Cerebrospinal Fluid (CSF) System
By the end of the lecture, students must be able to describe

- Physiological Anatomy of CSF Compartments
- Composition
- Formation
- Circulation
- Reabsorption
- CSF Pressure
- Functions
- Diseases
CEREBROSPINAL FLUID SYSTEM

➤ Capacity of entire cerebral cavity enclosing the brain and spinal cord---1600 to 1700 milliliters

➤ Cerebrospinal fluid ---150 milliliters
C.S.F Location

- Ventricles of brain
- Cisterns around & outside the brain
- Subarachnoid space around:
  - Brain
  - Spinal cord
- All these chambers are connected with one another
- Constant pressure
Ventricles of Brain (Right Lateral aspect)

- Lateral ventricles
- Interventricular foramen
- Third ventricle
- Mesencephalic aqueduct
- Fourth ventricle
- Lateral aperture
- Median aperture
- Central canal
Ventricles of Brain (Anterior aspect)
Choroid Plexus in a lateral Ventricle
**Formation of CSF**

**Sites:**

>2/3 by **Choroid plexus** in 4 ventricles mainly in two lateral ventricles

<1/3 by **Ependymal surfaces** of all the ventricles and by the arachnoidal membranes

**Choroid plexus:** Cauliflower like growth of blood vessels covered by thin epithelium, projecting into all ventricles

**Mechanism of secretion:**

- Active transport of Na → Passive transport of Chloride → Osmosis of water

- 500 – 700 ml/day (0.2 ml/min)
- Total 100 – 160 ml
Composition and Characteristics

1. Osmotic pressure is equal to that of plasma
2. [Na+] is nearly equal to that of plasma
3. [Cl⁻] ≈ 15% greater than plasma
4. [K⁺] is ≈ 40% less
5. Ca++ is also less
6. Glucose is 30% less (64mg%) 
7. Protein. Only 20-25mg% as compared to 6000mg% in plasma
8. Cells. Very few lymphocytes (1-5 cell/mm³)
9. Specific gravity = 1.005
Circulation of C.S.F.

Lateral Ventricle $\xrightarrow{\text{Monro}}$ 3rd Ventricle $\xrightarrow{\text{Aqueduct of Sylvius (Mesencephalic Aqueduct)}}$ 4th Ventricle

Subarachnoid Space $\xleftarrow{\text{1 – Magendie}}$ $\xrightarrow{\text{2 – Luschka (lat.)}}$ 4th Ventricle
Pathway of CSF

Formation of CSF in lateral ventricle
- Foramen of Monro
- Third Ventricle
- Aqueductus Sylvius
- Fourth Ventricle
- Foramen of Magendie and foramen of Luschka
- Cisterna magna and cisterna lateralis
- Subarachnoid spaces
  - To spinal cord
  - To cerebral hemispheres
Flow of CSF
Flow of CSF

- *cisterna magna*- a fluid space that lies behind the medulla and beneath the cerebellum

- The cisterna magna is continuous with the *subarachnoid space*
CSF flows upward-- cisterna magna through the subarachnoid spaces surrounding the cerebrum---arachnoidal villi -- sagittal venous sinus and others

fluid empties into the venous blood through pores of these villi
Absorption

• To the **venous system** by bulk fluid through **arachnoid granulations**, located in the superior sagittal sinus by pressure gradient.

• **Arachnoid granulations**:
  - Projections of arachnoidal membrane in venous sinuses:- **Arachnoid villi** *(Microscopic)*
  - Collection of Arachnoid villi:- **Arachnoidal Granulations** *(Macroscopic)*
  - **Endothelial cells** cover the villi and absorb through vesicular passages directly through the bodies of the cells
    - • **CSF**
    - • **Dissolved protein molecules**
    - • **RBC, WBC**
Drainage of a **PERIVASCULAR SPACE** into the subarachnoid space
Perivascular Spaces and Cerebrospinal Fluid.

- ends of large arteries and veins penetrate inward—carry *pia mater* (the membrane that covers the brain)
- pia loosely adherent to vessels -- *perivascular space*, exists between it and each vessel
Lymphatic Function of the Perivascular Spaces

- Protein leak from brain capillaries----interstitial spaces of brain----perivascular spaces-----subarachnoid spaces
- Absorbed through the arachnoidal villi ---- large cerebral veins
- In case of infection in the brain, dead white blood cells and infectious debris are carried away through the perivascular spaces
CSF Pressure

• 130 mm H$_2$O (10 mmHg) lying in horizontal position
• Range: 65 ---195 mm H$_2$O
• C.S.F absorption stops below 68 mm H$_2$O
Regulation of CSF Pressure

Balance between formation and reabsorption

• **Formation**
  - Almost constant rate
  - Abnormally high amount of **cells or proteins** may block the reabsorption
• Reabsorption

- Arachnoidal villi function like “valves” that allow cerebrospinal fluid and its contents to flow readily into the blood of the venous sinuses while not allowing blood to flow backward in the opposite direction.

- Due to pressure gradient.

- CSF flows into venous sinuses when its pressure is 1.5 mm Hg greater than the pressure of the blood in the venous sinuses.
Normally pressure does not rise due to ↑ reabsorption in case of increased pressure.

Increase in CSF pressure occurs (diseases):
- The villi get blocked by
  - large particulate matter
  - fibrosis
  - excesses of blood cells that have leaked into the cerebrospinal fluid
- Diseases of villi result in ↓ reabsorption
  - Number of villi
  - Quality of villi
Effects of ↑CSF Pressure

• Hydrocephalus
  ➢ Excess water in cranial vault
  ➢ Types
    • Communicating
    • Non-Communicating
1. Communicating hydrocephalus
   - fluid flows readily from the ventricular system into the subarachnoid space

2. Non-communicating hydrocephalus
   - fluid flow out of one or more of the ventricles is blocked
   - block in the aqueduct of Sylvius-- closure before birth
Hydrocephalus

- Communicating Hydrocephalus
  - Blockage of fluid flow in subarachnoid space
  - Blockage of Arachnoid villi
  - Fluid collects outside and inside brain

- Non-Communicating Hydrocephalus
  - Block in Aqueduct of Sylvius
    - Atresia (Closure)
    - Brain tumors
Effects of hydrocephalus

- Swelling of head in children
- Brain damage
Diseases related to CSF (Brain edema)

• When systems for protecting against transudation of fluid into the brain break down e.g.
  - Brain concussion
    • Blow to head
  - High blood pressure

• Mechanism
  - ↑Capillary Pressure
  - ↑Damage to capillary walls

• Coma and death
Effects of Brain Edema

- Brain compression
  - Brain damage
- Compression of blood vessels
- Initiation of two vicious cycles
Two vicious cycles due to Brain Edema

1. Arteriolar Dilatation → Increased Capillary Pressure → EDEMA
2. Compression of blood vessels → Decreased Blood flow → Brain ischemia

Contd……
Two vicious cycles due to Brain Edema

- Compression of blood vessels
- ↓Cerebral Blood flow
- ↑Capillary Permeability
- ↓O₂ Delivery

Contd……
Treatment of Brain Edema

• Emergency
• Osmotic diuretics
  ➢ Mannitol
• Ventricular needle puncture
Cushioning Function of C.S.F

Specific gravity of brain and CSF is about same
so a blow to head
(if not too severe)
moves the entire brain simultaneously with skull
Diseases related to CSF (Brain injury)

• Coupe
  ➢ Damage/injury to the brain on the same side of trauma

• Countercoup
  ➢ Damage/injury to the brain on the opposite side of trauma
Effects of ↑ CSF Pressure

1. Papilledema
2. Hydrocephalus
Effects of ↑CSF Pressure

- **Papilledema**: Edema of the Optic Disc
- Retinal edema
- **Mechanism:**
  1. Fluid pushed into
     - Optic nerve sheath
     - Spaces between optic nerve fibers
  2. ↓outward flow of fluid in optic nerves
  3. ↓outward flow of blood in retinal veins

- **Significance of Papilledema**
  - Clinical diagnosis of ↑CSF Pressure by ophthalmoscope
- **Effects of Papilledema**
  - Blindness/ blurred vision
Blood-CSF and Blood-Brain Barriers

- **Blood-CSF barrier**
  - tight junctions between adjacent choroid epithelial cells

- **Blood-brain barrier**
  - tight junctions between adjacent endothelial cells of brain capillaries
Blood-CSF and Blood-Brain Barriers

• All areas of brain parenchyma except
  ➢ Some areas of hypothalamus, pineal gland, area postrema
    • Sensory receptors
      ❖ Osmolarity, glucose

• Controlled permeability
  ➢ Highly permeable to
    • Water, CO₂, O₂, most lipid-soluble substances
  ➢ Slightly permeable to
    • Electrolytes e.g. Na⁺, Cl⁻, K⁺
  ➢ Impermeable to
    • Plasma proteins, most lipid-non-soluble organic molecules

• Therapeutic drugs
Functions of C.S.F

1. Acts as fluid buffer (cushioning the CNS against injury)
2. Acts as reservoir to regulate the contents of the cranium
3. May act as a medium of nutrient exchange in the CNS. However, brain carries out its metabolic exchanges directly.
4. Clinical - Diagnostic Therapeutic
THANK YOU