A review on hydrocephalus

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Abstract:-
This review explains about types of hydrocephalus, its pathophysiology, diagnosis, new therapies. Hydrocephalus is condition in which CSF within the ventricles or subarachnoid space of brain accumulates abnormally, causing dilation of ventricles and occupies various parts of brain. It is characterized by gait disturbance, urinary incontinence and cognitive decline in absence of elevated CSF pressure. It was first described by Adams and hakim. NPH is combined with widening of cerebral ventricles. CSF is produced from choroid plexus inside brain ventricles (70-80%) Remaining CSF is produced from ependymal lining of ventricles as interstitial fluid (extra choroidal source). CSF is ultimately absorbed from SAS via arachnoid villi and granulations, small herniations of arachnoid space into venous system. It is absorbed by means of hydrostatic gradient. It occurs along olfactory nerves, extracellular spaces in brain, glial cells. Symptoms include headache, vomiting, nausea, papilledema, sleepiness or coma. Congenital brain defects, hemorrhage (ventricles on SAS), infection of CNS (syphilis, herpes, meningitis, encephalitis, mumps), tumor are some causes for hydrocephalus. CT and MRI play an important role in the diagnosis. CT can assess size of ventricles and other structures. MRI can find chiari malformation or cerebellar or periaqueductal tumors. It can differentiate normal pressure hydrocephalus from cerebral atrophy. Surgical installation of stunts is involved in treatment of hydrocephalus. Further research is required in order to recognize disease at early stages which helps in reducing severity of disease.

Key words:-
CSF, diagnosis, Hydrocephalus, treatment.

Abbreviations:-
INPH:- Idiopathic normal pressure hydrocephalus
CSF:- cerebrospinal fluid
VM:- ventriculomegaly
CST:-Corticospinal tract
HC:- Hydrocephalus
NHC:- Neonatal hydrocephalus
IVH:- intraventricular haemorrhage
ETV:- Endoscopic Third Ventriculostomy
ICP:- intracranial pressure
MRI:- Magnetic Resonance Imaging
SCO:- Sub comissural organ
VP:-ventriculo peritoneal
MRI:- Magnetic Resonance Imaging
CT:- Computed Tomography
RASSL:-R01 receptor activated solely by synthetic ligands
RF:-Reissner Fiber
GFAP:- Glial fibrillary acidic protein
CBF:- cerebral blood flow
SAS:-Sub Arachnoid Space
RNA:-Ribonucleic Acid
tTA:-tet Trans activator
LP:-Lumbar puncture
HVV:- Horizontal vertical valve
Iba-1: Iodinized calcium binding adapter molecule-1
Dox: doxycycline

**Introduction:**

**Hydrocephalus:**
It is a condition in which CSF within the ventricles or subarachnoid space of brain accumulates abnormally, causing dilation of ventricles and occupies various parts of brain. So, it compresses nervous tissue that further leads to several neurodegenerative or neurological disorders.¹

**Types:**
1. Non-communicating
2. Communicating

1. Non-communicating: obstructive
   - Congenital:
     - Stenosis of the aqueduct of Sylvius, Dandy–Walker syndrome, craniofacial
   - Acquired:
     - Midline supratentorial tumours (e.g. craniopharyngioma), Cysts (e.g. colloid cyst)
     - Tumours of the posterior Fossa

2. Communicating:
   - Congenital:
     - Arnold-chiari malformation (myelomeningocele), Meningoceles/encephaloceles
     - Venous hypertension (e.g., achondroplasia, syndromes)
   - Acquired:
     - Subarachnoid hemorrhage, Meningeal carcinomatosis, post meningitis²

iNPH:
It is characterized by gait disturbance, urinary incontinence and cognitive decline in absence of elevated CSF pressure.³⁴ It was first described by Adams and hakim. NPH is combined with widening of cerebral ventricles.⁵ The annual incidence of NPH has been estimated at 1/100000.⁶ MRI studies of NPH shows ventricular enlargement, diminution of high convexity sulci, periventricular hyperintensity. Neuropathologicals of NPH reveals presence of white matter damage and metabolic derangement.⁷

**CSF physiology:**
CSF occupies SAS (space between arachnoid matter and pia matter) and ventricular system around and inside brain and spinal cord. It constitutes content of ventricles, cisterns, sulci of brain, as well as central canal of spinal cord.

The total volume of CSF in the human ventricular system is ca. 125 ml [2], ca. 500 ml of CSF is produced per day, and some CSF seeps down around the spinal cord. CSF contains small molecules, salts, peptides, proteins, enzymes, etc. that play critical roles in many physiological processes. Changes (concentration; modification of proteins and peptides) in CSF compositions accurately reflect pathological processes in the CNS, and CSF offers a unique window to study CNS disorders.⁷

It is based on 3 key points.
1. Formation of CSF
2. Passive absorption of CSF
3. Unidirectional flow of CSF from place of formation to place of absorption.
CSF formation:-

CSF is produced from choroid plexus inside brain ventricles (70-80%). Remaining CSF is produced from ependymal lining of ventricles as interstitial fluid (extra choroidal source).

CSF circulation:-

CSF flows in to and fro motion in unidirectional manner. It flows from lateral brain ventricles through foramen of magnum into third ventricle and through aqueduct of sylvius into fourth ventricle. They finally descend through 2 lateral foramina of Luschka and 1 median foramin of Magendie into subarachnoid space and then into arachnoid granulations, dural sinus and venous drainage. Some amount of CSF descends into spinal cord.

Absorption:-

CSF is ultimately absorbed from SAS via arachnoid villi and granulations, small herniations of arachnoid space into venous system. It is absorbed by means of hydrostatic gradient. It occurs along olfactory nerves, extracellular spaces in brain, glial cells.8,9

Symptoms:-2

The symptoms of hydrocephalus varies with chronicity. It depends on patients disease severity i.e., brain damage dependent, persons age, cause of blockade.

Symptoms include headache, vomiting, nausea, papilledema, sleepiness or coma. If intracranial pressure is elevated, then it may lead to several consequences like uncal/ cerebellar tonsil herniation, with resulting life threatening brain stem compression.

In infants, symptoms include eyes that appear to gaze downwards, irritability, seizures, separated sutures, sleepiness, increased head circumference, tense fontanelle, separation of cranial sutures, episodic apnoea and bradycardia. In adults or older children, symptoms like excessive sleepiness, loss of bladder control, spasm, vomiting, crossed eyes, changes in personality, memory or thinking ability, headache, slow or restricted movement, gait disturbance.

Etiology:-

Hydrocephalus is caused by complex interaction of genetic and environmental factors. Aqueductal stenosis, an obstruction of cerebral aqueduct is most commonly seen as a cause for hydrocephalus. This obstruction to cerebral aqueduct causes CSF to accumulate in ventricles and results in increased pressure of ventricles.

Congenital brain defects, hemorrhage (ventricles on SAS), infection of CNS (syphilis, herpes, meningitis, encephalitis, mumps), tumor are some causes for hydrocephalus.

Etiology of aqueduct stenosis:-

Intrinsic:-

Septum or membrane formation, forking of aqueduct, gliosis of aqueduct, stenosis of aqueduct.

Extrinsic:-

Infections, abscesses, pineal tumors, brainstem gliomas, medulloblastoma, ependymoma.

Hydrocephalus ex vacuo:-

It involves presence of excess CSF, but CSF pressure seems to be normal. This condition is usually seen during stroke to brain or injury, or chronic degeneration, actual shrinkage of brain substance. NPH is associated with dementia, balance disorder, urine incontinence and general slowing of activity.

Pathophysiology:-

Congenital:-

It is present at birth and may be caused by events like genetic abnormalities or alterations of fetal development.12 Most common causes of congenital are obstruction to cerebral aqueduct flow, Arnold-chiari malformation, Dandy-walker malformation, Bickers-Adams syndrome.

Acquired:-

It occurs at time of birth or may be at some later stage. It may affect any age and may caused by injury or disease.12 Causes for acquired include mass lesions or tumors (medulloblastoma, astrocytoma), cysts, abscesses, hematoma, hemorrhage.15,16
Non-communicating:-
This occurs when one or more passages connecting the ventricles are blocked. So much CSF accumulates in ventricles. This prevents the drainage of CSF into arachnoid space just inside skull.

Communicating:-
Reduction in the absorption rate is caused by damage to absorption tissue. This occurs in blockade of CSF outflow result. It is caused by overproduction of CSF, defective absorption of CSF or venous drainage insufficiency.12

The pathophysiology of hydrocephalus is very complex issue. It can be assessed by examination of cerebral cortex mainly. Extrapolations of structure like hippocampus, basal ganglia, hypothalamus, cerebellum, brain stem need to be assessed and found in detail.

Injury mechanisms also play a vital role in hydrocephalus. Ventriculomegaly is a brain condition where ventricles get dilated that include compression and stretch of periventricular tissue, ischemia and hypoxia and increased CSF pulsatility in cerebral aqueduct. ventriculomegaly becomes chronic and/or progresses to more severe forms: gliosis and neuroinflammation, periventricular edema, demyelination, axonal degeneration and slow axoplasmic transport, metabolic impairments, stagnant CSF flow, altered bloodbrain barrier transport that can lead to toxicity as with reduced amyloid clearance, dendritic and synaptic deterioration resulting in altered connectivity, and cell death.

The role of neuronal cell death in the overall pathophysiology of hydrocephalus is interesting because apoptosis and necrosis of cortical neurons seem to occur only after prolonged hydrocephalus.

Brain damage:-
Periventricular axons, myelin, microvessels are earlier affected parts. Secondary changes in neurons reflect responses to axonal disconnection, diminished cerebral blood flow and ischemia, and altered metabolism. Cerebrovascular injury mechanisms are prominent (e.g. hypoxia, ischemia, capillary damage), Gliosis and neuroinflammation play major roles in acute and chronic (subthreshold) injury. Altered efflux of extracellular fluid, slow CSF flow, and altered capillary transport mechanisms cause accumulation of toxins. Altered efflux of extracellular fluid, slow CSF flow, and altered capillary transport mechanisms cause accumulation of toxins.17

Diagnosis:-
CT can assess size of ventricles and other structures. MRI can find chiari malformation or cerebellar or periaqueductal tumors. It can differentiate normal pressure hydrocephalus from cerebral atrophy.18

MRI cine is MRI technique to measure CSF stroe volume in cerebral aqueduct.19

Diffusion tensor imaging is a novel imaging technique that detects differences in fractional anisotrophy (FA) and mean diffusity (MD) of brain parenchyma surrounding ventricles.20
Treatment:-

The surgical installation of shunt is treatment for hydrocephalus. This shunt system diverts flow of CSF from CNS to another part of body where it can be absorbed as part of normal circulatory process. Cerebral shunt can be of many types like shunt, catheter, valve.\(^{21}\)

There are different type of valves like delta\(^{22}\), medical pressure cylindrical\(^{22}\), nulsen and spitz\(^{23}\). All shunts have a valve system that regulate CSF pressure and prevents backward flow of fluid into ventricles. It opens automatically when the pressure exceeds a certain level and allows CSF to drain. The valve closes again when pressure reaches normal level.

Shunt has three basic components. 
Catheter:- (tube) which is inserted into brain ventricles 
Valve:-which regulates flow of spinal fluid. 
Long catheter that carries CSF from head to whatever CSF is diverted.

1. Ventriculo-peritoneal shunt:-

This procedure is done in the operating room under general anesthesia. It takes about 1 1/2 hours. The child's hair behind the ear is shaved off. A surgical cut in the shape of a horseshoe (U-shape) is made behind the ear. Another small surgical cut is made in the child's belly. A small hole is drilled in the skull. A small thin tube called a catheter is passed into a ventricle of the brain. Another catheter is placed under the skin behind the ear and moved down the neck and chest, and usually into the abdominal (peritoneal) cavity. Sometimes, it goes to the chest area. The doctor may make a small cut in the neck to help position the catheter. A valve (fluid pump) is placed underneath the skin behind the ear. The valve is attached to both catheters. When extra pressure builds up around the brain, the valve opens, and excess fluid drains out of it into the belly or chest area. This helps decrease intracranial pressure. The valves in newer shunts can be programmed to drain more or less fluid from the brain.\(^{24,25}\) 

Advantages:-
A large amount of tubing can be placed in abdomen to minimize the need for lengthening. It is short operation.\(^{26}\)

2. Ventriculo atrial shunt:-

This is a device which drains extra fluid in brain into right atrium of heart. A shunt catheter is placed into vein in neck and threaded down where vein joins larger vein called superior vena caca. This large vein returns blood to right atrium of heart. CSF is added to blood supply and is absorbed.\(^{27}\)

3. Ventriculopleural shunt:-

The chest cavity can be used as an alternative to abdominal cavity. Distal catheter is placed between lining of lungs called pleural cavity. It is not commonly used due to breathing difficulty.\(^{28}\)

Third ventriculostomy

Third ventriculostomy allows movement of CSF from a blocked ventricle to the subarachnoid space. The procedure involves making tiny holes in the floor of the third ventricle, allowing CSF to flow into the subarachnoid space. Third Ventriculostomy can eliminate the need for a shunt in some cases, though the procedure is not the appropriate solution in all cases.\(^{29}\)

Choroid plexectomy

This is a procedure in which a part of the choroid plexus is removed to reduce the amount of CSF being produced. This procedure is only performed in rare cases in which there is increased secretion from the choroid plexus.\(^{30}\)
Shunt malfunctions:-

Shunt failures can occur due to obstruction, disconnection, migration, fracture, ascites, abdominal pseudocyst, infections, constipation.

The risk factors for shunt infections include wound complications, leakage of CSF, surgery at very young age, pathogens like staphylococcus epidermis.2

Shunt blockade may be due to abnormal content of CSF, choroid plexus enveloping catheter, incorrect placement (catheter tip within brain parenchyma, extraperitoneal placement of distal catheter)

Symptoms of shunt failure:-

Headache, gait difficulties, lethargy, loss of cognitive ability, dementia, vision problems, impaired or slurred speech, difficulty in breathing, coma, persistent small grade fever >100°F if infection is more aggressive.

Treatment for shunt failure includes high doses of intravenous antibiotics to fight for infection. The shunt system should be removed in order to prevent further infections. EVD system is used in order to remove CSF.31

References:-


[31] www.littlemadisonrocks.com