Physiology of CSF and Pathophysiology of Hydrocephalus

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Introduction

- Dynamic component of CNS
- Invaluable tool to diagnosis
- Physiological reservoir of human proteome
- Reflects the physiologic state of CNS
Historical account

- Hippocrates described fluid in brain
- Galen described ventricles
- Vesalius showed the anatomy
- Megendii performed first cisternal puncture in animals
- Quinke performed first LP
- Dandy was credited first ventricular puncture
- Quekenstedt did first cisternal puncture in humans.
Functions of CSF

- Mechanical cushion to brain
- Source of nutrition to brain
- Excretion of metabolic waste products
- Intracerebral transport medium
- Control of chemical environment
- Autoregulation of intracranial pressure
Production of CSF

- Choroidal
- Extrachoroidal
  - Ependyma
  - ? Neighboring brain substance
Histology of choroid plexus
Facts of interest

- Only choroidal CSF production is tightly regulated active process.
- CSF secretion shows diurnal variation with peak in the morning.
Factors affecting production

- Vascular bed autoregulation
- Intracranial pressure
- Brain metabolism
- Drugs
Absorption of CSF

- Arachanoid granulations
- Along the olfactory nerves
- Extracellular spaces in brain
- Brain substance (glial cells).
Factors affecting absorption

- Intracranial pressure
Quantitative dynamics

- Daily secretion:
- Total CSF volume:
  - Ventricular
  - Cisternal
  - Spinal
CSF pathways
Techniques of CSF analysis

- Lumbar puncture
- Cisternal puncture
- Ventricular puncture
Lumbar puncture

- **Diagnostic indications:**
  - Infective pathology
  - Inflammatory pathology
  - Subarachnoid hemorrhage
  - Malignancy and spread
  - Pressure recordings
  - Cisternography, myelography,

- **Therapeutic indications:**
  - CSF drainage
  - Drug delivery
Contraindications

- **Absolute**
  - Posterior fossa mass
  - Coagulopathy, blood dyscrasias
  - Known spinal AVM

- **Relative**
  - Raised ICT (guarded LP)
  - Local infection
Technique

- Positioning
- Cleaning and draping
- Puncture
- CSF
figure
Complications

- Post LP headaches
- Hematoma
- Infection
- Neural injury
- Iatrogenic dermoids
Other methods

- Cisternal puncture
- Lateral cervical puncture
- Ventricular puncture
Lateral cervical puncture
Ventriculostomy

- Dandy's point
- Keen's point
- Frazier's point
- Kocher's point
Dandy's point
Keen`s point
Kocher`s point
Frazier`s point
## Analysis

<table>
<thead>
<tr>
<th>Glucose</th>
<th>60-90</th>
<th>≥ 0.66</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proteins</td>
<td>35mg/dl</td>
<td>0.005</td>
</tr>
<tr>
<td>Globulins</td>
<td>10-50 mg/L</td>
<td>0.001</td>
</tr>
<tr>
<td>RBC</td>
<td>0-1</td>
<td></td>
</tr>
<tr>
<td>WBC</td>
<td>0-1 (L)</td>
<td></td>
</tr>
<tr>
<td>Lactate</td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>
## Diagnostic characteristics

<table>
<thead>
<tr>
<th>Type</th>
<th>Sugar</th>
<th>Cells</th>
<th>Lactate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial</td>
<td>Very low</td>
<td>Neutrophils</td>
<td>Increased</td>
</tr>
<tr>
<td>Fungal</td>
<td>low</td>
<td>L/N</td>
<td>-</td>
</tr>
<tr>
<td>Viral</td>
<td>Normal to low</td>
<td>L/N</td>
<td>-</td>
</tr>
<tr>
<td>Aseptic</td>
<td>Normal</td>
<td>Neutrophils</td>
<td>Normal</td>
</tr>
<tr>
<td>Post operative</td>
<td>Normal</td>
<td>Neutrophils</td>
<td>(≥1000)</td>
</tr>
</tbody>
</table>
Hydrocephalus

- Definition

- Imbalance between production and absorption of CSF leading to accumulation of fluid in the ventricular system leading to elevation of intracranial pressure.
Epidemiology

- Infantile HCP: 3-4 per 1000 LB
- As a single congenital disorder: 0.9-1.5 per 1000 live births
- Associated with SD: 1.3-2.9 per 1000 LB
Classification

- Communicating
  - AKA extraventricular,

- Noncommunicating
  - AKA obstructive
    - Triventricular
    - Biventricular
### TABLE 365-1 Classification of Hydrocephalus

<table>
<thead>
<tr>
<th>Noncommunicating Hydrocephalus</th>
<th>Communicating Hydrocephalus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I.</strong> Congenital lesions</td>
<td><strong>I.</strong> Congenital lesions</td>
</tr>
<tr>
<td>A. Aqueductal obstruction</td>
<td>A. Arnold-Chiari malformation</td>
</tr>
<tr>
<td>(stenosis)</td>
<td>B. Encephalocele</td>
</tr>
<tr>
<td>1. Gliosis</td>
<td>C. Leptomeningeal inflammations</td>
</tr>
<tr>
<td>2. Forking</td>
<td>D. Lissencephaly</td>
</tr>
<tr>
<td>3. True narrowing</td>
<td>E. Congenital absence of</td>
</tr>
<tr>
<td>4. Septum</td>
<td>arachnoidal granulations</td>
</tr>
<tr>
<td>B. Atresia of the foramina of</td>
<td><strong>II.</strong> Acquired lesions</td>
</tr>
<tr>
<td>Luschka and Magendie</td>
<td>A. Leptomeningeal inflammations</td>
</tr>
<tr>
<td>(Dandy-Walker cyst)</td>
<td>1. Infections</td>
</tr>
<tr>
<td>C. Masses</td>
<td>2. Hemorrhage</td>
</tr>
<tr>
<td>1. Benign intracranial cysts</td>
<td>3. Particulate matter</td>
</tr>
<tr>
<td>2. Vascular malformation</td>
<td><strong>B.</strong> Masses</td>
</tr>
<tr>
<td>3. Tumors</td>
<td>1. Tumors</td>
</tr>
<tr>
<td><strong>II.</strong> Acquired lesions</td>
<td>2. Non-neoplastic masses</td>
</tr>
<tr>
<td>A. Aqueductal stenosis (gliosis)</td>
<td>C. Platybasia</td>
</tr>
<tr>
<td>B. Ventricular inflammations and scars</td>
<td></td>
</tr>
<tr>
<td>C. Masses</td>
<td><strong>III.</strong> Oversecretion of CSF (choroid</td>
</tr>
<tr>
<td>1. Tumors</td>
<td>plexus papilloma)</td>
</tr>
<tr>
<td>2. Non-neoplastic masses</td>
<td></td>
</tr>
</tbody>
</table>
Pathogenesis

- Obstruction of CSF pathways leading to decreased absorption
- Increased production
- Increased venous pressure
Increased production

- Choroid plexus papilloma
Decreased absorption

- Due to anatomical block in the pathways
- Block at arachanoid granulations level
Increased venous pressure

- Evidence with this theory
  - VOGM
  - Experimental studies in animals

- Evidence against this theory
  - Ligation of various sinuses doesn’t cause HCP
  - Experimental studies
Pathology of hydrocephalus

- Atrophy of white matter
- Spongy edema of brain
- Fibrosis of choroid plexuses
- Stretching and denuding of ependyma
- Fenestration of septum pellucidum
- Thinning of interhemispheric commissures
Acute HCP

- Cerebral, IV or cerebellar hematoma
- Paraventricular tumors
- Gunshots
- Subarachnoid hemorrhage
- Acute head injuries
- Shunt malfunction.
Progression

- Ventricular dilatation
  - Occipital and frontal horns f/b temporal horns
  - Anterior and posterior recess of third ventricle
  - Fourth ventricle
  - Third ventricular ballooning
Hydrocephalic edema

- Available space in the cavity consumed
- Stretching and denuding of ependyma
- Edema of white matter
Mechanism

- Stasis of brain interstitial fluid
- Reflux of CSF into the periventricular area
- Increase in cerebral capillary permeability
Progression

- Dorsal angles of lateral ventricle
  - 3-6 hrs

- Centrum semiovale
  - 19-24 hrs

- Diffuse
  - afterwards
Chronic HCP

- Compensatory mechanisms in chronic HCP
  - Expansion of skull
  - Contraction of cerebral vascular volume
  - White matter atrophy and ventricular enlargement
  - Decreased rate of CSF formation.
  - Diversion of CSF flow to alternative pathways
Changes in cerebral circulation

- Increased venous pressure
- Delayed emptying of cerebral veins
- Narrowing of cerebral arteries
- Prolongation of circulation time
- Reduced cerebral blood flow
- Lowering of CMRO2
- Reduced glucose metabolism
Clinical features

- Age
- Expansibility of skull bones
- Type of HCP
- Duration of HCP
Pediatric hydrocephalus

- Enlargement of head
- Thin and glistening scalp
- Tense, bulging fontanel
- Dilated and tortuous scalp veins
- Unilateral or bilateral abducens palsies
- Cracked pot or Macewen`s sign
- Hypopituitarism and growth retardation
- Transillumination of skull
Adult acute HCP

- Headache, nausea, vomiting
- Alteration of sensorium
- Visual obscurations
- Perinaud’s syndrome
- Progression to herniation syndromes
Adult chronic HCP

- Bifrontal generalized headache, vomiting
- Papilledema and secondary optic atrophy
- Cognitive deficits
- Unilateral or bilateral abducens palsy
- Upward gaze palsy
- Spastic quadriplegia, dysmetria,
- Bitemporal hemianopia
- Endocrine disturbances
Normal pressure hydrocephalus

“Hydrocephalus with normal CSF opening pressure on lumbar puncture and absence of Papilledema”
Pathophysiology

- Intermittent rise of CSF pressure causing ventricular dilatation.
- Intraventricular pressure head is decreased
Basis of clinical symptoms

- Gait problems
- Urinary incontinence
- Memory problems
Arrested hydrocephalus

- Definitions
  - CSF pressure has normalized
  - Pressure gradient between ventricles and parenchyma has been dissipated
  - Ventricular size remains stable or decrease
  - New neurological deficits do not appear
  - Advancing psychomotor development with age.
Pediatric NPH

- Enlarged head usually in or above ninth percentile
- History of delayed psychomotor development
- Mild to moderate mental retardation
- Glib verbal abilities
- Mild spastic paraparesis
Hydrocephalus ex vacuo

- Cerebral atrophy and dilatation of sulci
- Intracranial pressure is normal
- Absence of periventricular edema
- Absence of retrograde filling Isotope cisternography
Thank you