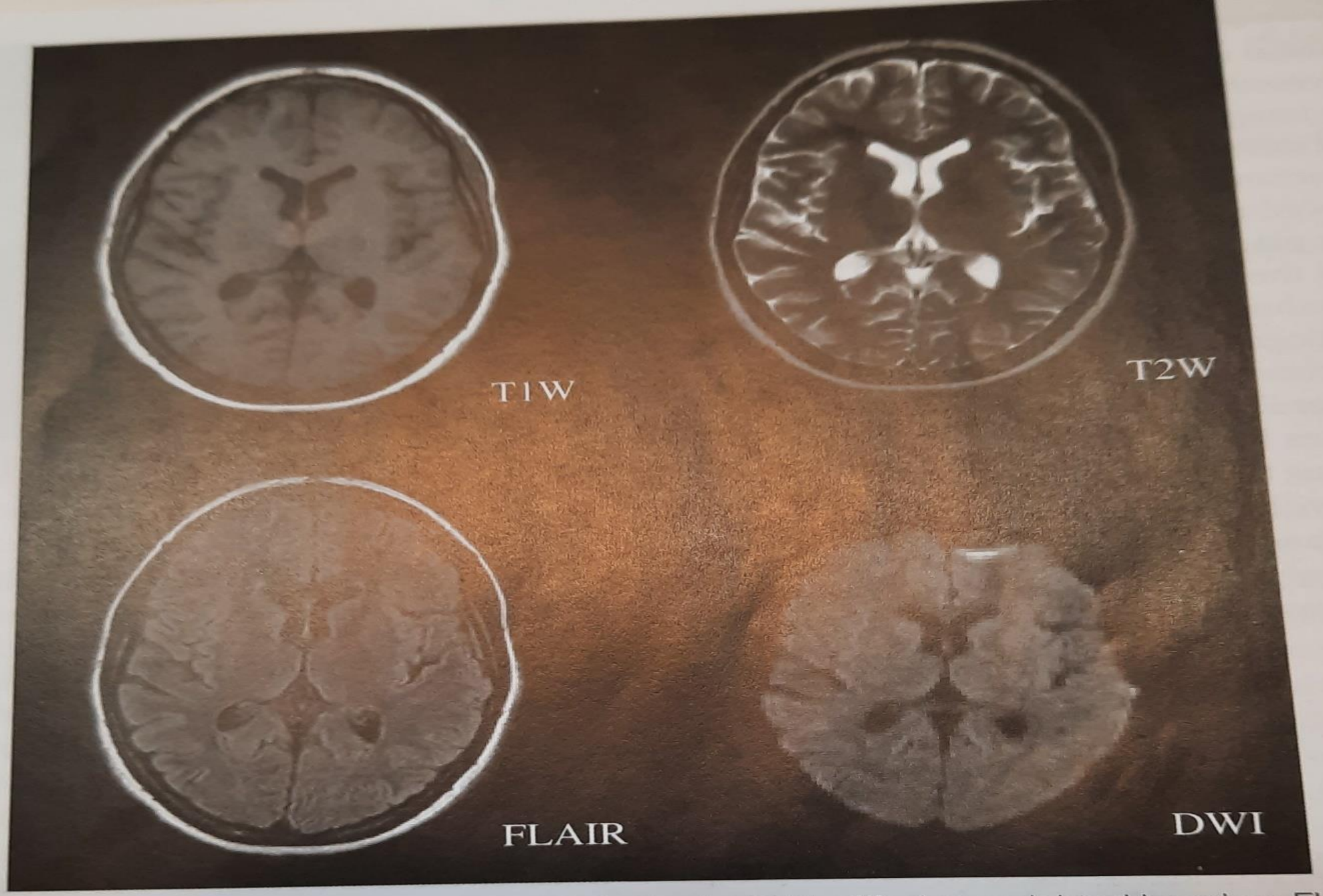
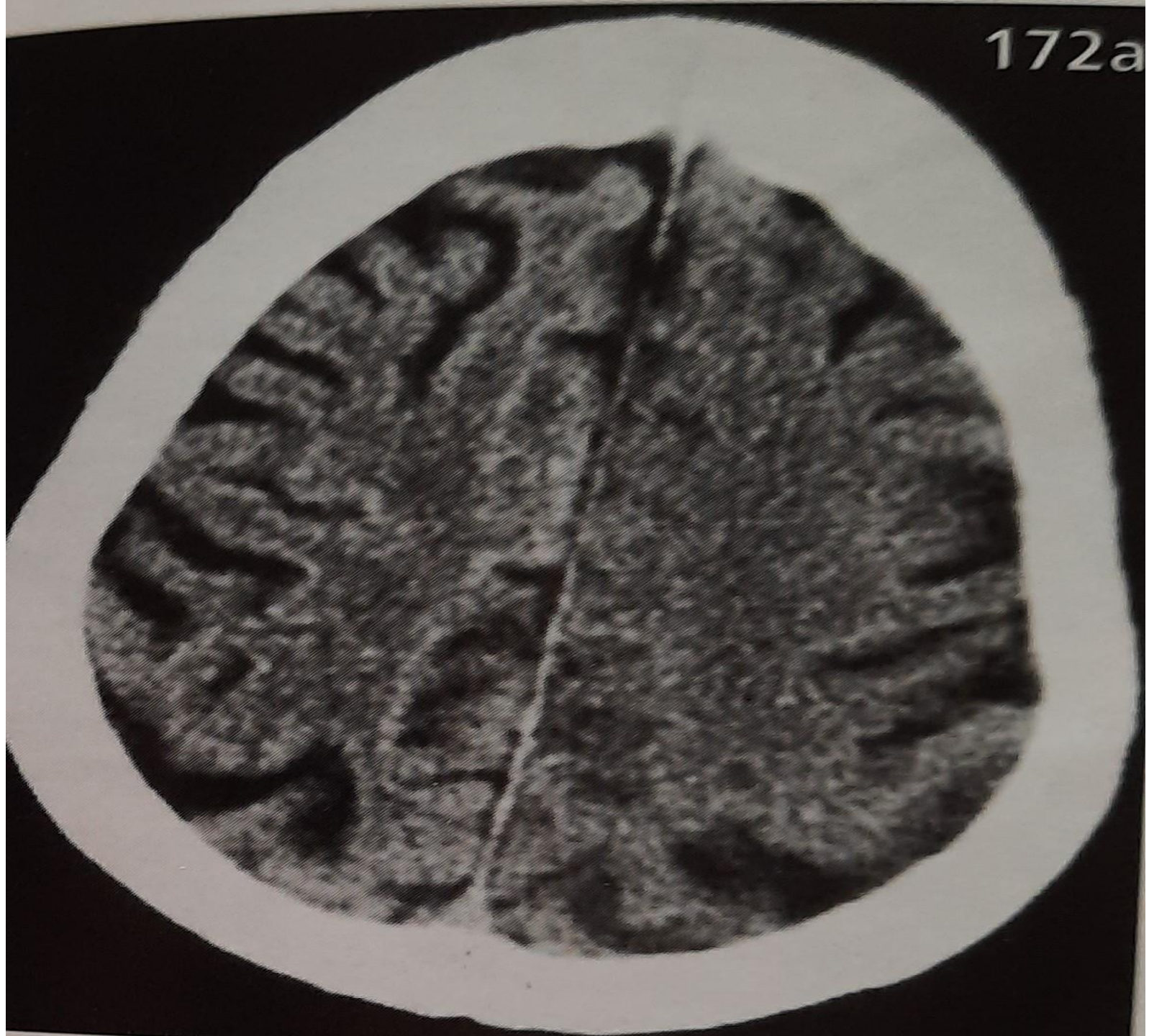


FIGURE 2-2. Normal T1, T2, FLAIR, and DWI images of the brain. DWI, diffusion-weighted imaging; FLAIR, fluid attenuated inversion recovery.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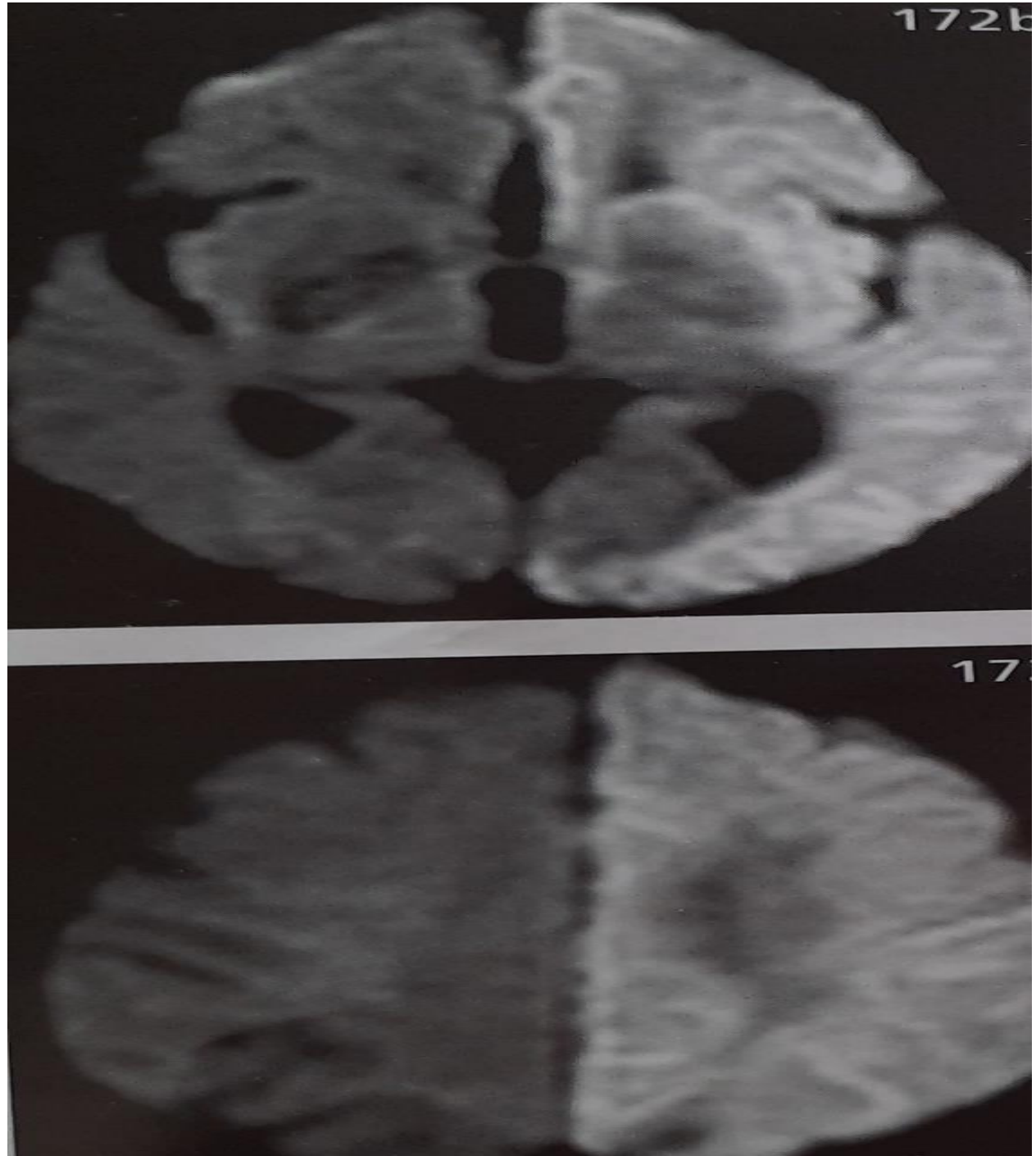
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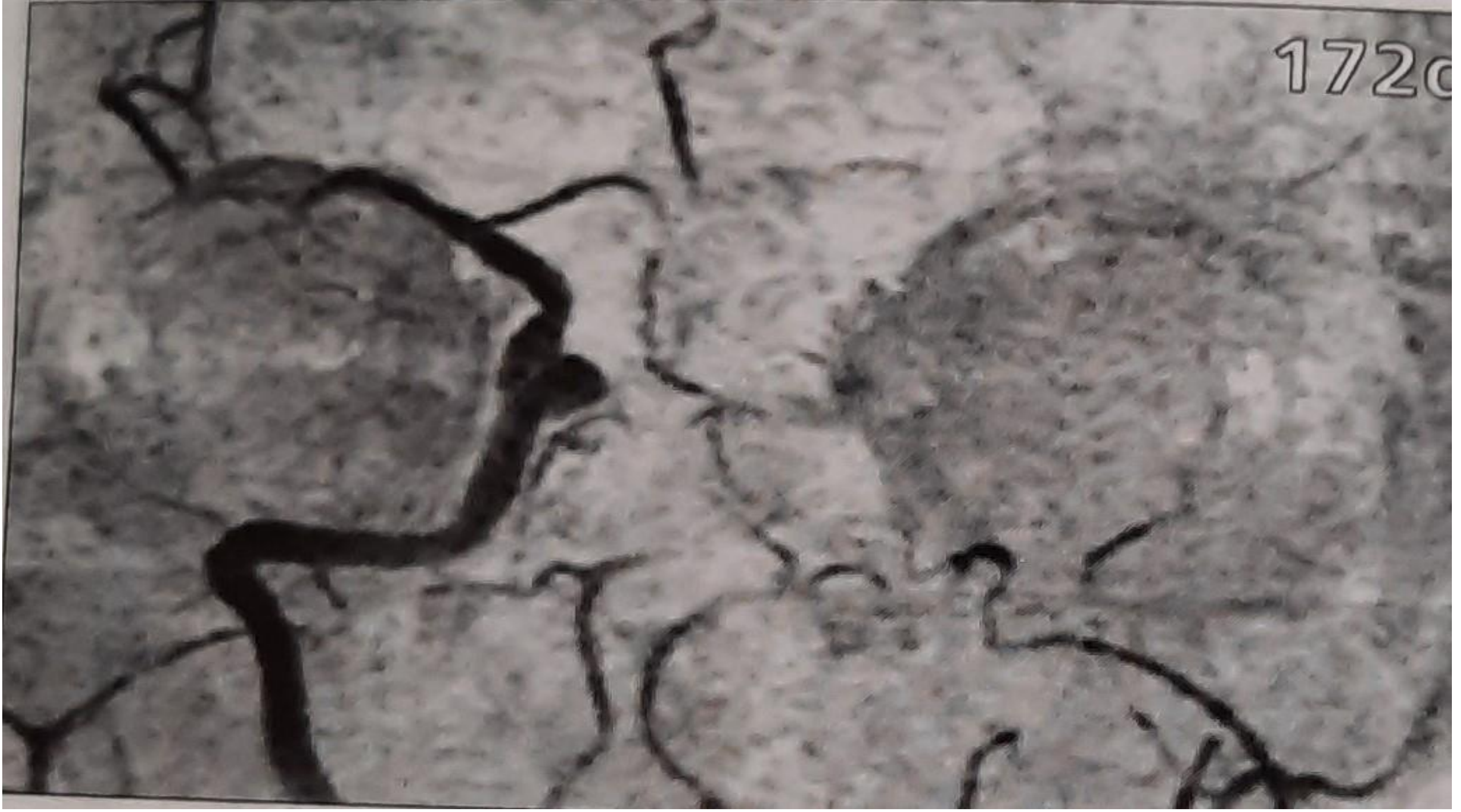
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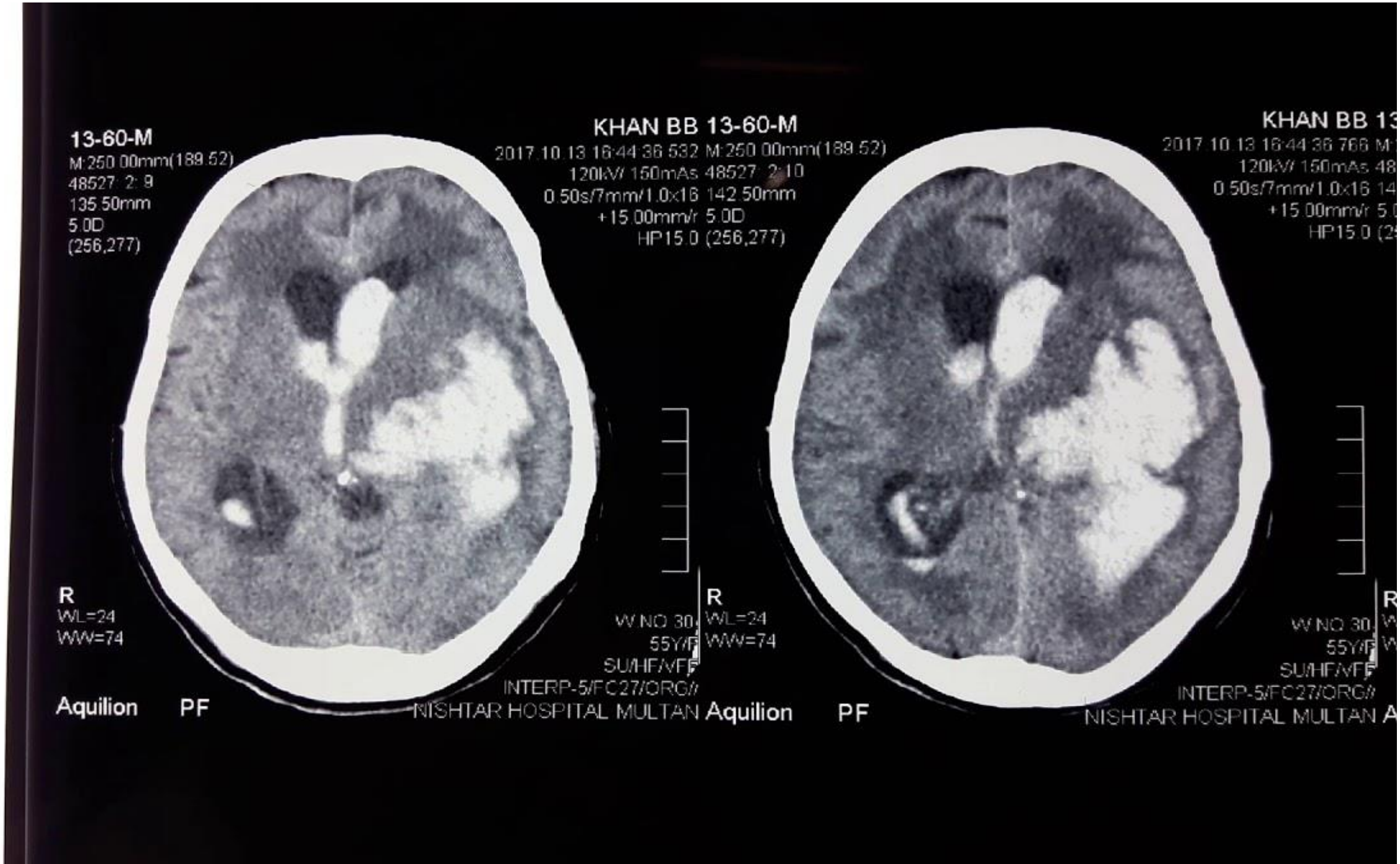
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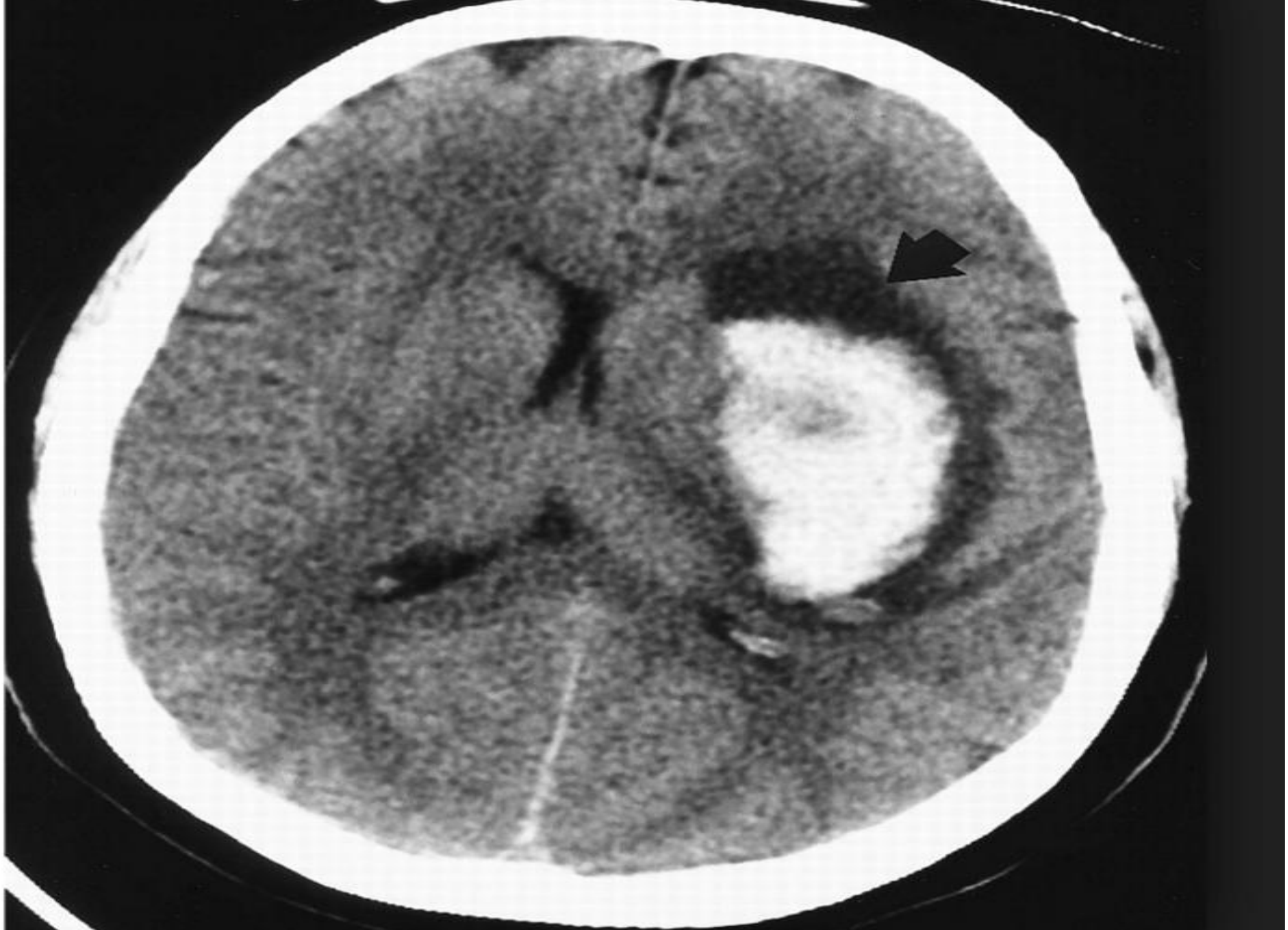
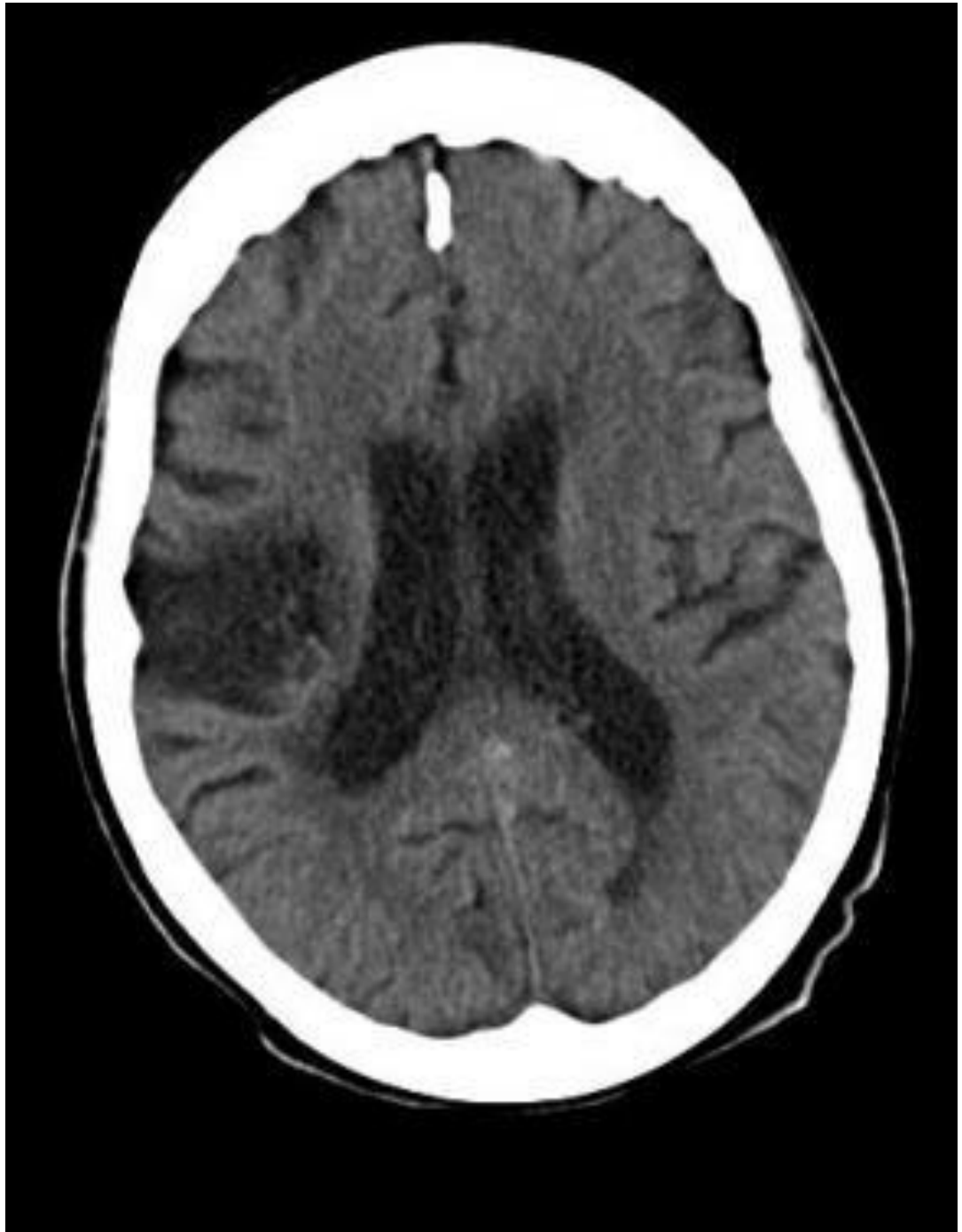
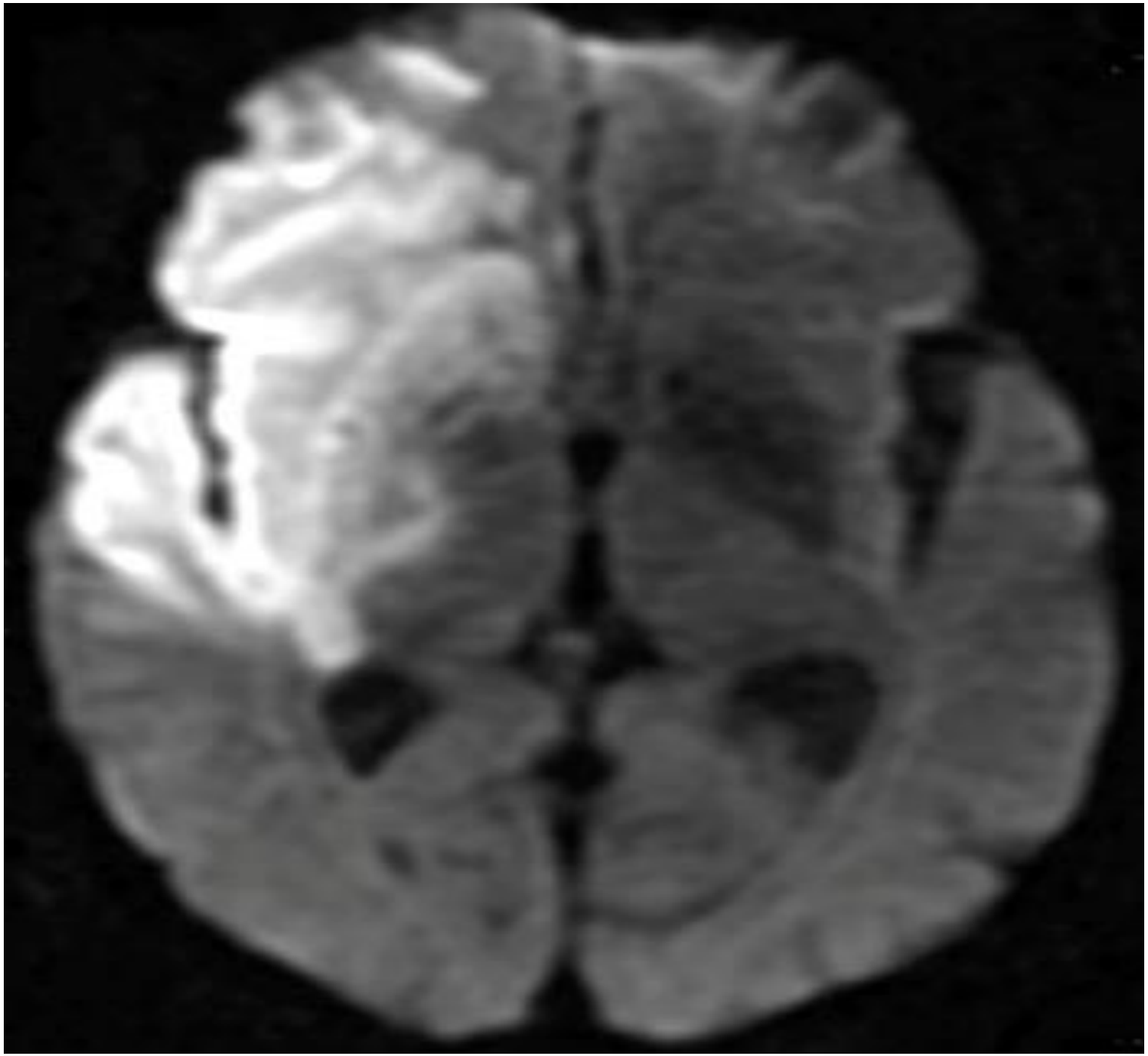






The symptoms and signs, when combined with brain imaging, should allow localization to the left or right anterior circulation, the posterior circulation or to a lacunar syndrome.

In patients with cerebral infarction, the heart, aorta, and neck and intracranial arteries and their branches should be imaged.

This can be performed using echocardiography, extracranial and intracranial Doppler ultrasound, CT angiography (CTA) , or MR angiography (MRA).

In patients in whom the signs localize to the anterior circulation, vascular imaging of the ICAs should be emphasized, whereas in posterior circulation cases, the VAs and their intracranial branches should be emphasized.

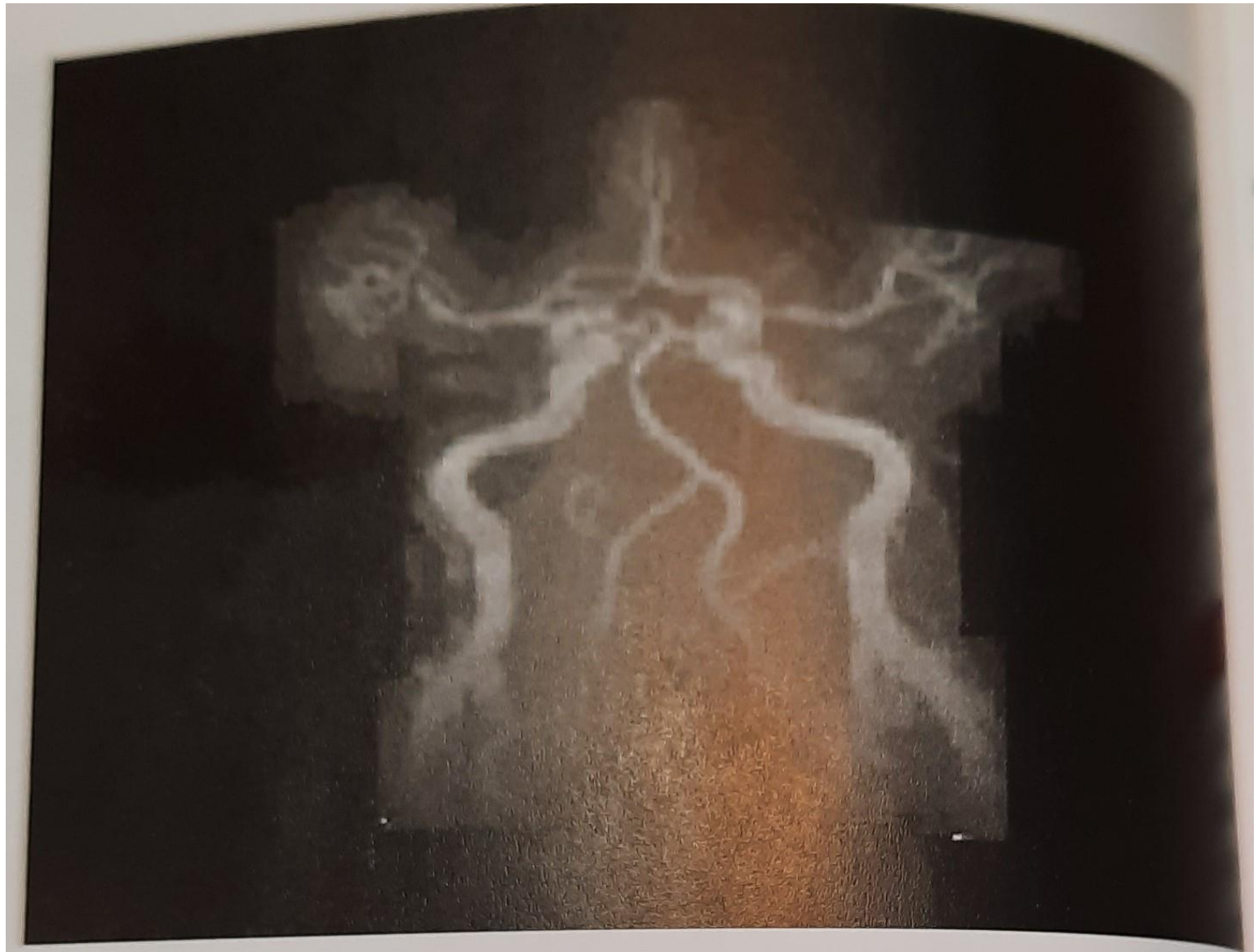
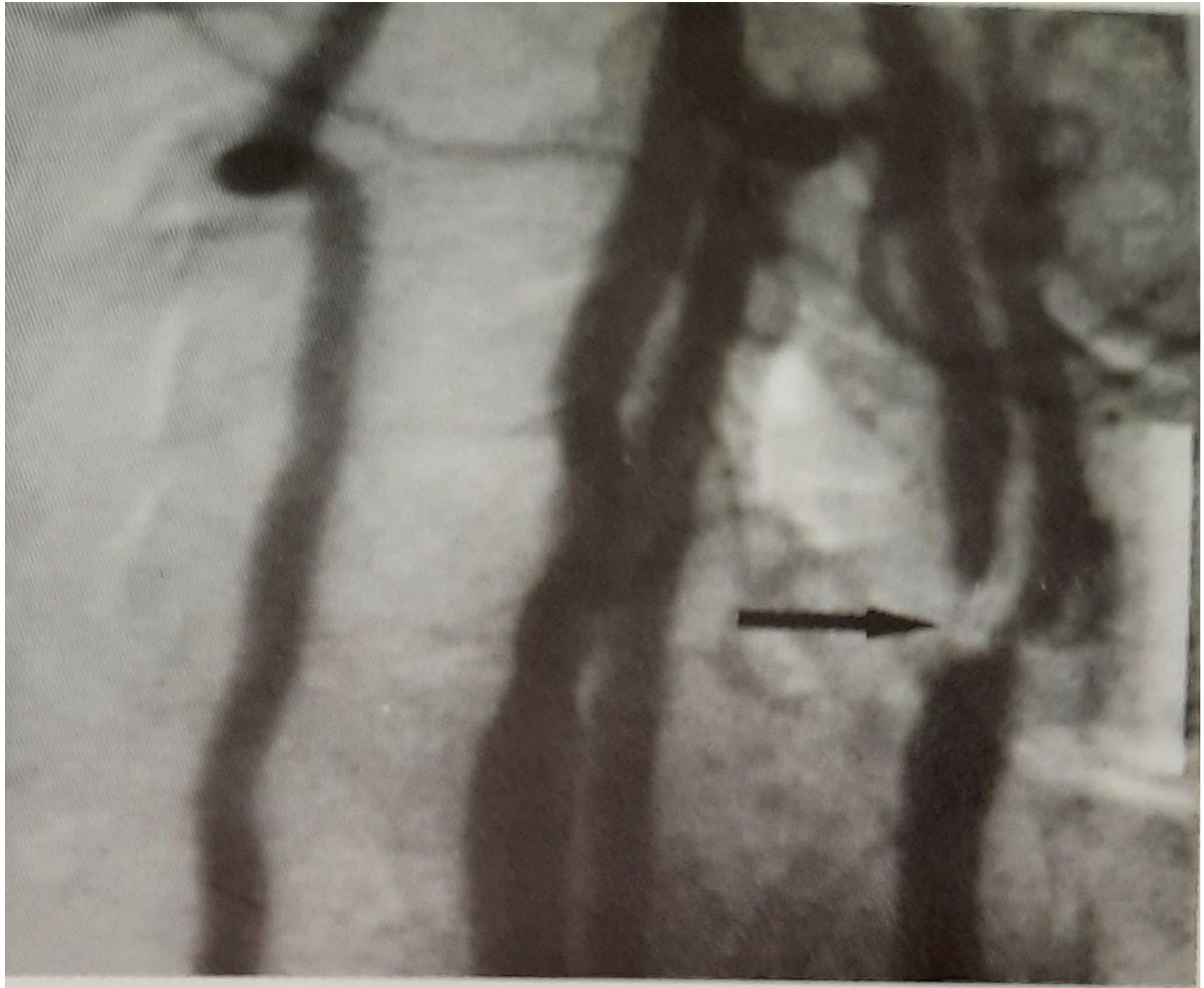


FIGURE 2-4. MRA of the circle of Willis. MRA, magnetic resonance angiography.



In cases of suspected arterial dissection, CTA or MRA with fat-suppressed imaging (“fat sats”) to evaluate the cervical carotid and vertebral arteries should be obtained.

The blood should be checked for abnormalities of erythrocytes, leukocytes and coagulation by ordering a CBC, platelet count and PT reported as an INR.

Intensive investigation for coagulopathy may be required for some patients.

5. Treatment

In patients seen after the onset of neurologic symptoms, an attempt should be made to reperfuse the ischemic brain if a large artery is occluded and if a large portion of the brain area supplied by that artery is not already infarcted (penumbra)

Cerebral and vascular imaging (usually CTA) can show the location and extent of brain infarction and vascular occlusion.

Reperfusion can be attempted using intravenous thrombolysis (recombinant tissue plasminogen activator or tPA, Alteplase), intra-arterial thrombolysis or mechanical means.

The intravenous thrombolytic agent tissue plasminogen activator (tPA) improves stroke outcome if given to patients with disabling stroke within 4.5 hours of stroke onset.

Intravenous thrombolysis can be associated with cerebral hemorrhage, and patients must undergo careful evaluation for factors that would increase this risk even further, such as thrombocytopenia, bleeding diatheses and recent surgery.

Hyper- and hypoglycemia must also be excluded before initiating tPA because abnormally high or low blood sugar levels may mimic the symptoms and signs of acute stroke.

Intra-arterial tPA is used for patients who have had symptoms longer than 4.5-hour window for IV tPA and a well-defined occlusion visualized by CTA or conventional angiography.

Mechanical thrombectomy using clot-retrieving stent devices is helpful for patients with internal carotid or proximal MCA occlusion who are not tPA candidates .

Prevention of further brain ischemia starts with maximizing cerebral blood flow.

Lowering the blood pressure should be avoided unless there is other evidence of end-organ damage (e.g. cardiac ischemia or pulmonary edema).

Almost all patients will require an antithrombotic agent as secondary prophylaxis.

For most patients, antiplatelet drugs such as aspirin, clopidogrel or a combination of aspirin and modified-release dipyridamole are the agents of choice.

In patients with stroke due to intracranial atherosclerosis ,dual antiplatelet therapy with aspirin and clopidogrel is favored.

Anticoagulation with warfarin is useful in specific instances, mostly in patients with atrial fibrillation, cerebral venous sinus thrombosis and inherited hypercoagulable states.

The newer oral anticoagulants apixaban, dabigatran, edoxaban and rivaroxaban may be more effective and have better safety profiles than warfarin, and are used as secondary prophylaxis for patients with atrial fibrillation and sometimes for other indications that would require anticoagulation.

Control of stroke risk factors(hypertension, diabetes, obesity,

hyperlipidemia,and smoking) is accomplished by attention to lifestyle, behavior, nutrition and exercise and by prescribing appropriate medications.

6. Transient ischemic attack

A transient ischemic attack (TIA) is defined as a focal neurologic syndrome produced by brain ischemia that lasts 24 hours or less.

The mechanisms of TIA are identical to those of ischemic stroke.

Patients who have had a TIA have a 10% risk of stroke in the 90 days following the event, and the greatest risk is within the first 24 hours following a TIA.

Therefore the evaluation should be identical to that for a completed stroke and should be conducted just as quickly.

The evaluation includes brain MRI with diffusion-weighted imaging (which is abnormal in 50% of patients with TIA), lipid profile, echocardiography, cardiac telemetry and carotid artery imaging as appropriate.

Preventive treatment strategies are identical to those described for ischemic stroke.

7. Intracranial hemorrhage

Bleeding inside the skull can be divided into subarachnoid, intracerebral, epidural and subdural hemorrhages.

The latter 2 types of hemorrhage are almost always traumatic.

Intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH) have different causes, clinical findings and management.

A) Subarachnoid hemorrhage (SAH)

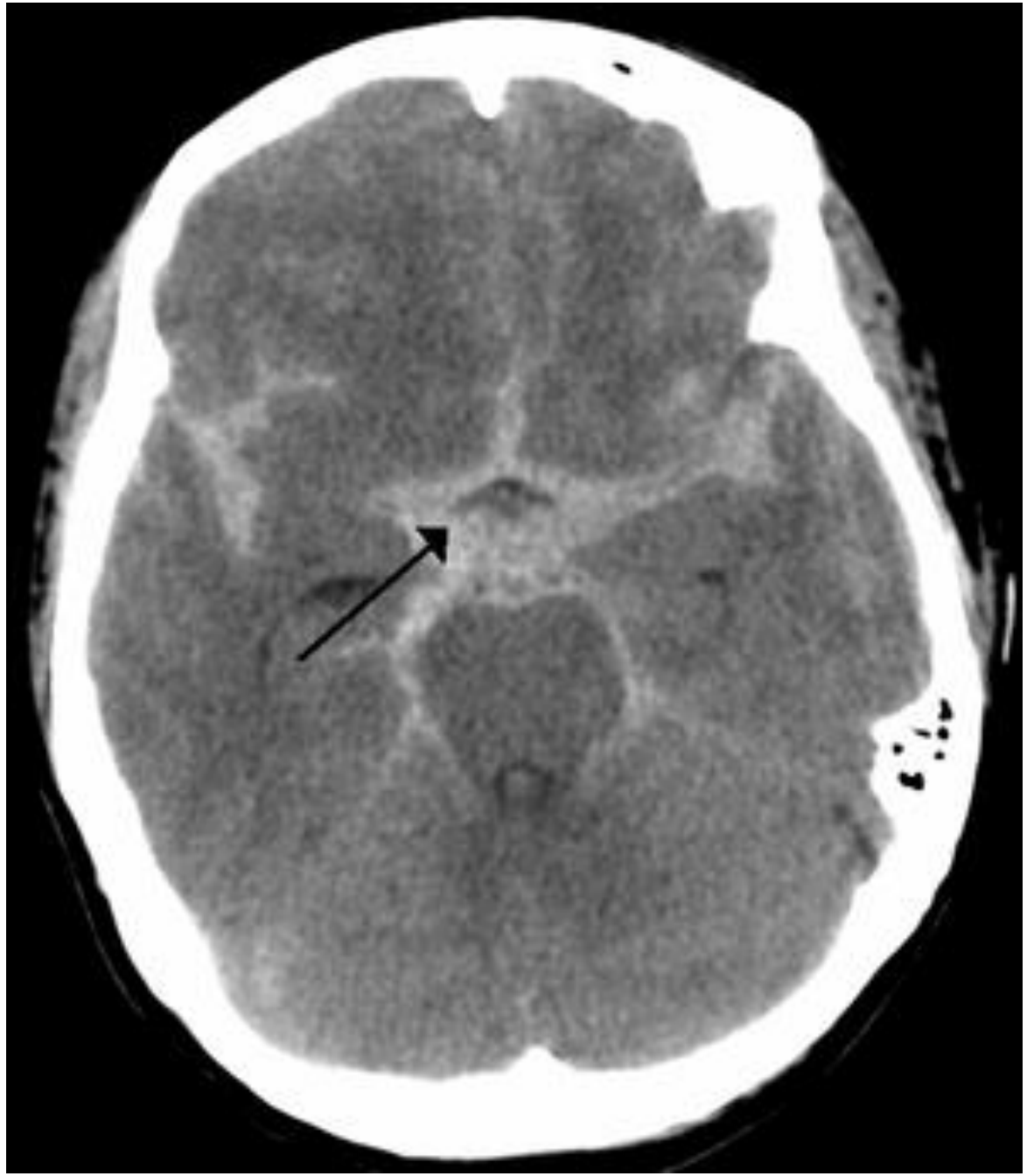
SAH is often due to traumatic injury.

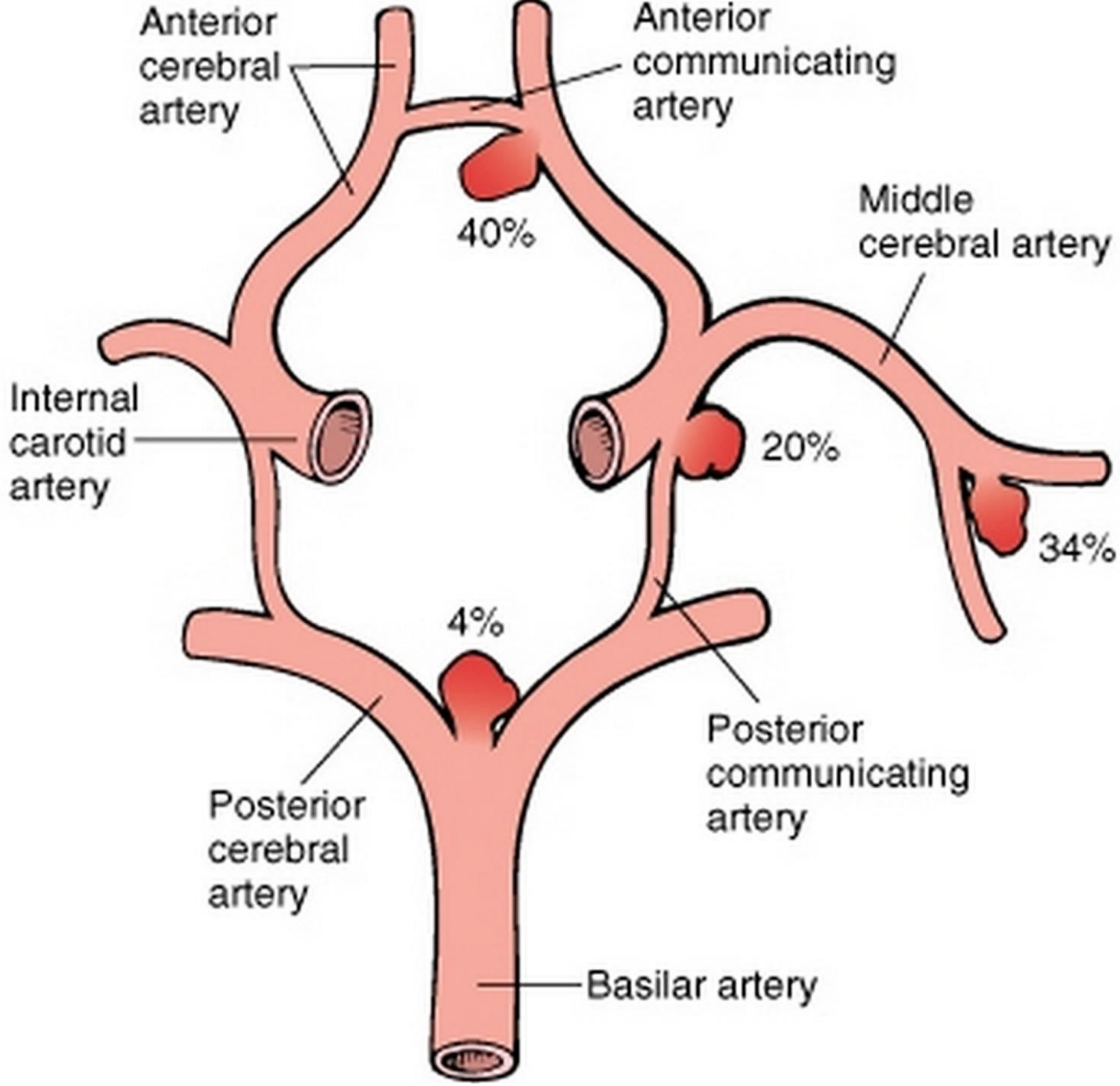
More serious, though, is SAH caused by bleeding from an aneurysm located along the circle of Willis.(Figure).

When blood under arterial pressure is suddenly released into the space around the brain, patients develop sudden-onset, severe headache.

Often ,they vomit and cease what they are doing at the time of the hemorrhage.

When the intracranial pressure increases rapidly or the insulae are affected, coma or death may ensue(Figure).




Anterior cerebral artery
Anterior communicating artery
40%
Middle cerebral artery
Internal carotid artery
20%
34%
4%
Posterior communicating artery
Posterior cerebral artery
Basilar artery

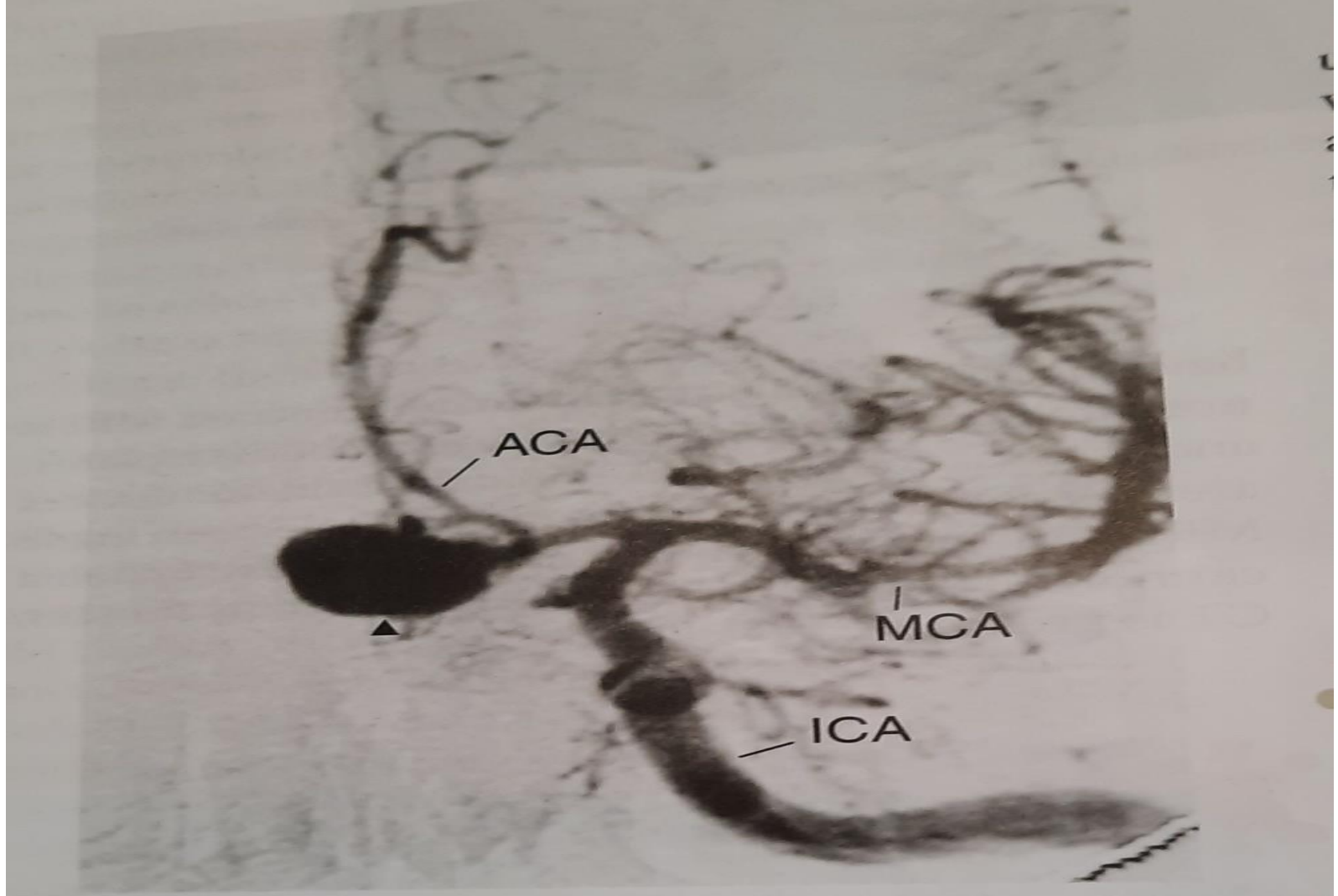


FIGURE 2-3. Conventional cerebral angiogram demonstrating aneurysm of the right middle cerebral artery (*arrow*). ACA, anterior cerebral artery; ICA, internal carotid artery; MCA, middle cerebral artery. (Reproduced with permission from Yochum TR , Rowe LJ. *Yochum and Rowe's Essentials of Skeletal Radiology*. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2004.)

Treatment is aimed at preventing the rebleeding and vasoconstriction that often follow SAH.

Aneurysms can be clipped surgically or “ coiled” by interventional techniques.

The calcium-channel blocker nimodipine is used to minimize vasoconstriction and delayed brain ischemia.

B) Intracerebral hemorrhage

ICH is bleeding directly into brain parenchyma.

The earliest symptoms are headache and neurologic signs referable to the region in which the bleeding occurs.

Hypertension (leading to Charcot-Bouchard microaneurysms) is the most common cause of ICH.

The most common locations for hypertensive ICH are the basal ganglia-internal capsule, caudate nucleus, thalamus, pons and cerebellum.

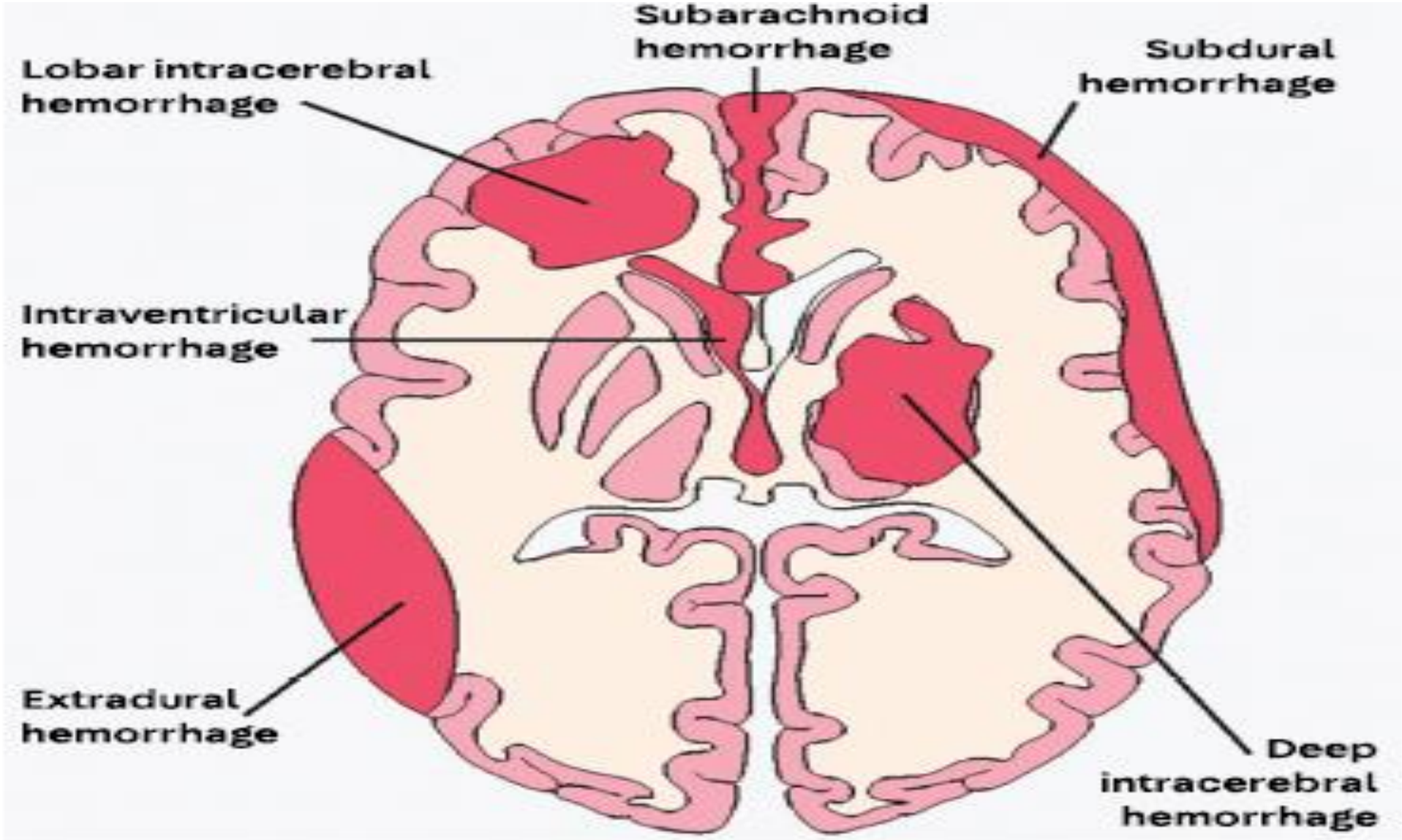
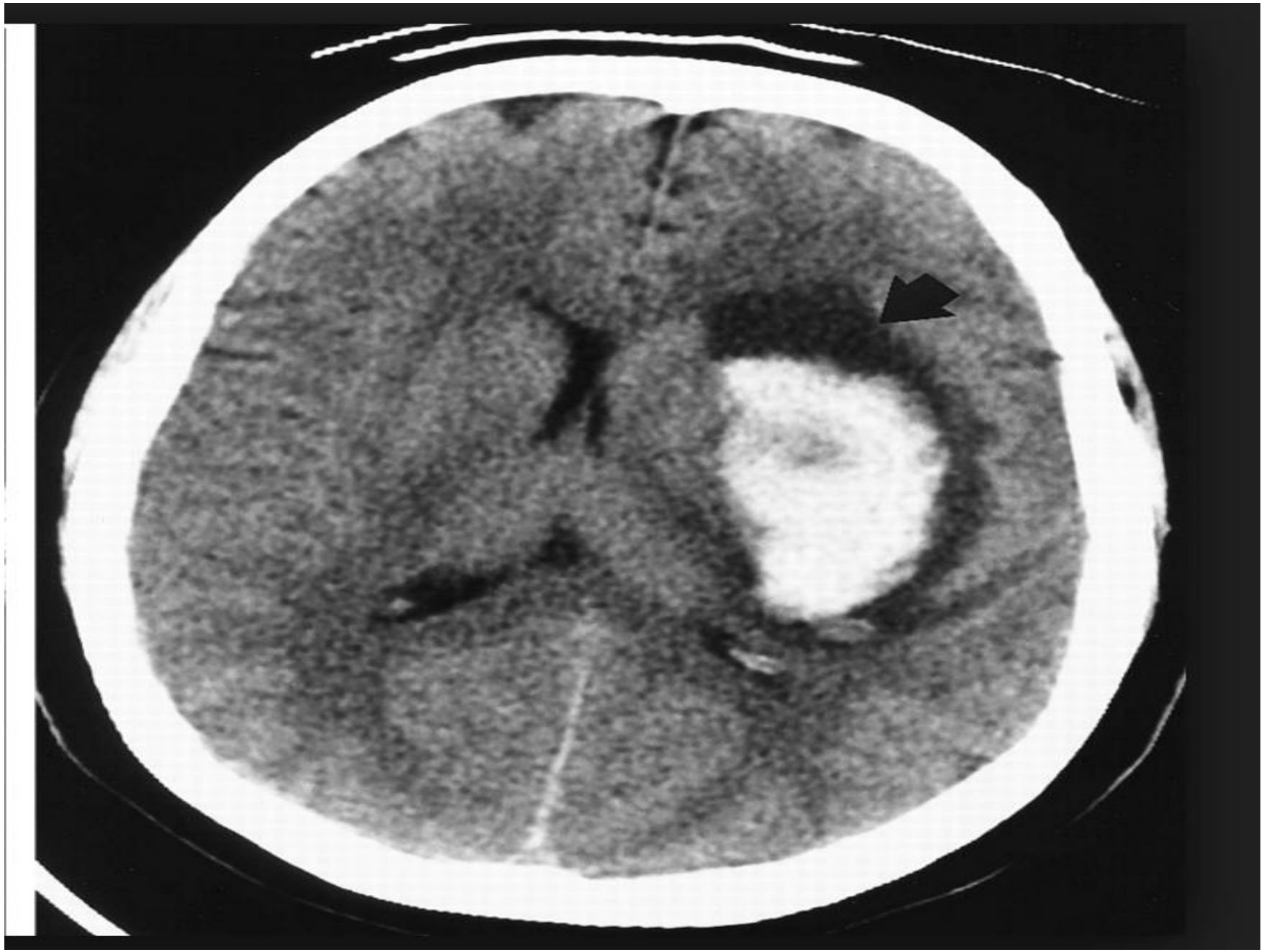


FIGURE 3-2
Locations and types of intracranial hemorrhage that may be seen on noncontrast CT.



Cerebral amyloid angiopathy is a cause of ICH that is more frequent in the elderly. and preferentially affects the parietal and occipital lobes.

Trauma, vascular malformations and bleeding diatheses (especially with patients who are taking anticoagulants) are other common causes.

ICH is often a devastating condition , and large hemorrhages are associated with high mortality rates.

Treatment involves correcting any coagulopathy.

In certain situations(particularly cerebellar hemorrhages) , surgical decompression is necessary.

Management of risk factors for hemorrhage, specifically hypertension, is necessary to prevent recurrence.

8. Vascular malformations

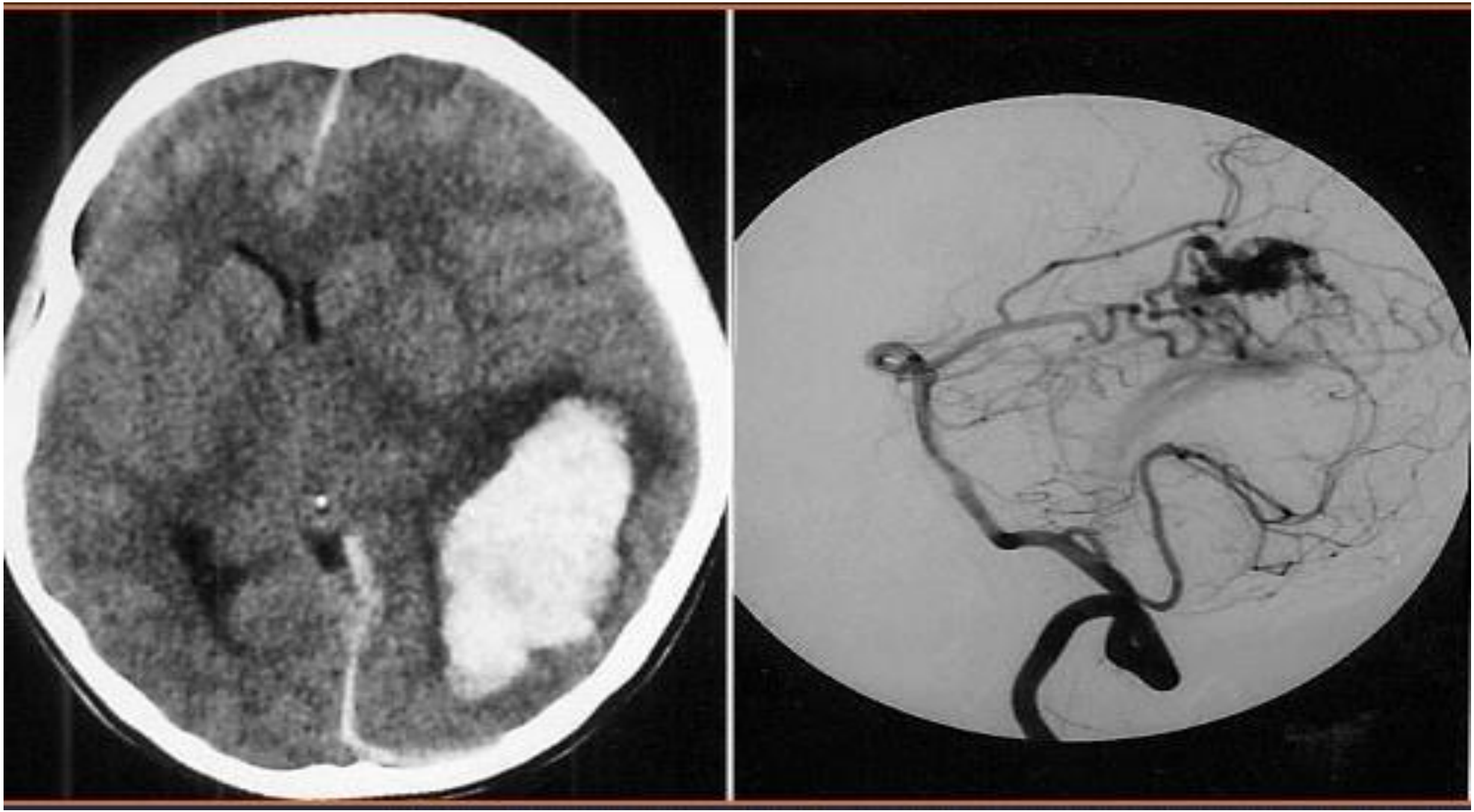
Variety of congenital and acquired vascular anomalies that have the potential to bleed, either within the brain (ICH) or around it.

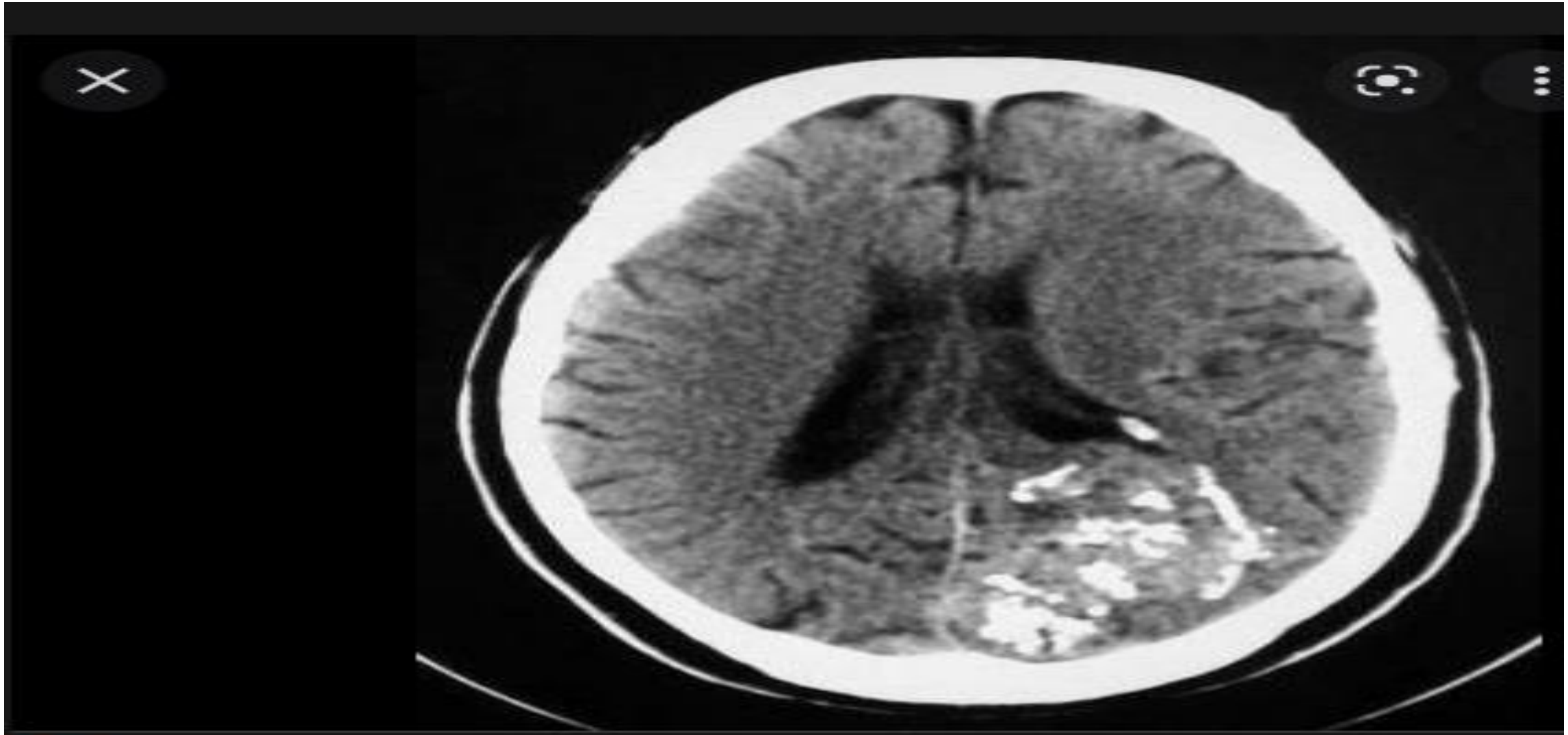
* Arteriovenous malformations (AVMs) contain arteries that empty into arterialized veins.

These lesions contain no recognizable normal capillary bed, but abnormal gliotic parenchyma can be found between the component vessels.

In addition to causing ICH , AVMs may result in seizures.

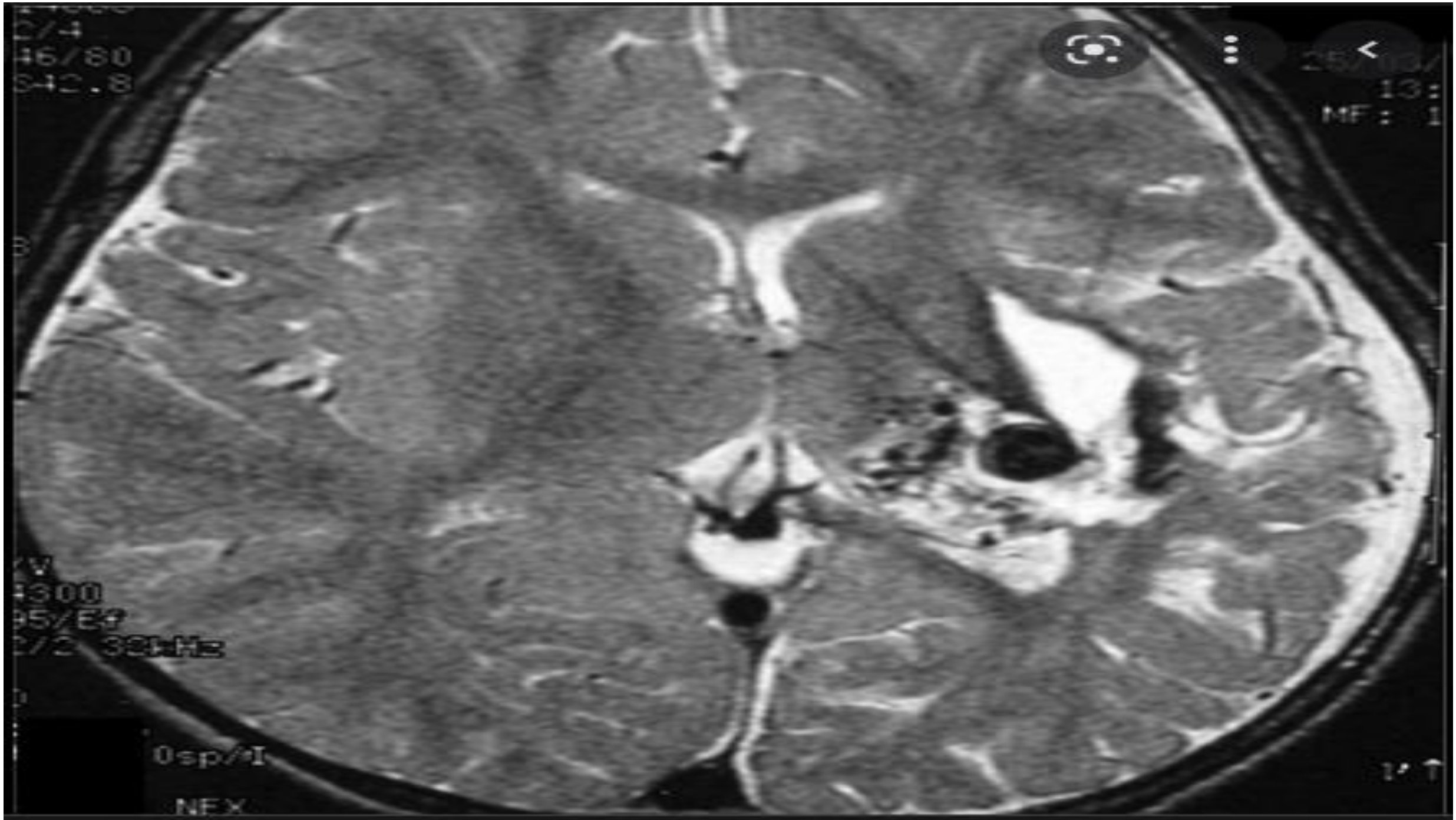
AVMs may be treated with embolization or surgical resection.





Medscape Reference

Arteriovenous Malformation Brain Imaging: Practice Essentials, Ultrasonography, Computed Tomography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* Cavernous angiomas consist of a relatively compact mass of sinusoidal vessels close together, without intervening brain parenchyma.

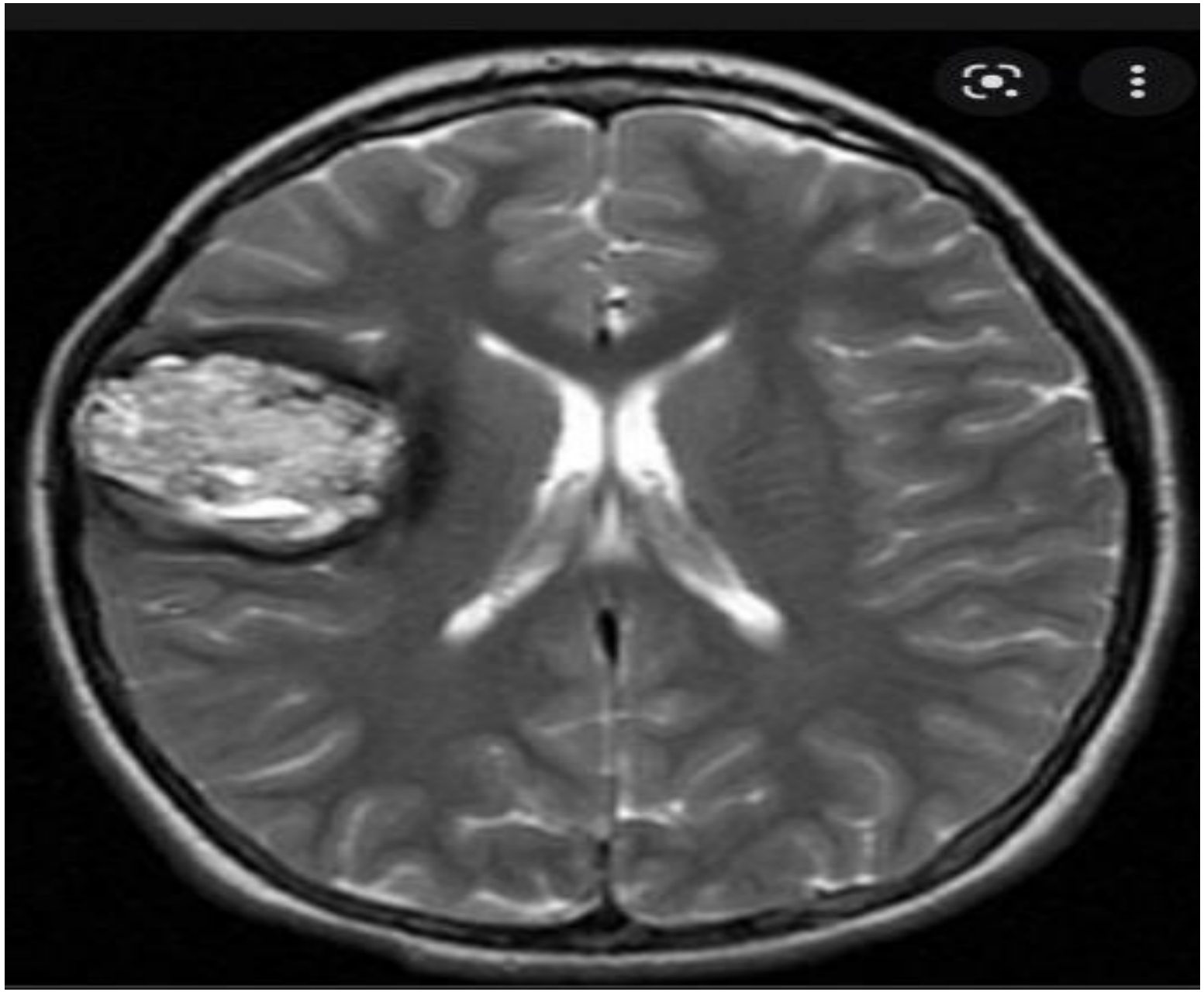
The lesions are well encapsulated.

Cavernous angiomas bleed or lead to seizures, occasionally, but are not threatening as AVMs are.

They may be followed with serial neuroimaging studies.

Surgery is required rarely.

They may require antiseizure drug treatment if recurrent seizures develop.



* Developmental venous anomalies (DVAs) are composed of anomalous veins usually separated by morphologically normal brain parenchyma are the most common vascular malformations of the brain.

They seldom hemorrhage and are generally not treated surgically or followed with serial neuroimaging studies.

* Telengiectasias are dilated capillaries with intervening brain parenchyma.

They are incidental findings and do not require treatment.