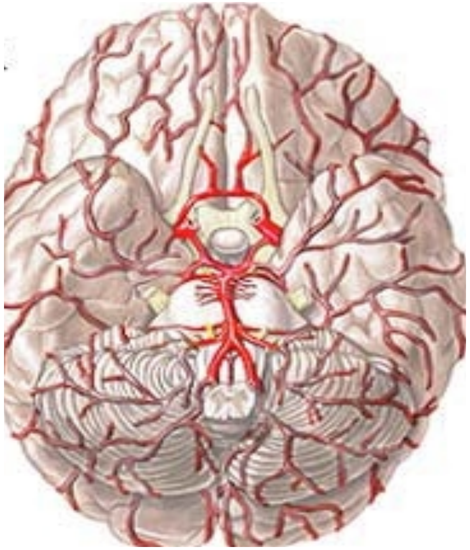
AUTO REGULATION OF CEREBRAL BLOOD FLOW



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LECTURE OBJECTIVES

Cerebral circulation

Circle of Willis

Regulation of Cerebral Blood Flow

Factors affecting cerebral blood flow

Role of carbon dioxide concentration, hydrogen ion concentration, and oxygen concentration in the auto regulation of cerebral circulation

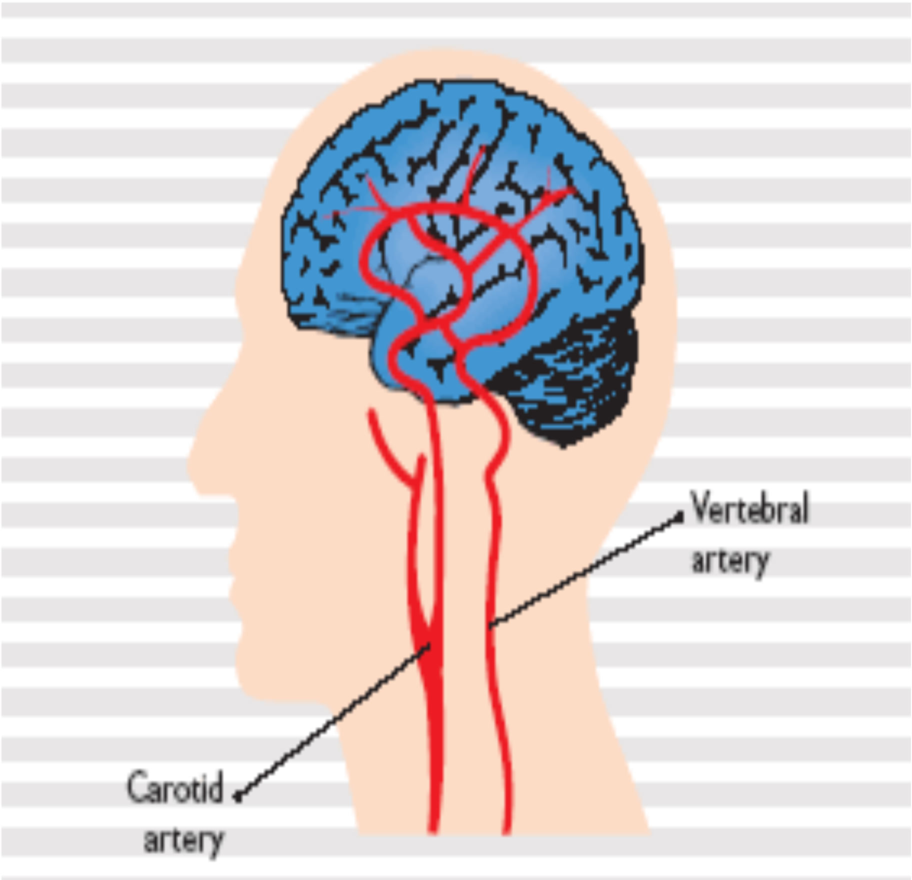
CEREBRAL CIRCULATION

Brain receive its blood supply from four main arteries:

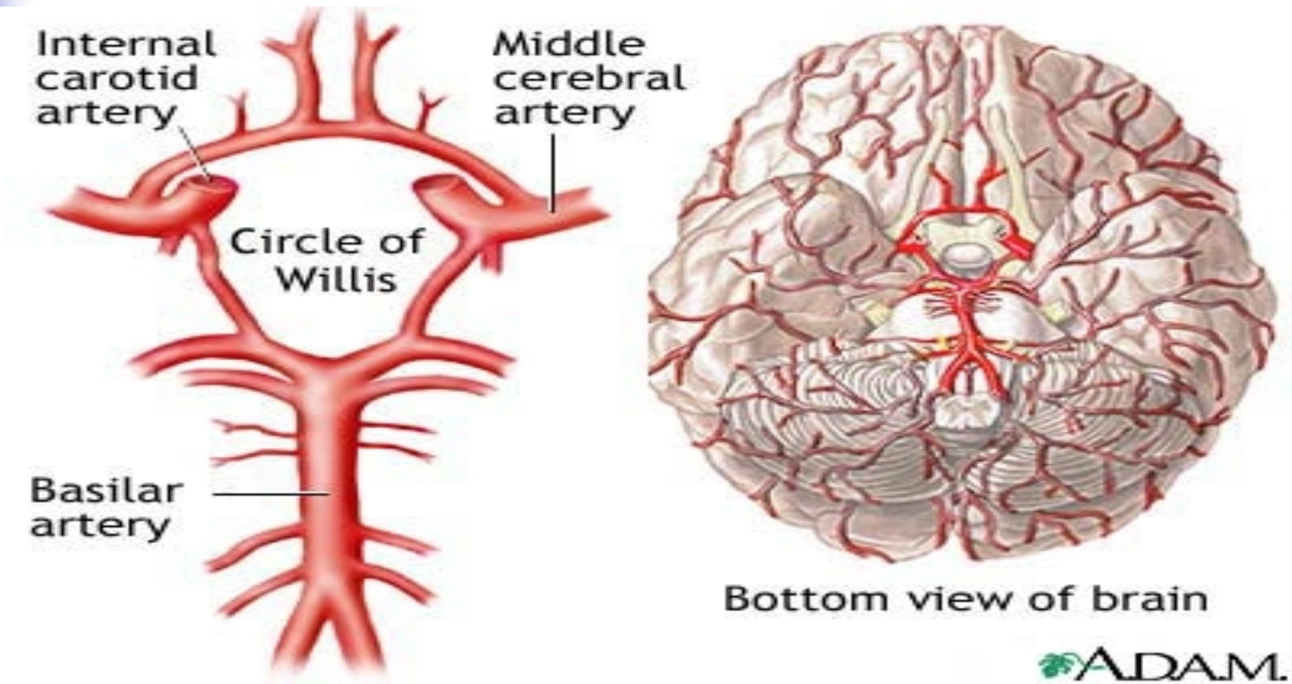
Two internal carotid arteries

Two vertebral arteries.

The clinical consequences of vascular disease in the cerebral circulation is depend upon which vessels or combinations of vessels are involved.



CEREBRAL CIRCULATION



Group of arteries near the base of the brain which is called the *Arterial Circle of Willis*. English physician, Thomas Willis, who discovered it and then published findings in 1664, on *Cerebri anatomi*

The vertebral arteries unite to form Basilar artery.
The basilar artery and the carotids arteries form the circle of Willis.
The circle of Willis is origin of six large vessels
Substances injected into one carotid artery distributed completely to the cerebral hemisphere on that side. Normally no crossing over occurs because of equal pressure on both sides.

CEREBRAL CIRCULATION

Physiological considerations:

Brain accounts for 2% of body weight yet requires 20% of resting oxygen consumption

O_2 requirement of brain is 3 – 3.5 ml/100gm/min

And in children it goes higher up to 5 ml/100gm/min

Brain has high metabolic rate

requires more substrate

lacks of storage of energy

That's why brain requires higher blood supply

55ml/100gm/min is the rate of blood supply

CEREBRAL BLOOD FLOW

Normal Rate of Cerebral Blood Flow

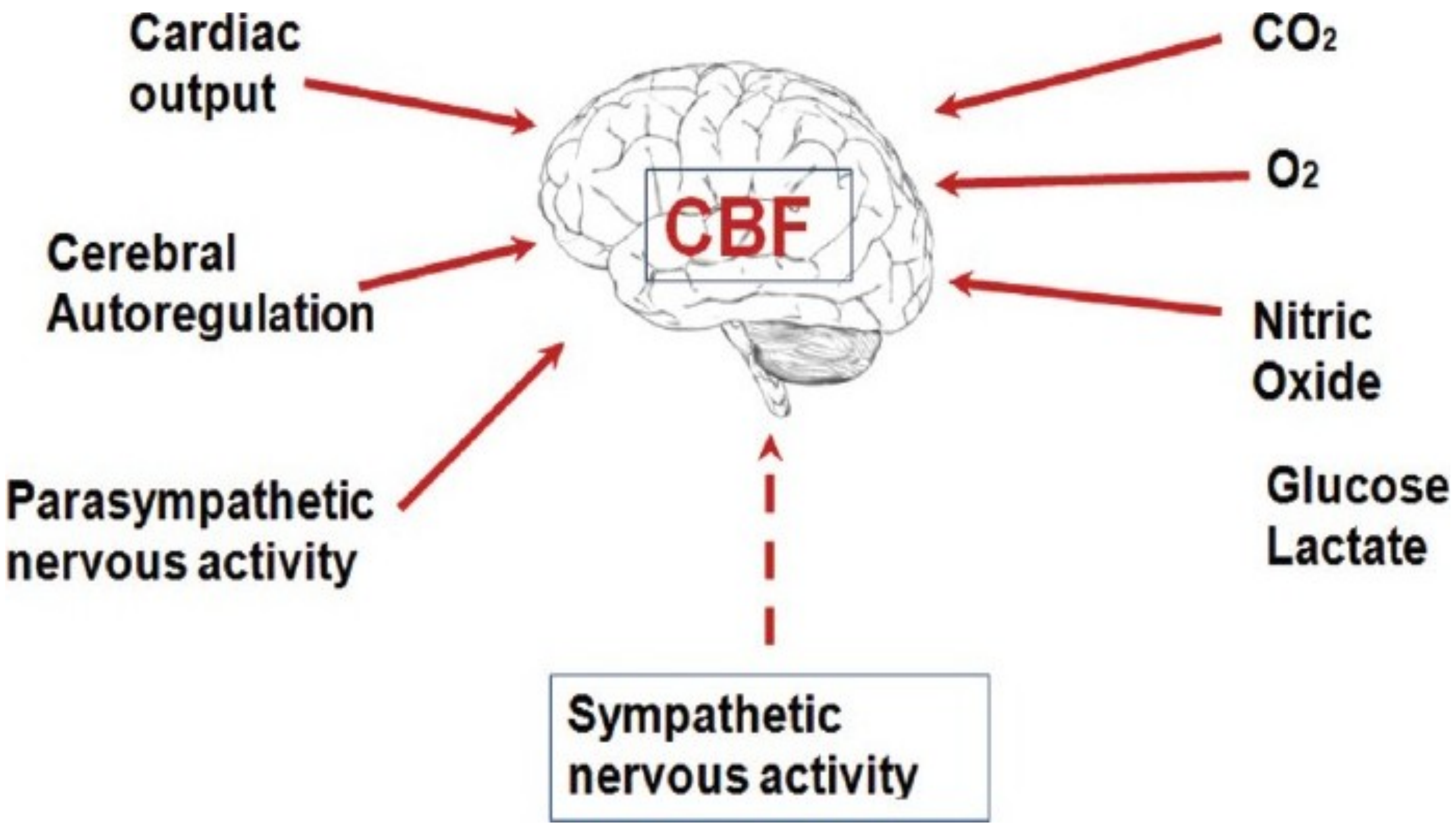
- Brain: 1350 gm; 2% of Total Body Weight
- Normal blood flow through the brain of the adult person averages 50 to 65 ml/ per 100 grams of brain tissue per minute.
- For entire brain: 750 to 900 ml/min,
- 15 per cent of the resting cardiac output.

REGULATION OF CEREBRAL BLOOD FLOW

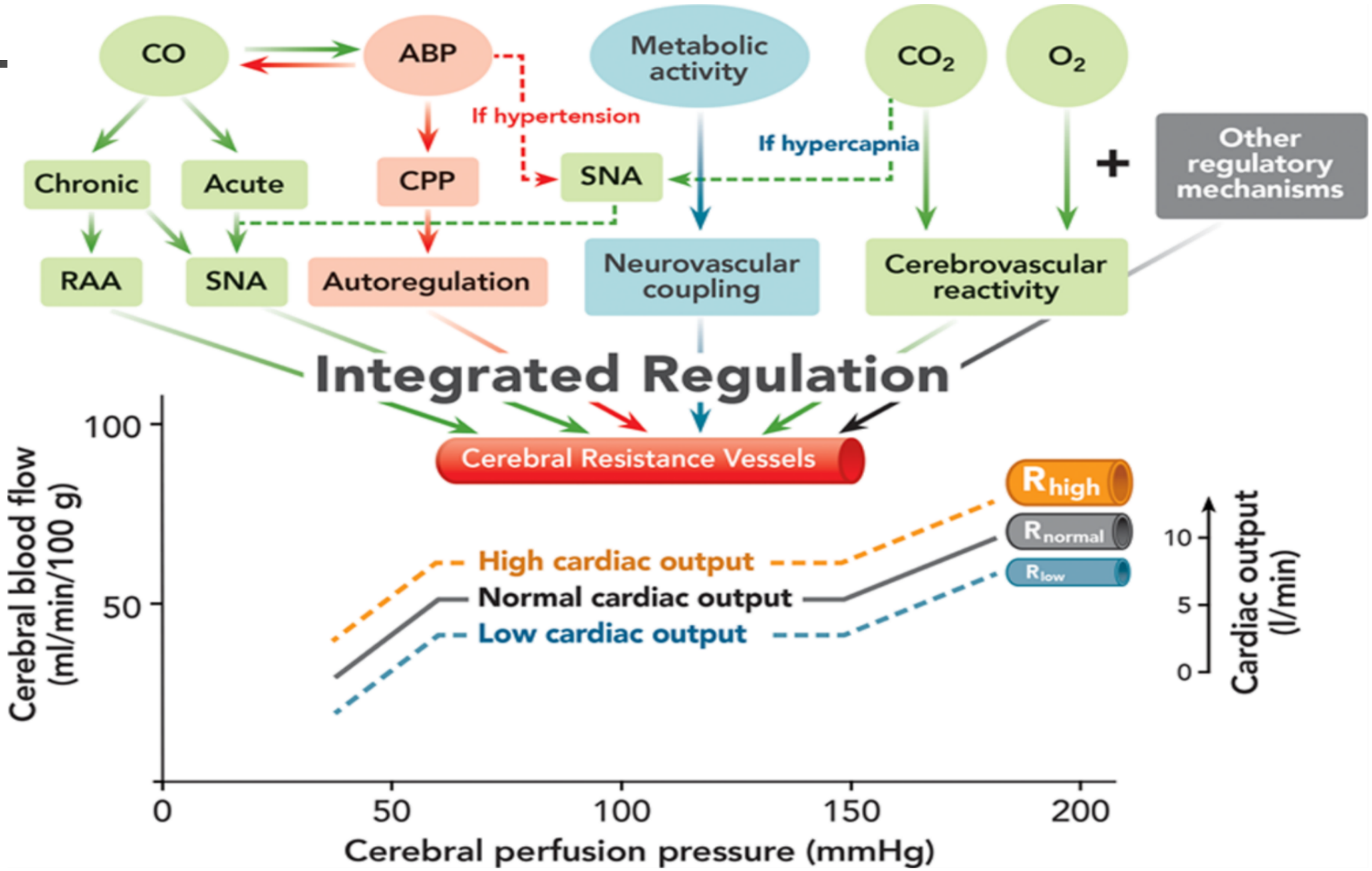
Factors Effecting Cerebral Blood Flow

factor	factor
CHEMICAL	MYOGENIC **1. Myogenic / Pressure Autoregulation:**
CMR	Autoregulation / MAP
anesthetics	
temperature	BLOOD VISCOSITY
PaCO2 **3. Metabolic Autoregulation:**	
PaO2	NEUROGENIC **2.Neurogenic Autoregulation:**

REGULATION OF CEREBRAL BLOOD FLOW

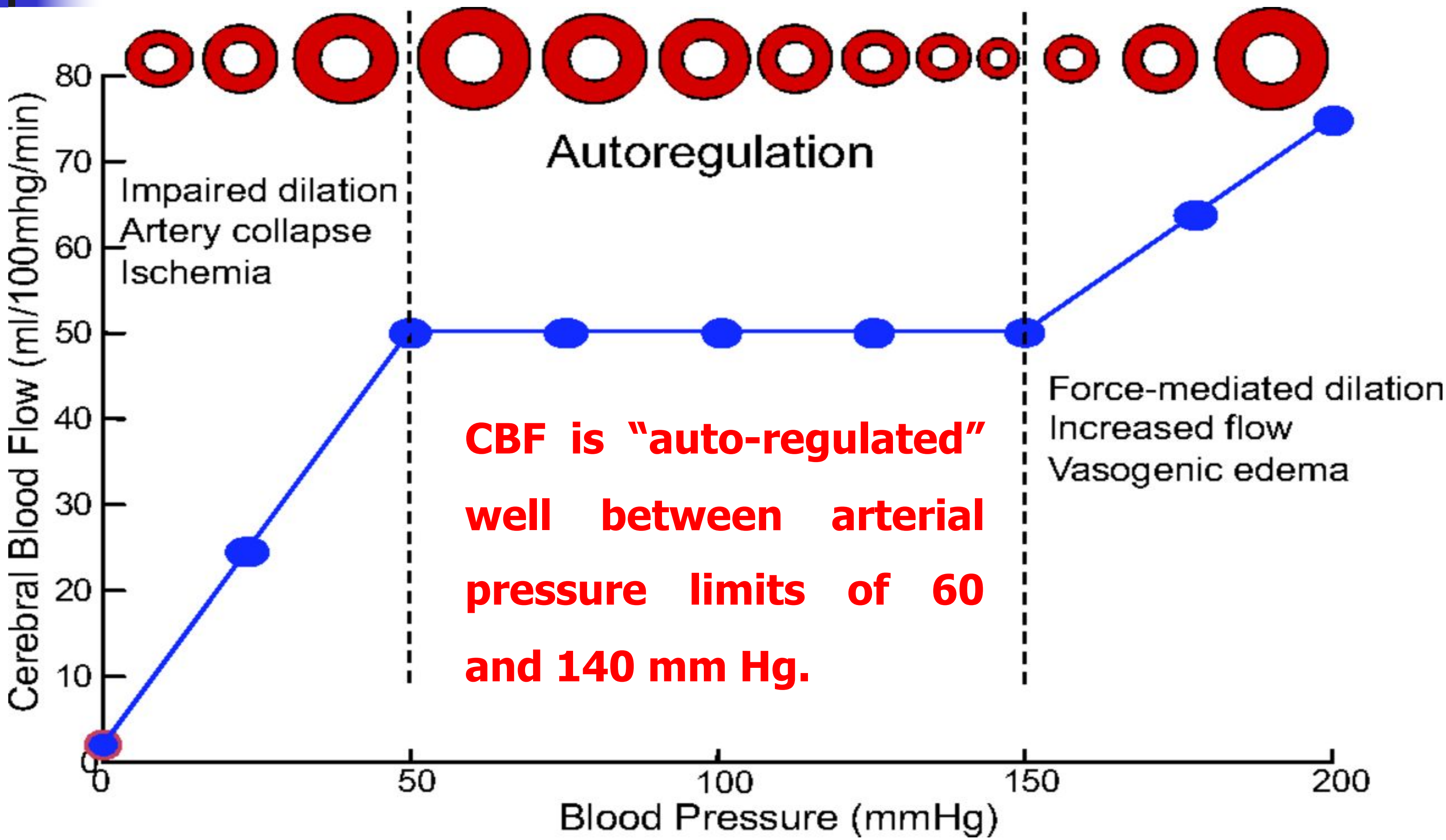


REGULATION OF CEREBRAL BLOOD FLOW



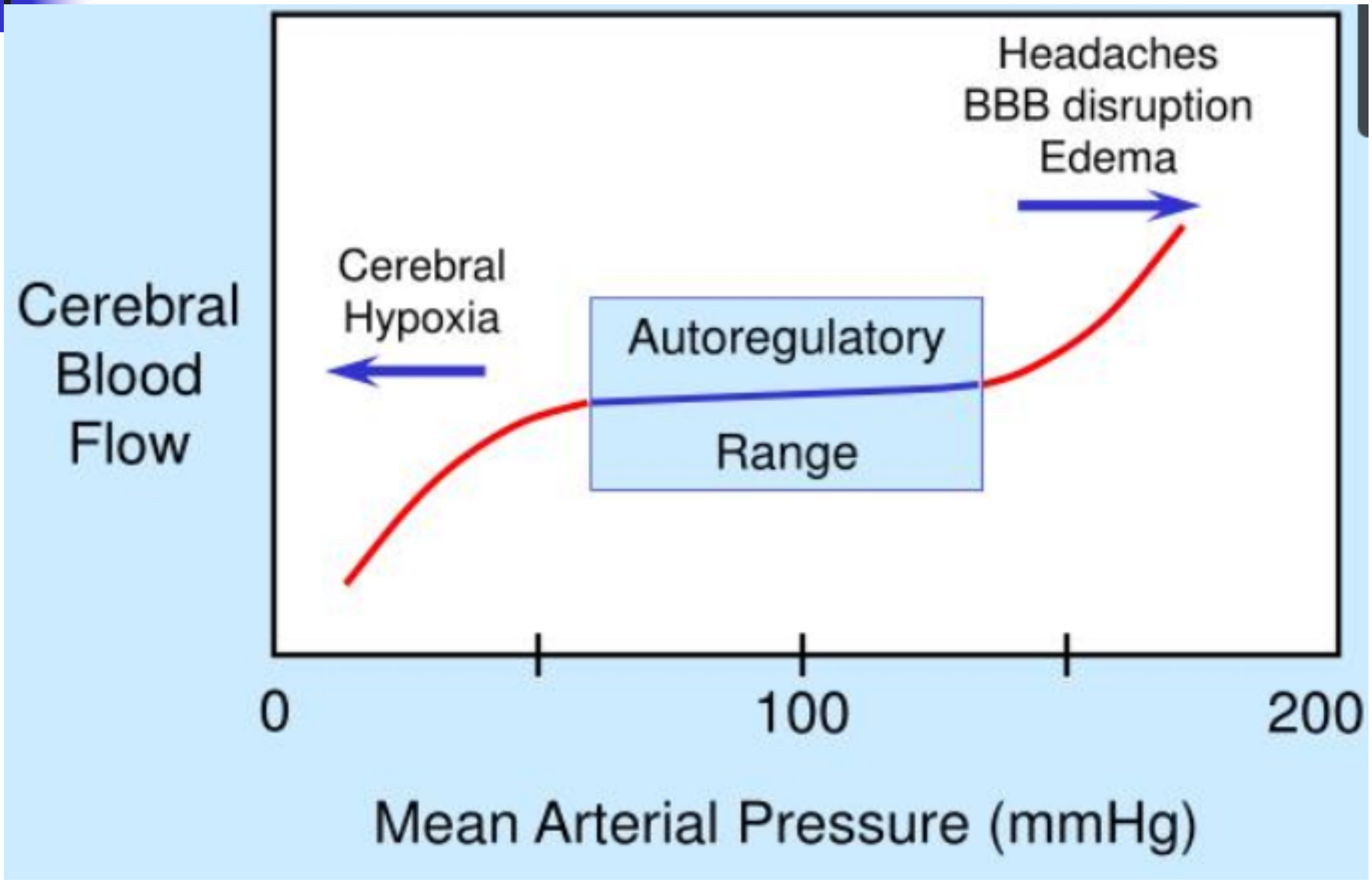
Cardiac output (CO); Sympathetic nervous activity (SNA); Renin–angiotensin–aldosterone (RAA) system; Arterial blood pressure (ABP); Cerebral perfusion pressure (CPP); Carbon dioxide (CO_2) and oxygen (O_2) (R) Cerebral resistance vessels at high (R_{high}), normal (R_{norm}), and low (R_{low})

REGULATION OF CEREBRAL BLOOD FLOW



CBF is "auto-regulated" well between arterial pressure limits of 60 and 140 mm Hg.

REGULATION OF CEREBRAL BLOOD FLOW



REGULATION OF CEREBRAL BLOOD FLOW

Myogenic / Pressure Autoregulation:

Arterioles dilate or constrict in response to changes in BP and ICP in order to maintain a constant CBF

Myogenic theory: The vascular smooth muscles are highly responsive to changes in pressure, a process called myogenic activity, that contributes to auto-regulation of cerebral blood flow.

Vascular smooth muscle within cerebral arterioles contract to stretch response, regulating pressure changes. Autoregulation of CBF completely BP-dependent

REGULATION OF CEREBRAL BLOOD FLOW

Myogenic / Pressure Autoregulation:

Cerebral blood flow is well extremely "auto-regulated" between arterial pressure limits of 60 and 140 mm Hg.

Mean arterial pressure can be decreased acutely to as low as 60 mm Hg or increased to as high as 140 mm Hg without significant change in cerebral blood flow.

Hypertension, auto-regulation of cerebral blood flow occurs even when the mean arterial pressure rises to as high as 160 to 180 mmHg. If arterial pressure falls below 60 mmHg, cerebral blood flow become severely decreased.

REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation

Cerebral blood flow is highly related to metabolism of the tissue. Three metabolic factors have potent effects in controlling the cerebral blood flow.
cerebral blood flow:
(1) Carbon dioxide concentration,
(2) Hydrogen ion concentration,
(3) Oxygen concentration.

REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation

Arterioles dilate in response to potent chemicals that are by-products of metabolism such as lactic acid, carbon dioxide and pyruvic acid

CO_2 is a potent vasodilator
Increased CO_2/decreased BP --> vasodilation
Decreased CO_2/increased BP --> vasoconstriction

REGULATION OF CEREBRAL BLOOD FLOW

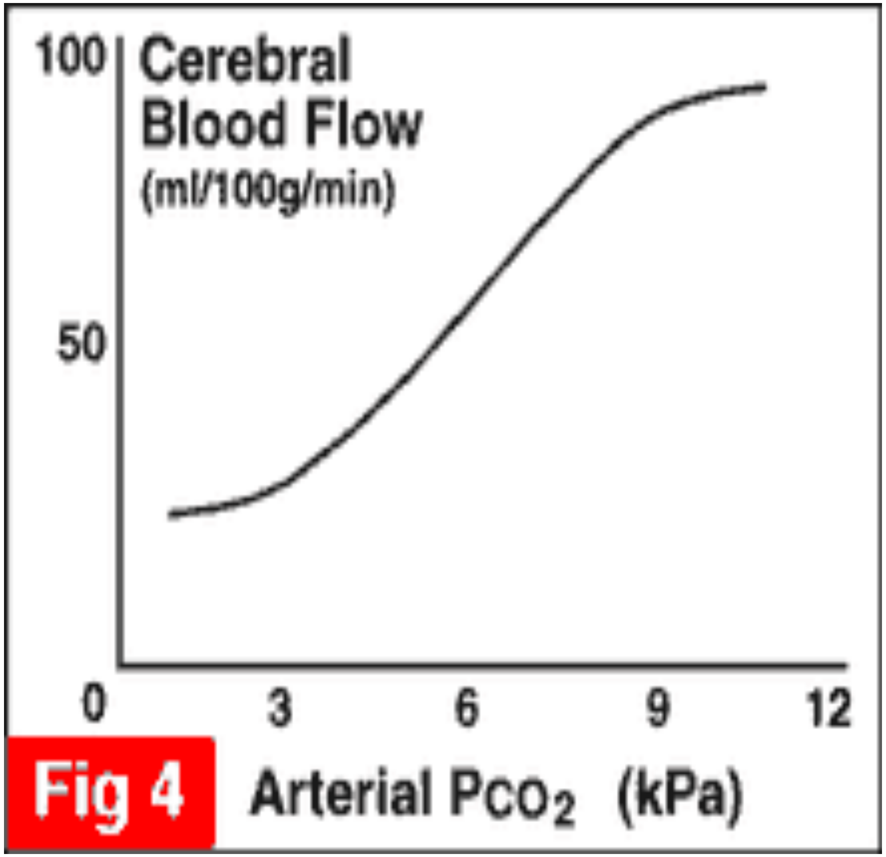
Metabolic Autoregulation

Increase Carbon dioxide (Hypercapnia) causes cerebral vasodilation.

As the arterial tension of CO2 rises, CBV and CBF increases

When it is decreased vasoconstriction is induced.

CBF and CO_2



REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation

- Increased arterial pCO_2 (hypercapnea) causes cerebral dilation
  - CO_2 diffuses through blood-brain barrier into the CSF to form H^+ (via carbonic acid) which then causes the vasodilation
- Decreased arterial pCO_2 as occurs during hyperventilation causes cerebral vasoconstriction, decreased blood flow, and cerebral hypoxia

CBF and CO_2

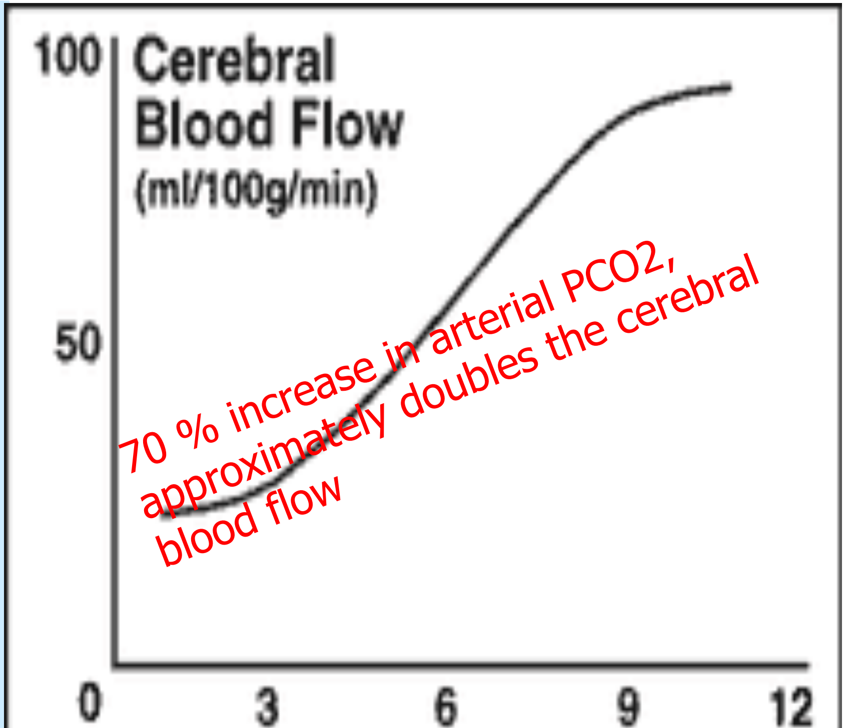
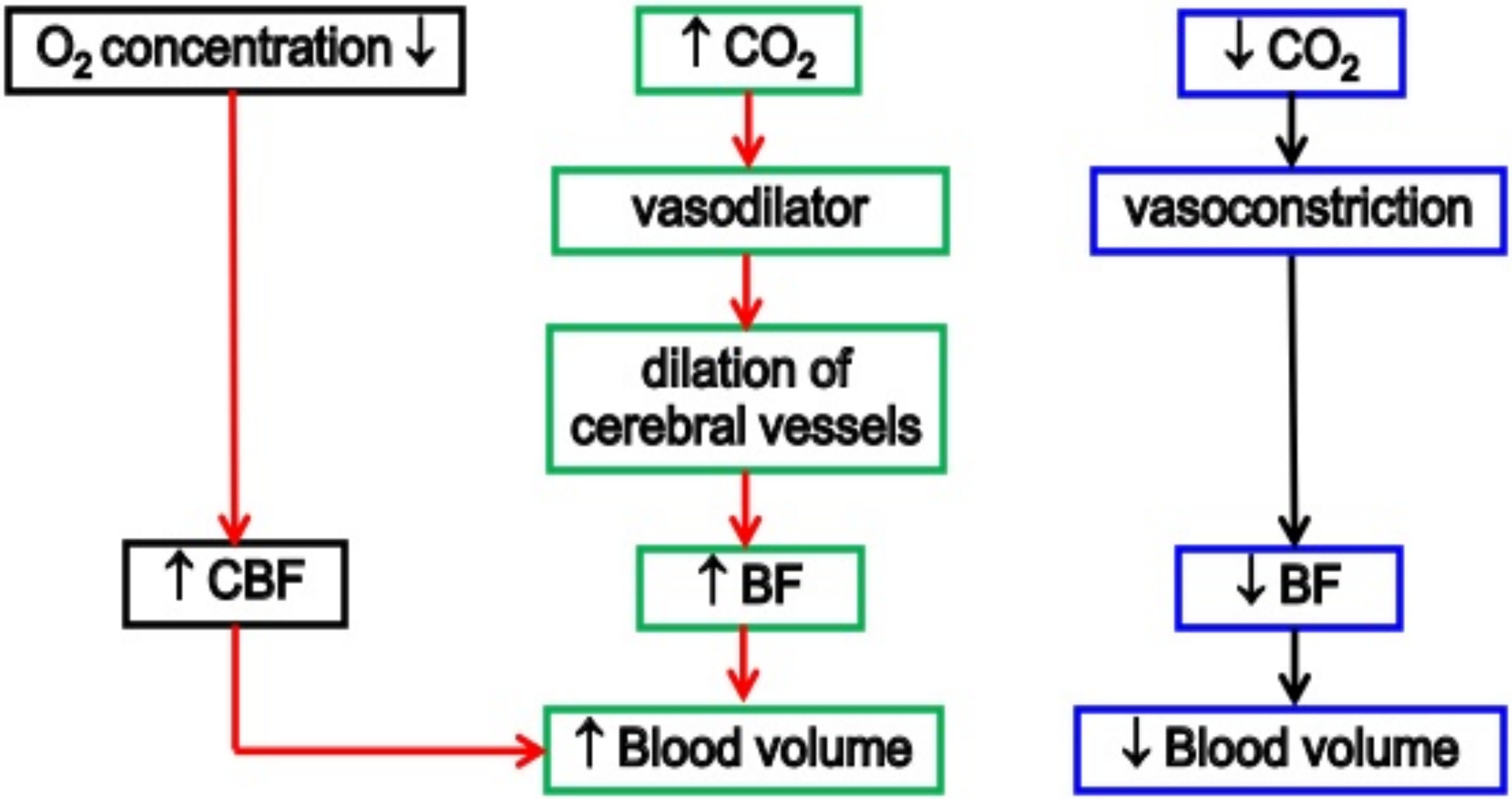


Fig 4

REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation

CBF: O2 and CO_2



REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation

Hydrogen ions

Carbon dioxide is increase cerebral blood flow by combining with water in the body fluids to form carbonic acid, with subsequent dissociation of this acid to form hydrogen ions.

The hydrogen ions cause vasodilation of the cerebral vessels.

The dilation directly proportional to the increase in hydrogen ion concentration.

Increases Hydrogen ion concentration, increase CBF

Such substances include lactic acid, pyruvic acid, and any other acidic material formed during the course of tissue metabolism.

REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation

Hydrogen: Increased hydrogen ion depresses neuronal activity. It is fortunate that an increase in hydrogen ion concentration also causes an increase in blood flow, which in turn carries hydrogen ions, carbon dioxide, and other acid forming substances away from the brain tissues.

Loss of carbon dioxide removes carbonic acid from the tissues; this, along with removal of other acids, reduces the hydrogen ion concentration back toward normal. Thus, this mechanism helps maintain a constant hydrogen ion concentration in the cerebral fluids and thereby helps to maintain a normal, constant level of neuronal activity

REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation

Oxygen

The rate of utilization of oxygen by the brain tissue remains within narrow limits—almost exactly 3.5 (± 0.2) ml of oxygen per 100 grams of brain tissue per minute.

If blood flow to the brain insufficient to supply this needed amount of oxygen, the oxygen deficiency mechanism causing vasodilation, returning the brain blood flow and transport of oxygen to the cerebral tissues to normal.

REGULATION OF CEREBRAL BLOOD FLOW

Metabolic Autoregulation
Oxygen

Decrease in cerebral *tissue PO2 below about 30 mm Hg (normal value is 35 to* 40 mm Hg) immediately begins to increase cerebral blood flow.

Brain function becomes unbalanced at lower values of PO2, at PO2 levels below 20 mm Hg.

Oxygen mechanism for local regulation of cerebral blood flow is important protective response against diminished cerebral neuronal activity and therefore, against derangement of mental capability.

REGULATION OF CEREBRAL BLOOD FLOW

Neurogenic Autoregulation

The cerebral circulatory system has strong sympathetic innervation that passes upward from the superior cervical sympathetic ganglia in the neck and then into the brain along with the cerebral arteries.

ANS and Neurochemical control has minor role

Pressure and Metabolic Autoregulation is most important

The sympathetic nervous system normally constricts the large and intermediate-sized brain arteries enough to prevent the high pressure from reaching the smaller brain blood vessels.

This is important in preventing vascular hemorrhages, preventing the occurrence of "cerebral stroke."

Factors disturb the Autoregulation

Noxious stimuli such as:

Hypoxia due to occlusive cerebro-vascular disease

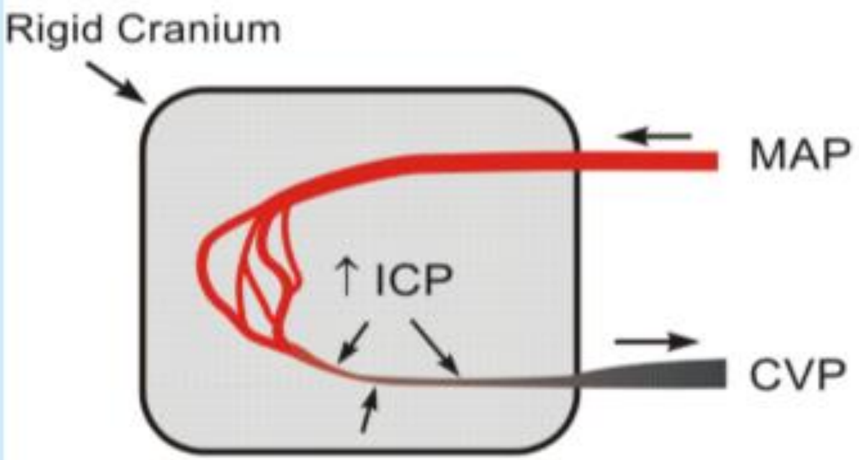
Trauma from head injury

Brain compression from tumors, hematoma, cerebral edema. These factors results in the loss of normal cerebral blood flow (CBF) autoregulation.

Factors disturb the Autoregulation

Cerebral Perfusion Pressure

CPP = MAP – ICP



CPP = cerebral perfusion pressure
MAP = mean arterial pressure
ICP = intracranial pressure **(normally 0-10 mmHg)**
CVP = central venous pressure

ICP increased by:

- Intracranial bleeding
- cerebral edema
- tumor

Increased ICP:

- collapses veins
- decreases effective CPP
- reduces blood flow

- Normal intracranial pressure 10 mmHg
- Pressure > 20 mmHg is abnormal
- ↑ ICP → ↓ CBF and ↓ cerebral perfusion

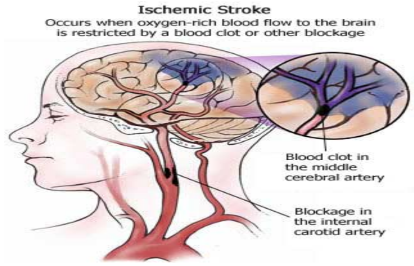
Factors disturb the Autoregulation

- Stroke
  - Hemorrhagic
    - Ruptured aneurism
    - Vascular weakening due to chronic hypertension
  - Ischemic
    - Thrombus formation or embolism
    - Vasospasm (ET-1?) associated with subarachnoid hemorrhage

Stroke: Occurs when the blood supply to a part of the brain is blocked resulting in the death of an area.

If a large vessel is blocked the outcome may be rapidly fatal or may lead to very severe disability.

The most common types of disability are the loss of functions of one side of the body and speech problems.



Fainting and Dementia

Fainting: Temporary loss of consciousness, weakness of muscles, and inability to stand up, caused by sudden loss of blood flow to the brain, changes in blood pressure.

Dementia: Result from repeated episodes of small strokes produce progressive damage to the brain over a period of time.

The main clinical feature of dementia is a gradual loss of memory and intellectual capacity. Loss of motor function in the limbs and incontinence can also occur.

Infarction

Figure 1. Cross sectional view of atheromatous plaque with blood clots formed in contact with its wall. Such blood clots can become loose and migrate toward the brain.

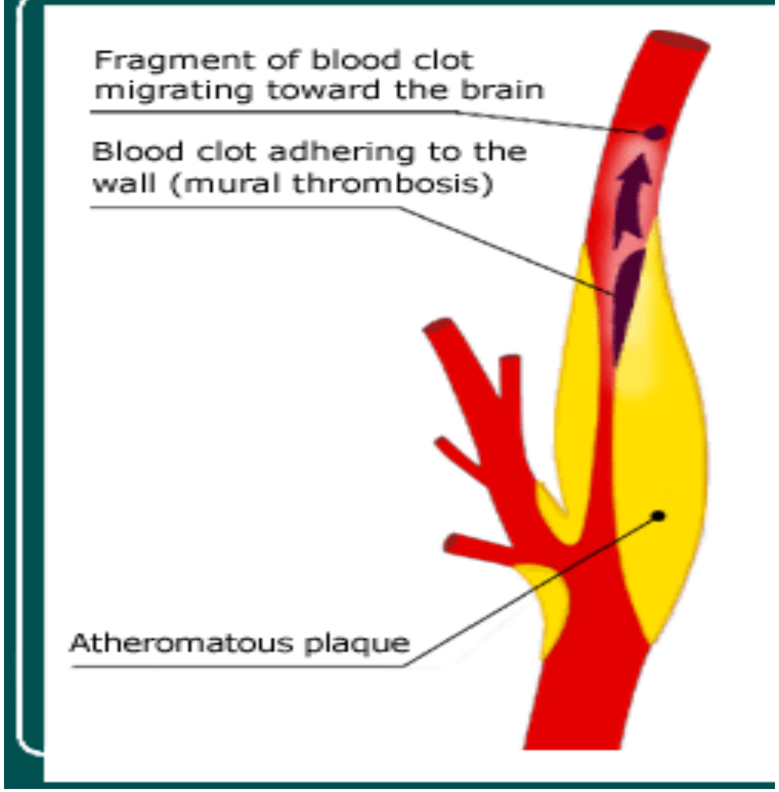
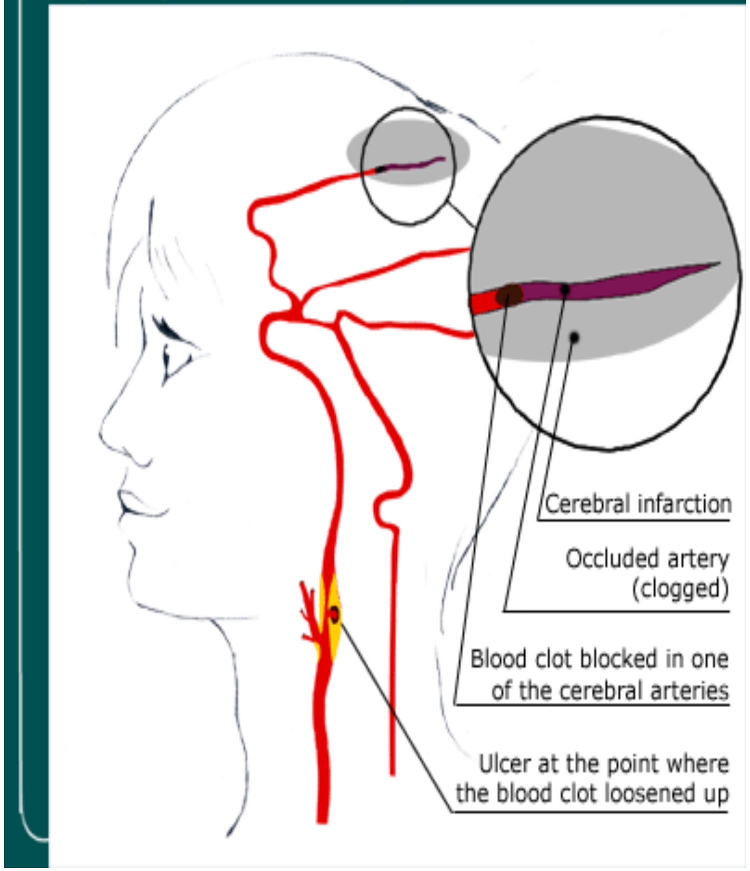


Figure 2. Cerebral infarction caused by an embolism originating in the carotid artery.



Lecture summary

- The Circle of Willis is a group of arteries at the base of the brain Brain receives its blood supply two internal carotid arteries and the two vertebral arteries.
- Normal blood flow through the brain of the adult person averages 50 to 65 milliliters per 100 grams of brain tissue per minute.
- The main systems regulate CBF, i) Myogenic / Pressure Autoregulation; ii) Metabolic Autoregulation; iii) Neurogenic Auto regulation
- Carbon dioxide, Hydrogen and Oxygen concentration have potent effect in the regulation CBF.
- Noxious stimuli such as hypoxia, trauma / head injury or brain compression from tumors, hematomas or cerebral edema, results in the loss of normal cerebral blood flow / auto regulation.

THANK YOU