Hydrocephalus

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Dr Qussay's notes + further explanations from Dr Walid's book

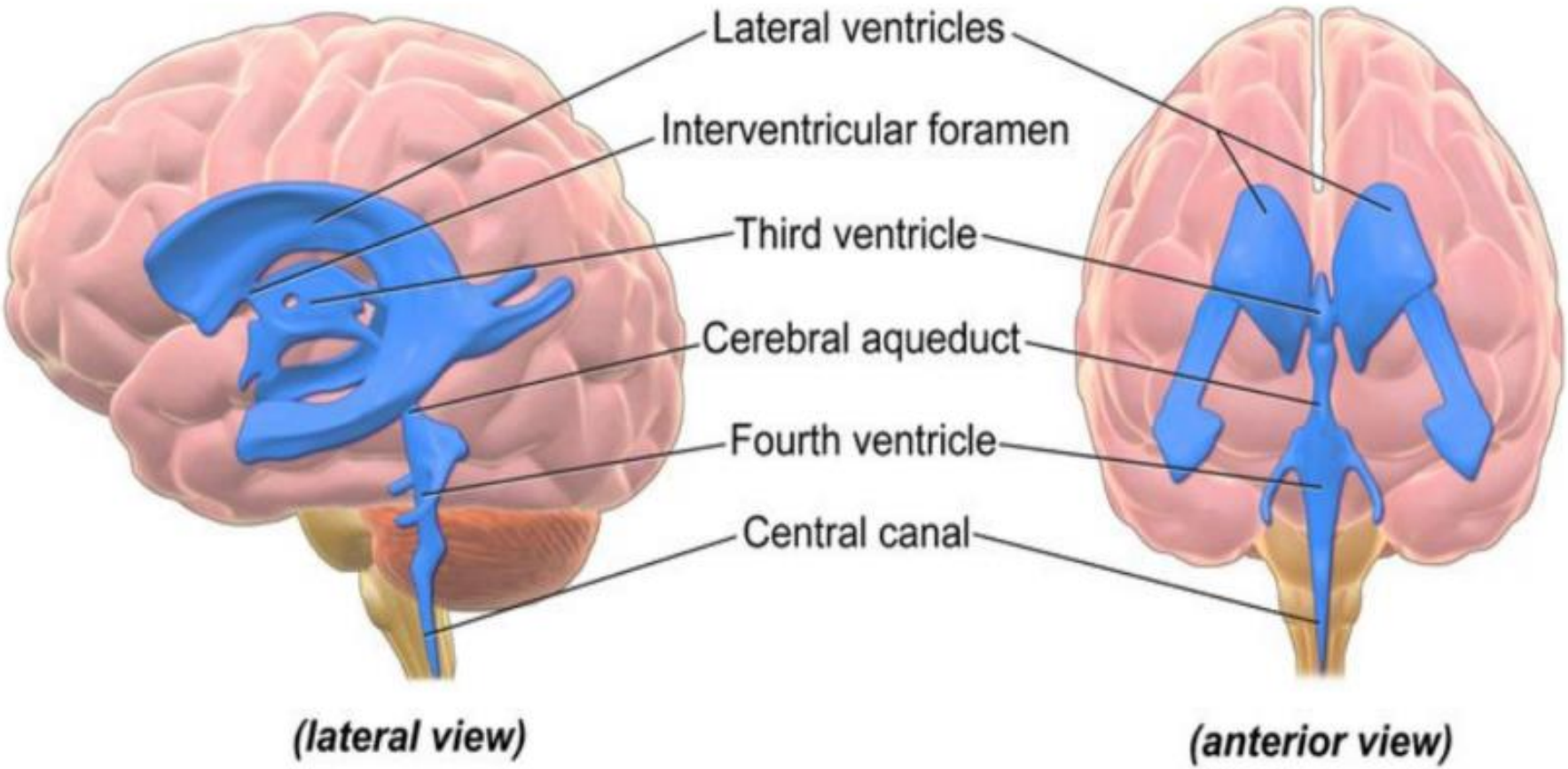
Outlines

- Definition
- Pathophysiology
- Etiology
- Types
- Clinical presentation
- Diagnosis
- Treatment

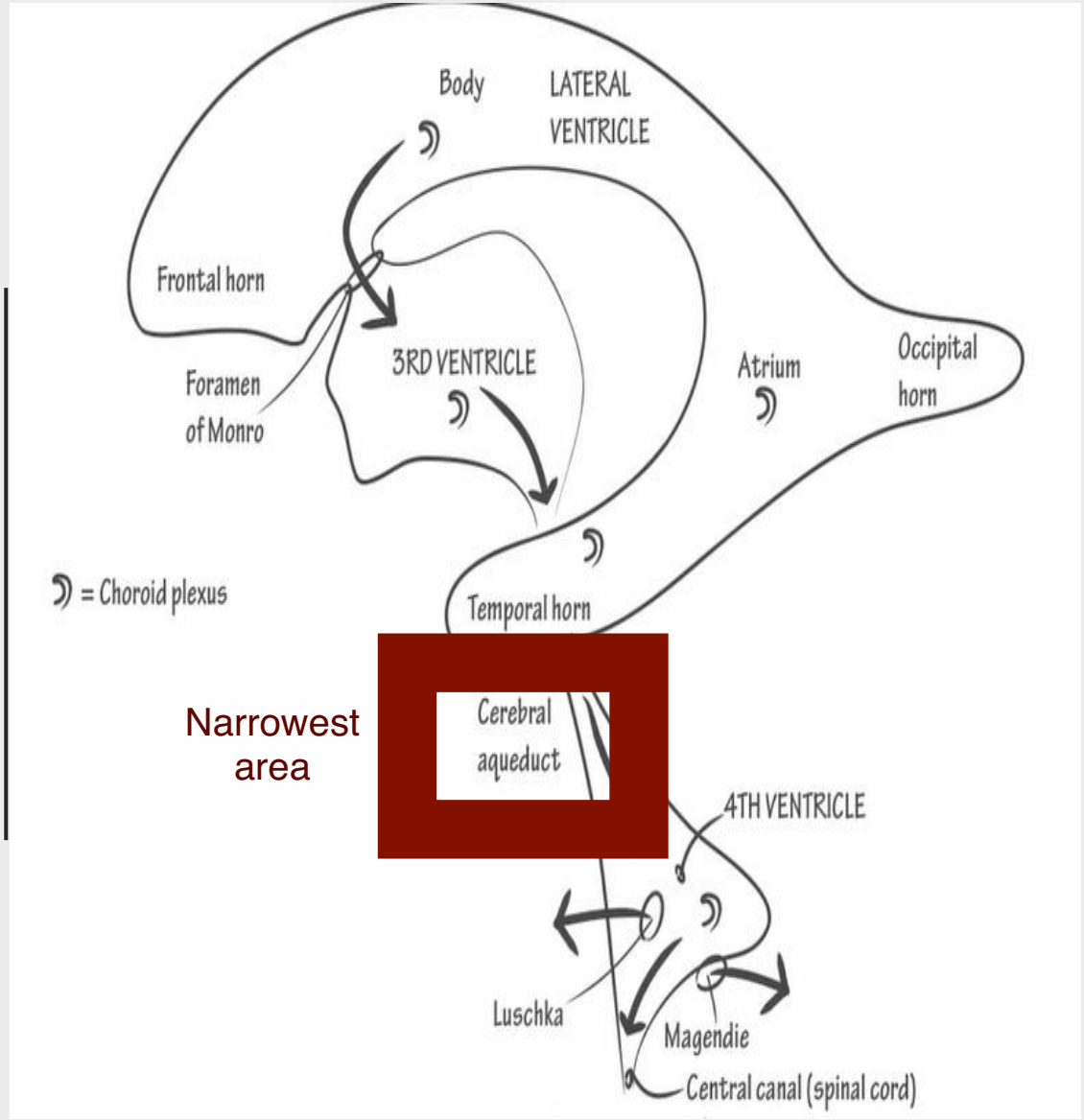
Hydrocephalus is a volume problem that is - in most of the cases - associated with a pressure problem

What is hydrocephalus?

- Is an accumulation of cerebrospinal fluid (CSF) within the ventricular space at an inappropriate pressure.
- Estimated prevalence is 1-105%
- Incidence of congenital cases is 0.9-1.8/1000 live birth.


Lateral ventricles
Interventricular foramen
Third ventricle
Cerebral aqueduct
Fourth ventricle
Central canal
(lateral view)
(anterior view)

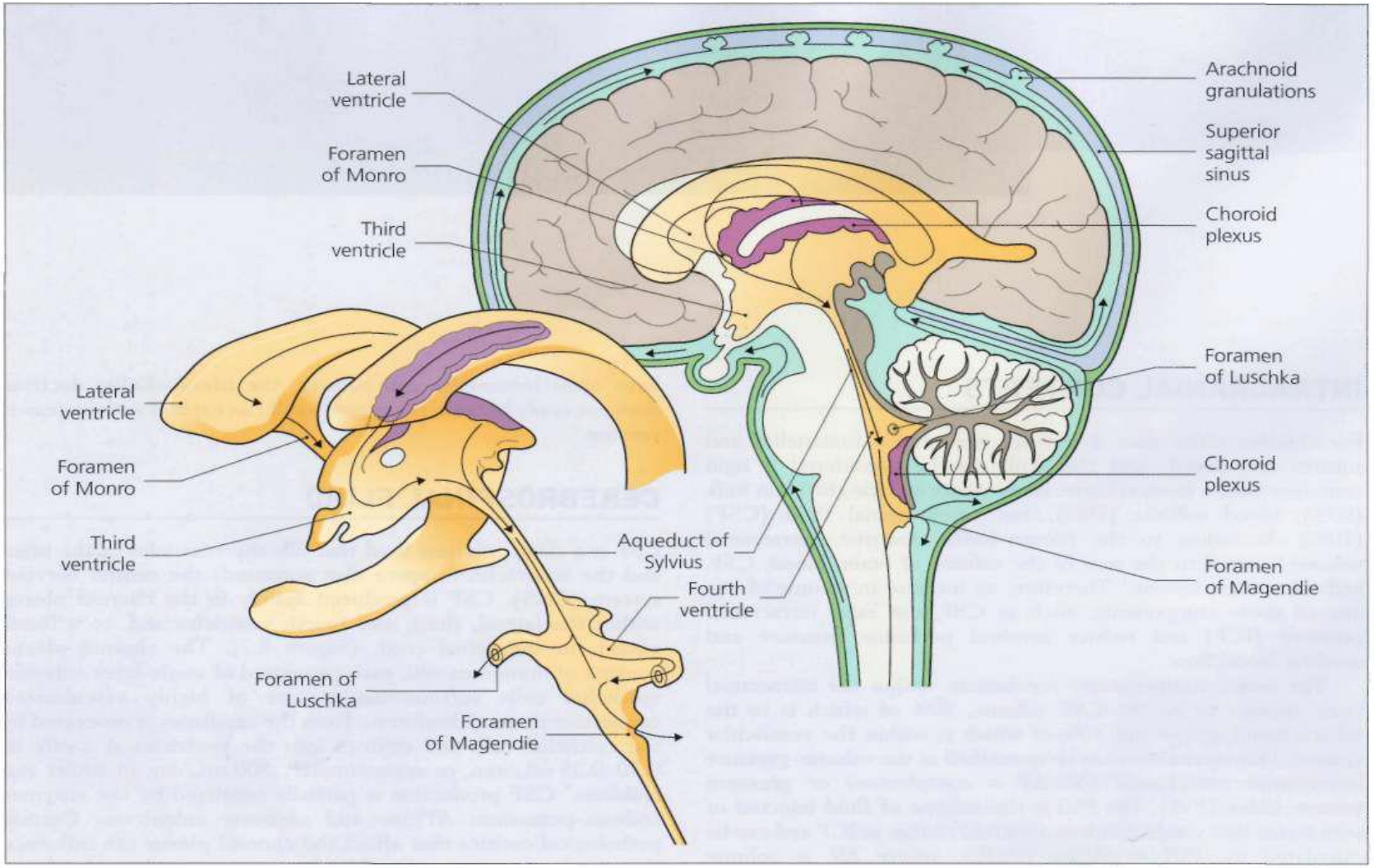
Physiology of CSF circulation



ANATOMY

The ventricular system is made of four ventricles; two lateral ventricles, situated one in each cerebral hemisphere, and a midline situated third ventricle. Each lateral ventricle is connected to the third ventricle by a foramen of Monro. The third ventricle has one exit to the aqueduct of Sylvius, which runs all the way through the brain stem until it opens into the roof of the fourth ventricle. The fourth ventricle is situated in the midline in the posterior fossa. It has a floor and three exits; one actual foramen in the midline posteriorly called the foramen of Magendie and two lateral meshes of openings termed loosely as the foramina of Luschka [7-9].

The ventricular system



The cerebrospinal fluid (CSF)production

- CSF is produced mainly in the choroid plexus.
- The choroid plexus=single-layer cuboidal epithelial cells surrounding a core of highly vascularized connective tissue.
- Rate o: 0.30-0.35 mL/min, or approximately 500 ml/day, in adults and children.
- CSF production is partially regulated by :

-sodium-potassium ATPase …and

- carbonic anhydrase.

PHYSIOLOGY

The CSF is produced by the choroid plexus, which is located mostly in the lateral ventricle, and in the 4th ventricle. A small amount is produced by the ependymal lining of the ventricles themselves, and still some of the CSF in the spinal theca is produced by the dura of the nerve root sleeves.

What is cerebrospinal fluid(CSF)?

- Clear colorless fluid
- Total volume: 150mls(40-50 mL in neonates and 65-140 mL in children).
- 25mls in ventricles + 125mls in subarach.space
- Production: 500mls/day and turnover: 3-4 times
- **Contents:**

1.Acellular (<5 lymphocytes, if higher: Pleocytosis)

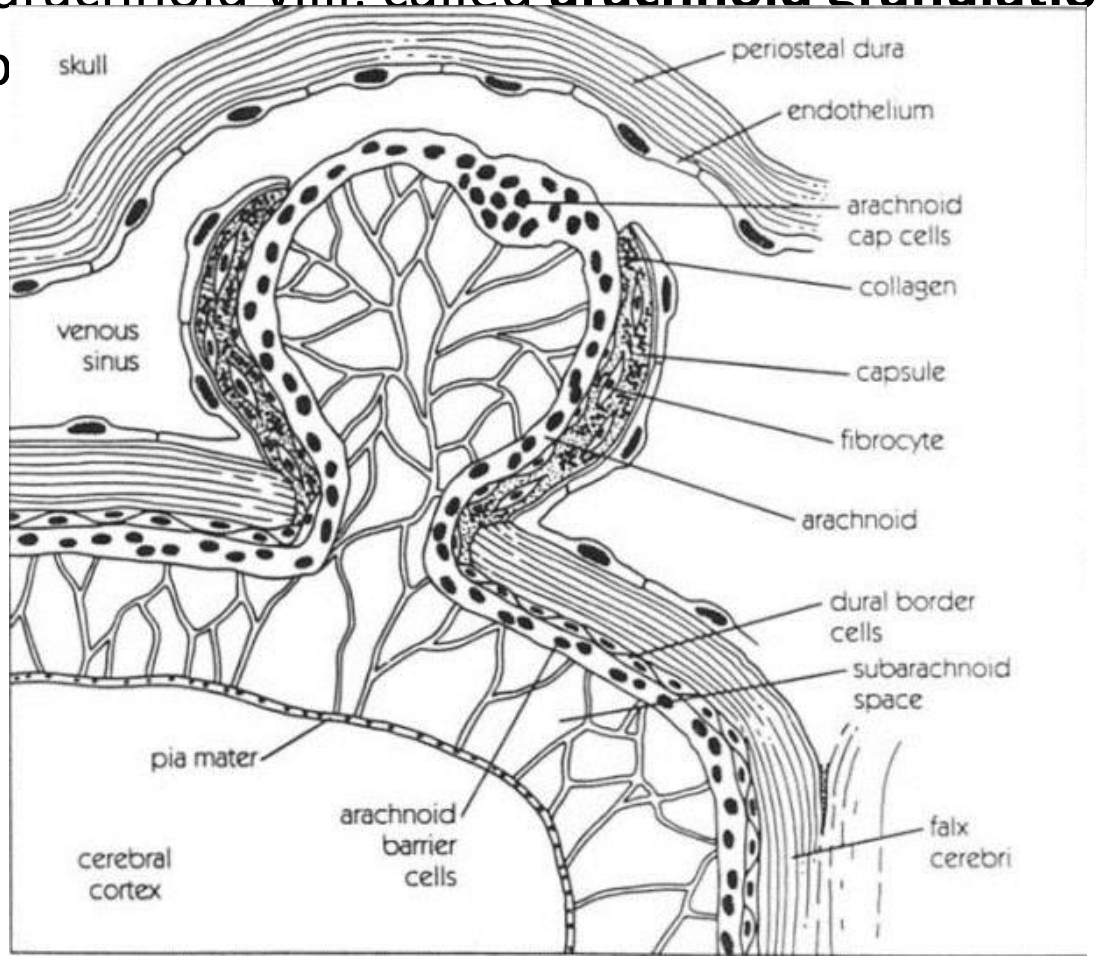
2. Similar Na+/ higher Cl-/ less K+ compared to plasma

3. ≈15-40mg/dl of proteins depending on site/age

4. 2/3 of sugar concentration in plasma

CSF is absorbed by ***arachnoid villi***, which are diverticula of arachnoid that invaginate within the sagittal sinus and nearby major cortical veins.

Clusters of arachnoid villi, called **arachnoid granulations**, are grossly visib



Driven by pressure gradient CSF (=ICP) to the SSS (negative pressure)

Once the CSF exits the fourth foramen it enters the subarachnoid space (SAS), circulates around the whole brain surface to gain access to the arachnoid granulations where it is absorbed into the superior sagittal sinus (SSS). Some CSF enters the spinal theca and circulates

around the spinal cord. Still a smaller amount enters the central canal of the spinal cord itself.

CSF is a clear colorless fluid, which can be obtained most commonly via a lumbar spinal tap, but can be obtained directly from the ventricle via a burr hole in adults or a tap into the lateral ventricle in infants, or by a tap into the cisterna magna at the junction of the posterior cranial fossa and the spinal cord [9].

IN GENERAL CSF WILL ACCUMULATE(**HYDROCEPHALUS**) DUE TO:

- ✓ Increase production
- ✓ Decrease absorption
- ✓ Obstruction to flow

Areas devoid of choroid plexus :

1. Cerebral aqueduct
2. Frontal horn of the lateral ventricle

The over production of CSF is a rare condition in which the benign tumor of papilloma of the choroid plexus produces large amounts of CSF resulting in dilatation of the ventricular system. Excising the papilloma usually treats the condition [7-9, 61, 62].

Obstruction within the ventricular system could result from:

1. Congenital causes:
    a. Usually in the area of the aqueduct of Sylvius as in the cases of aqueduct stenosis due to gliosis or forking, or
    b. In the area of the exits of the 4th ventricle, as in atresia of the foramina, called (Dandy - Walker malformation).
    c. Chiari type1 and Chiari type 2 malformations.
2. Non-congenital causes:
    a. Masses, as in colloid cyst of the 3rd. ventricle, or medulloblastoma in the posterior fossa.
    b. Arteriovenous malformations.

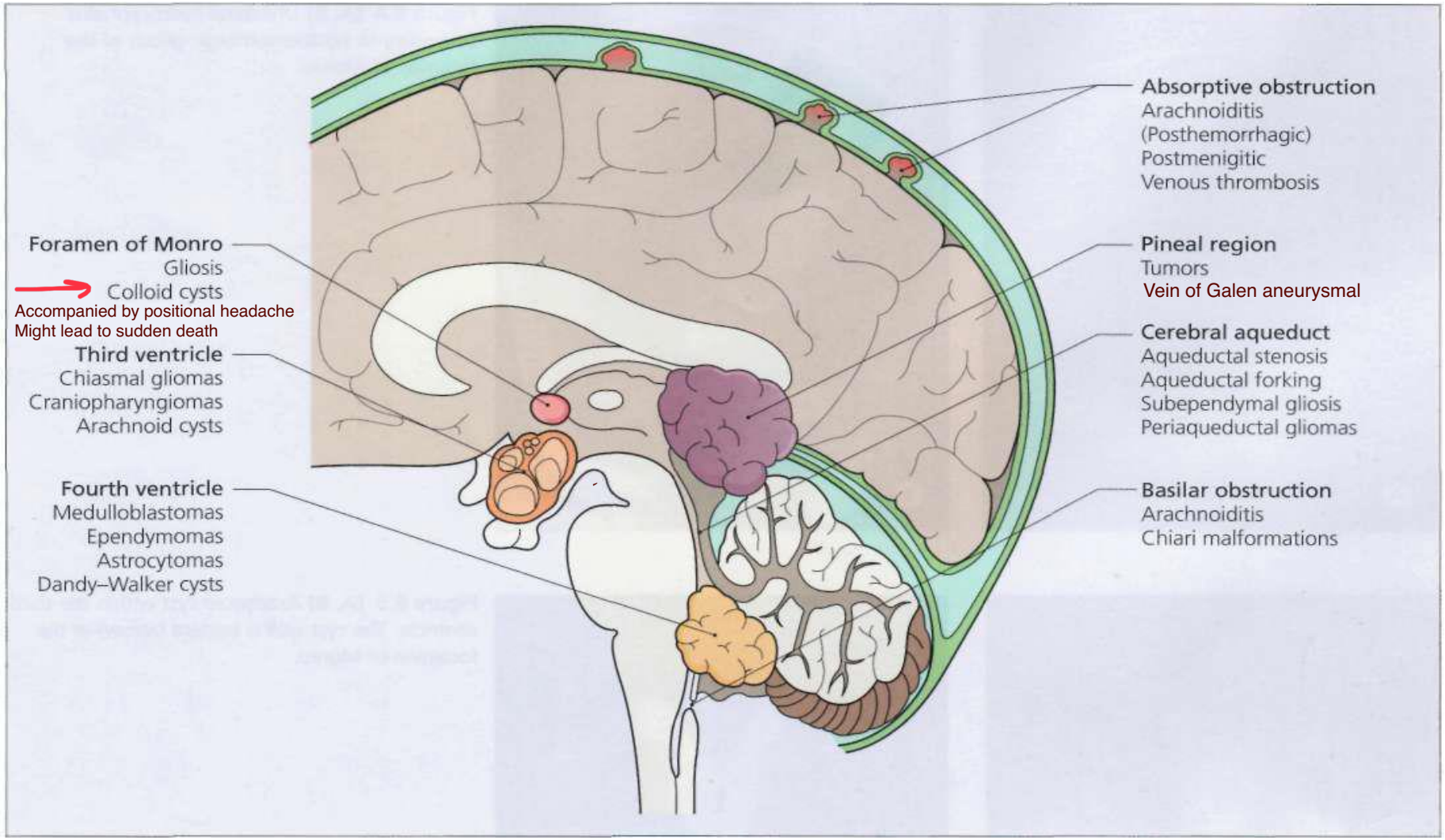
Diminished absorption may result from:

1. Fibrinous deposits due to meningitis.
2. Fibrinous deposits due to subarachnoid hemorrhage (SAH).

CAUSES OF HYDROCEPHALUS:

- Hydrocephalus is often associated with dilatation of the ventricular system and increased ICP.
- Hydrocephalus is almost always a result of an interruption of CSF flow and is rarely because of increased CSF production.
- Common obstruction sites and etiologies are displayed in the next Figure.

Common sites and causes of CSF obstruction. Midsagittal cut



PATHOPHYSIOLOGY OF HYDROCEPHALUS

- As ICP rises, CSF absorption increases somewhat, but CSFproduction remains constant.
- If progressive ventricular dilatation separates ependymal cells lining the ventricles, interstitial cerebral edema will develop.
- The CSF will eventually enter the white matter of the brain via bulk flow through the ependymal cells lining the ventricles.

Normal ICP by age

Age	ICP range (mmHg)
Neonate	< 2
Infant	1.5–6
Young child	3–7
Adolescent (> 15 years)	< 15 Cut-off point
Adult	< 15

(Modified from Greenberg, 2001.[70])

CLASSIFICATIONS

Differences:
1-LP can be done in communicating but not in noncommunicating
2- Endoscopic ventriculostomy can be done in noncommunicating but not in communicating

- A commonly used classification differentiates hydrocephalus between ***communicating*** *or* ***noncommunicating.***
- Its symptomatology as either **compensated** or ***noncompensated.***
- Its chronicity: ***acute versus chronic*** hydrocephalus.
- **Congenital** versus **acquired**.
- ***Internal*** *or* ***external***

TYPES OF HYDROCEPHALUS

Irrespective of the cause, there are usually two types:

Communicating hydrocephalus, when the problem lies at the level of the arachnoid granulation, and the ventricular system and its exits are free from obstructing agent. Here all the four chambers of the ventricular system are dilated and communicate with each other.

Non-communicating; when there is an obstruction within the ventricular system or at its exits into the subarachnoid space (Figure 67). Here the dilatation occurs only proximal to the site of obstruction, the rest of the ventricular system remains normal.

To differentiate between both types on a CT or MRI, one has to look at the 4^{th} ventricle which is dilated in the communicating type and normal or even smaller in the non-communicating type.

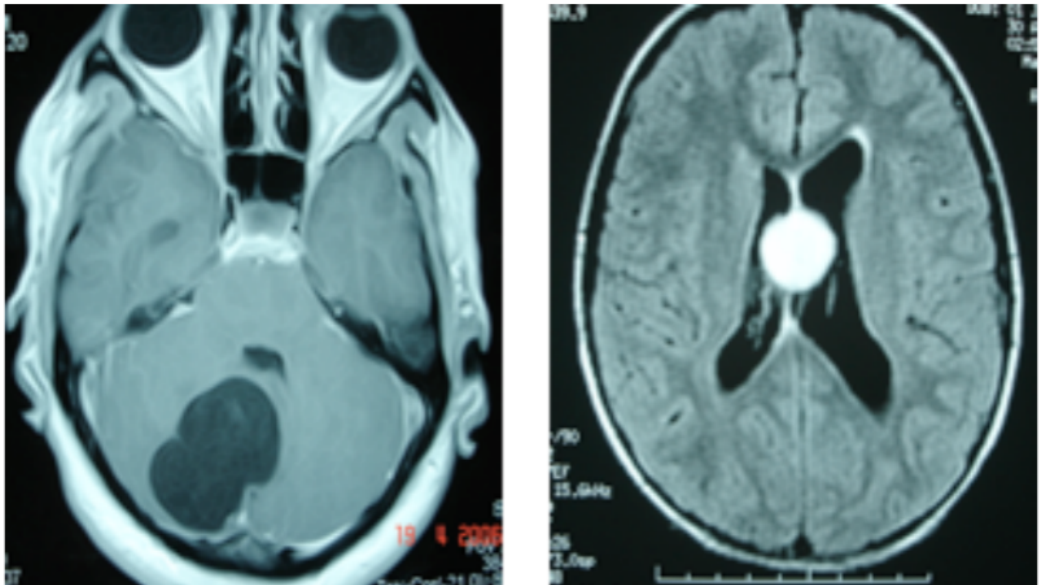


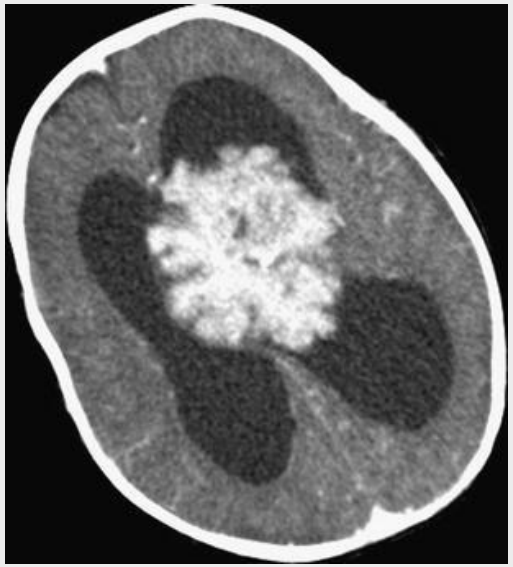
Figure (67) Tumors obstructing the 4th and 3rd ventricles leading to non-communicating hydrocephalus

AETIOLOGY - SITE

1. Lateral ventricles

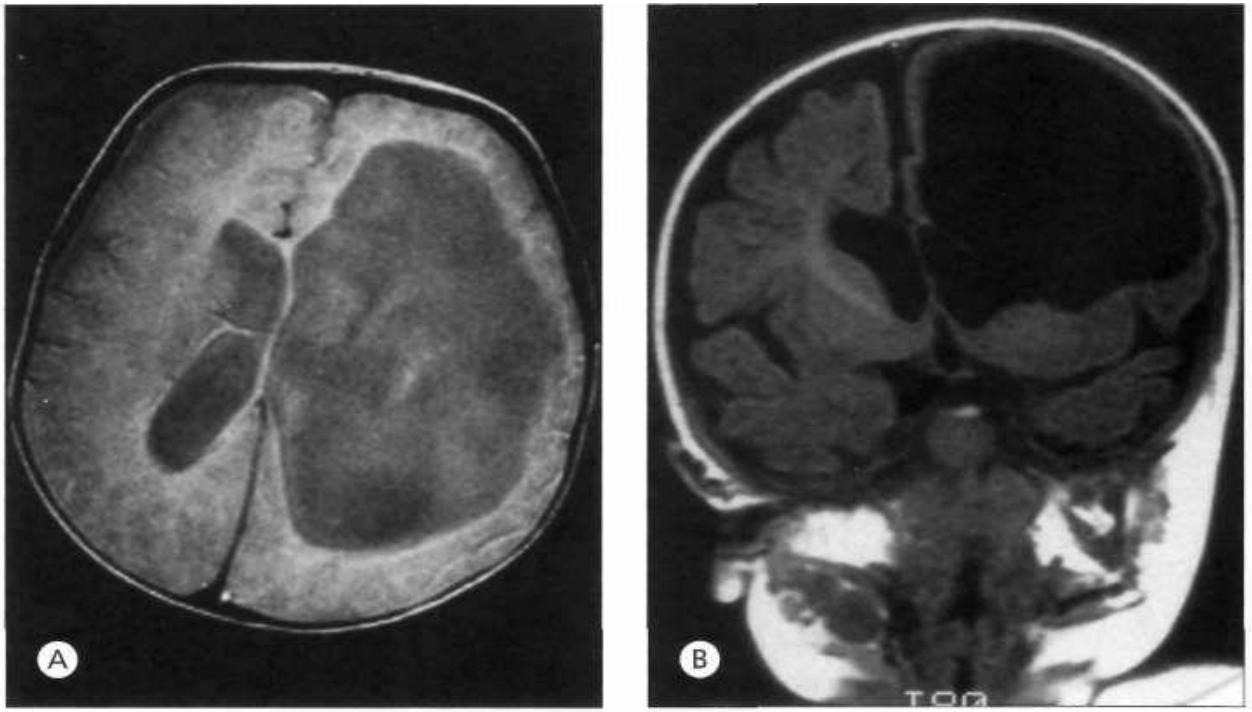
<u>Choroid plexus tumors:</u>

- Rare in the general population(0.4 to 0.6% of all CNS tumors).
- With CSF production rates three to four times the normal.
- Endoscopic coagulation of the choroid plexus or surgical removal of the papilloma .

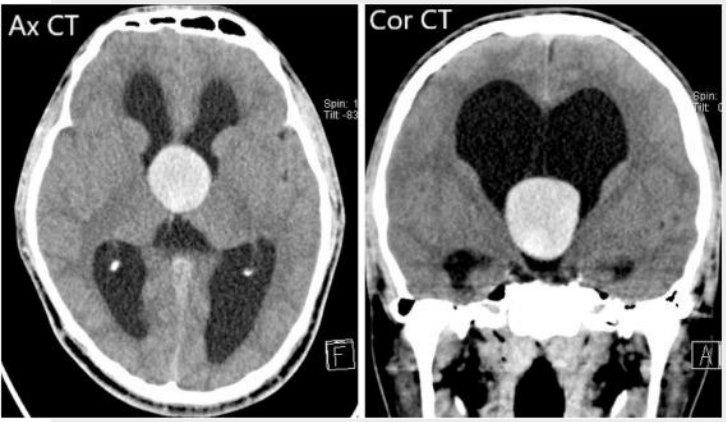


2-Foramina of Monro

- Occlusion of one foramen of Monro can occur secondary to a congenital membrane, atresia, or gliosis after intraventricular hemorrhage (IVH) or ventriculitis.



3-Third ventricle



Cysts and neoplasms within the third ventricle commonly cause hydrocephalus.

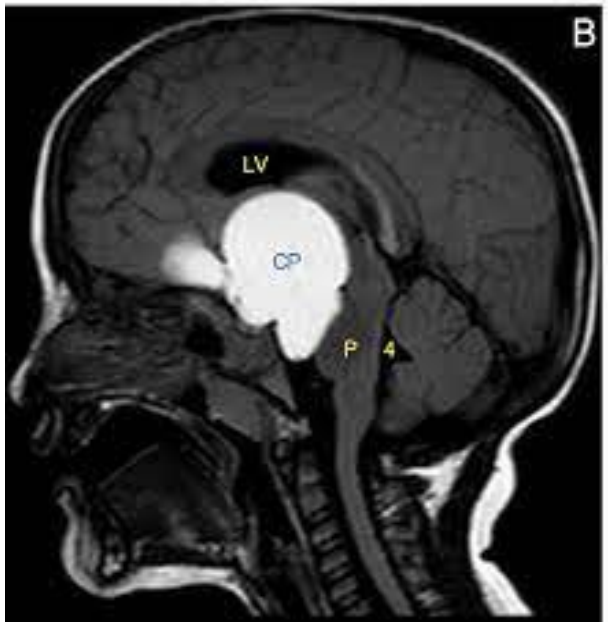
-Colloid cysts are uncommon neoplasms that present superiorly and anteriorly within the third ventricle,

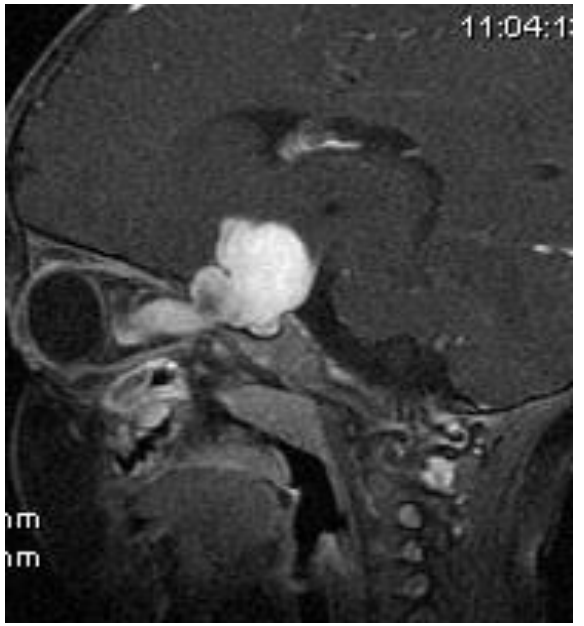
-**Ependymal and arachnoid cysts** within the third ventricle usually present with hydrocephalus in late childhood .Patients may present with bobble-head doll syndrome, a rhythmic head nodding at a frequency of two to three times per second.

The endoscopic fenestration is a treatment option.

Third ventricle

- The most common pediatric neoplasms that obstruct the third ventricle are **craniopharyngiomas** and **chiasmal-hypothalamic gliomas**.



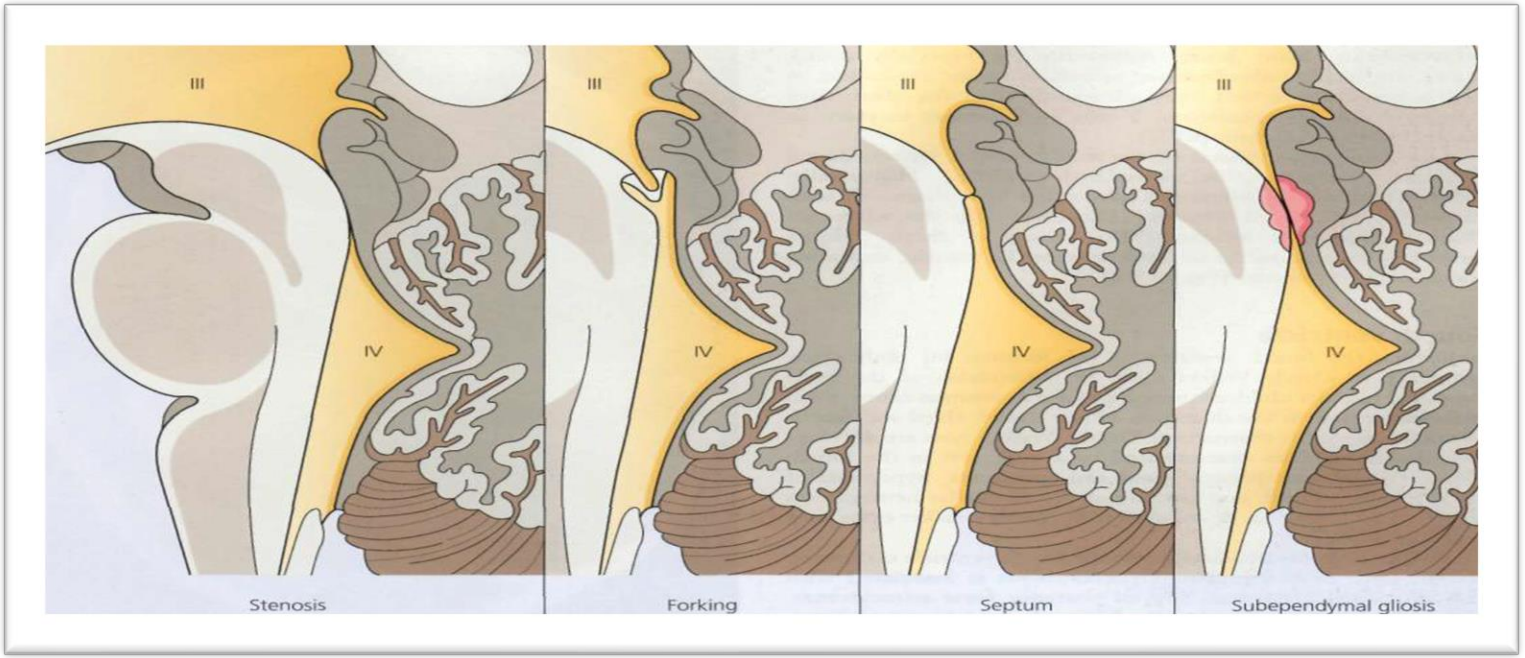


4-Sylvian aqueduct

The normal aqueduct of a neonate is 12-13 mm in length and only 0.2-0.5 cm in diameter,

Thus, it is prone to obstruction from a variety of lesions, including **congenital aqueductal stenosis**(classified as true stenosis, forking, septum, or subependymal gliosis)

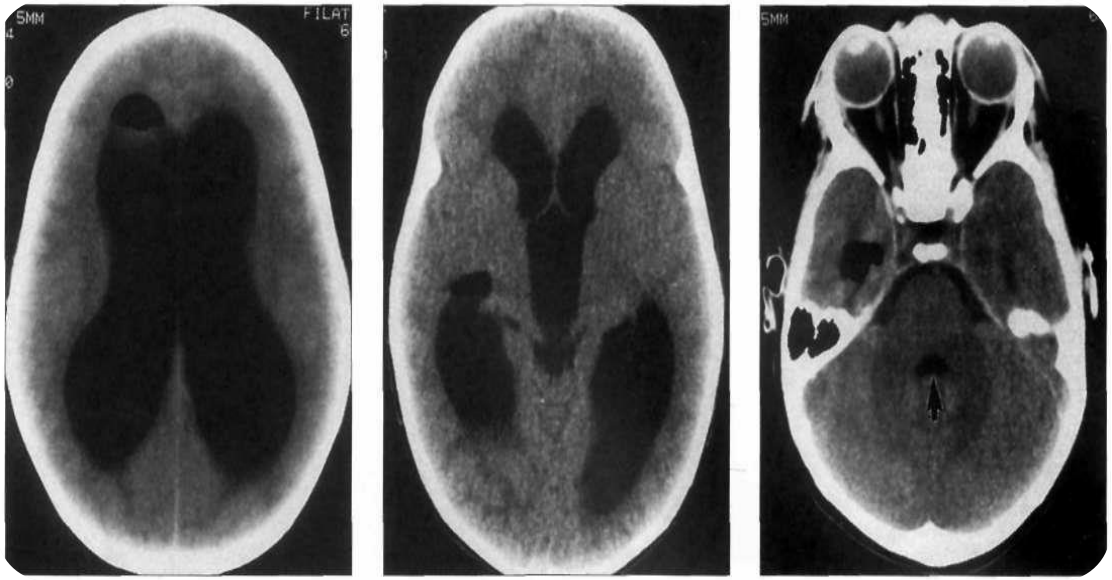
It may be secondary to *in utero infections (e.g. toxoplasmosis), intraventricular* hemorrhage, or mumps encephalitis.



Aqueductal congenital malformations: (from left to right) stenosis, forking, septum, and subependymal gliosis.

Sylvian aqueductai stenosis

- Is the commonest cause of congenital hydrocephalus
- Less than 2% of cases -recessively inherited X-linked Bickers-Adams-Edwards syndrome, which is associated with flexion-adduction of the thumbs ("cortical thumbs").



CT scan of infant with aqueductal stenosis, demonstrating lateral and third ventricular distension, separation of the thalami, and compression of the cerebral hemispheres . The fourth ventricle (arrow) is normal.

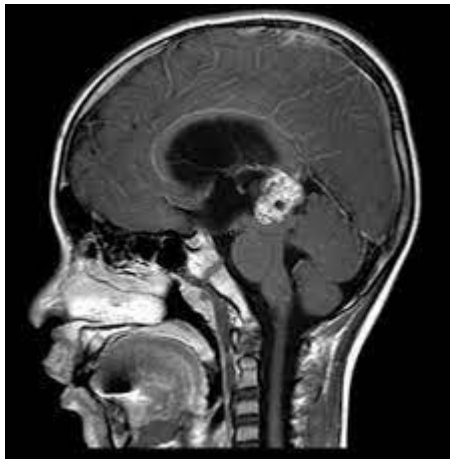
Sylvain aqueduct

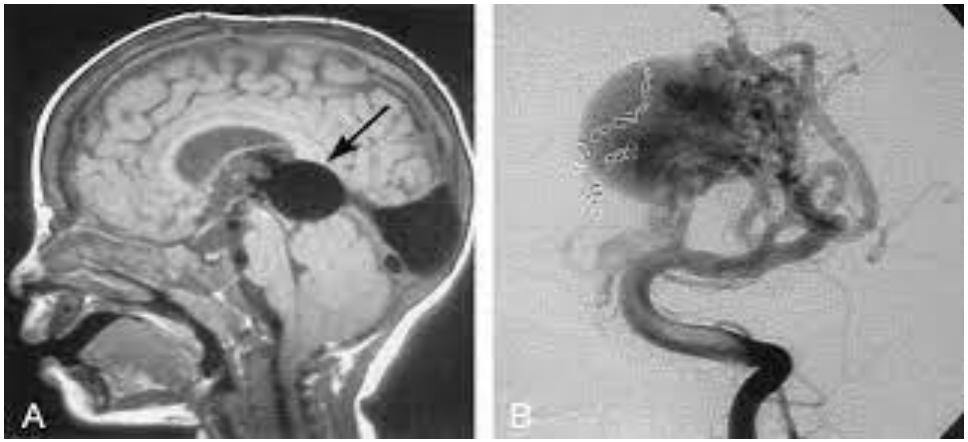
Pineal region neoplasms,

Arteriovenous malformations, and Periaqueductal neoplasms.

Any pineal mass can obstruct the aqueduct and produce hydrocephalus. Many pineal region tumors, especially germinomas, are highly radiosensitive; successful tumor irradiation, as well as surgical resection, may adequately treat the obstructive hydrocephalus.

Low-grade astrocytomas are the most common periaqueductal pediatric neoplasms that cause hydrocephalus.





4-Fourth ventricle

In infants, the fourth ventricle is the location for obstruction secondary to Dandy-Walker cysts or obliteration of the basal foramina.

In older children, neoplasms are a common cause.

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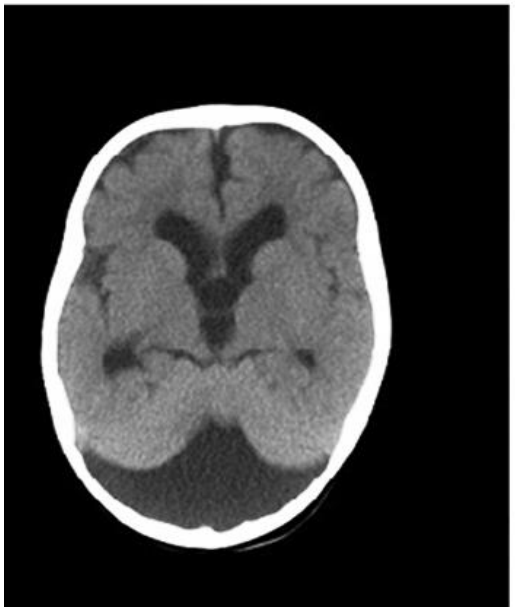
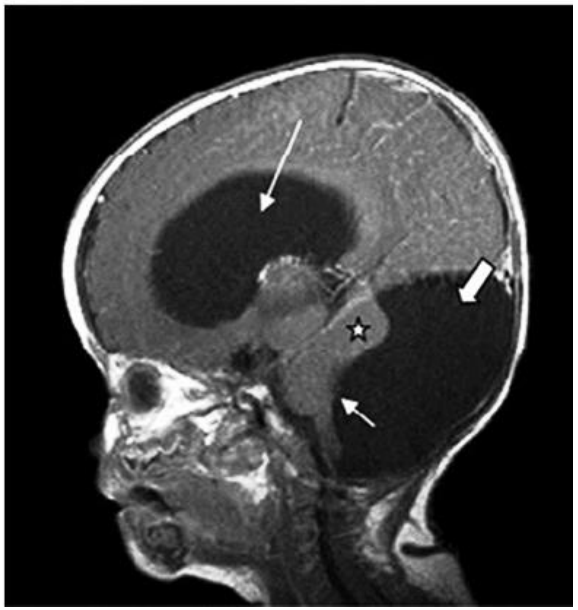
Dandy-Walker cysts are developmental abnormalities characterized by a large cyst in the fourth ventricle, hypoplasia of the cerebellar vermis, and atrophy of the cerebellar hemispheres.

Over 85% of children with Dandy-Walker cysts have hydrocephalus.





4TH Ventricle tumors

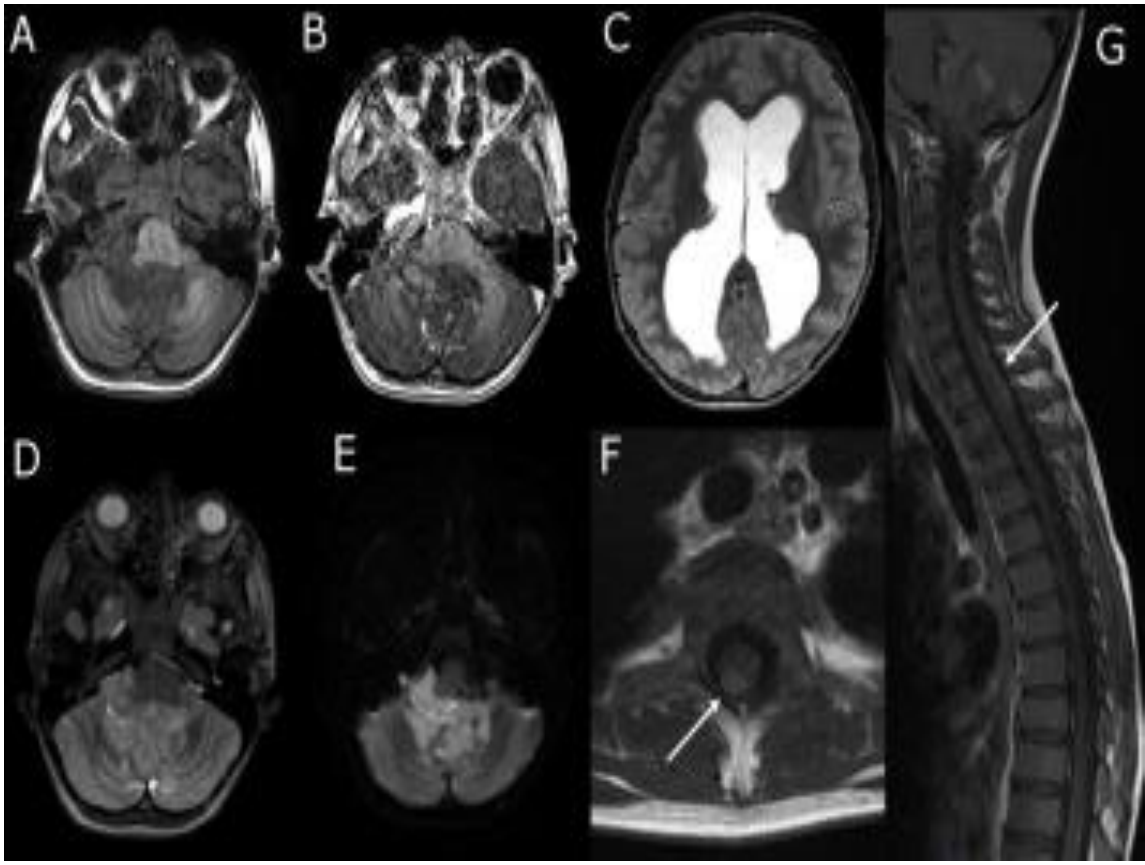
Hydrocephalus is associated with

85% of **medulloblastomas,**

65% of posterior fossa **astrocytomas,** Pilocytic astrocytoma

75% of **ependymomas**,

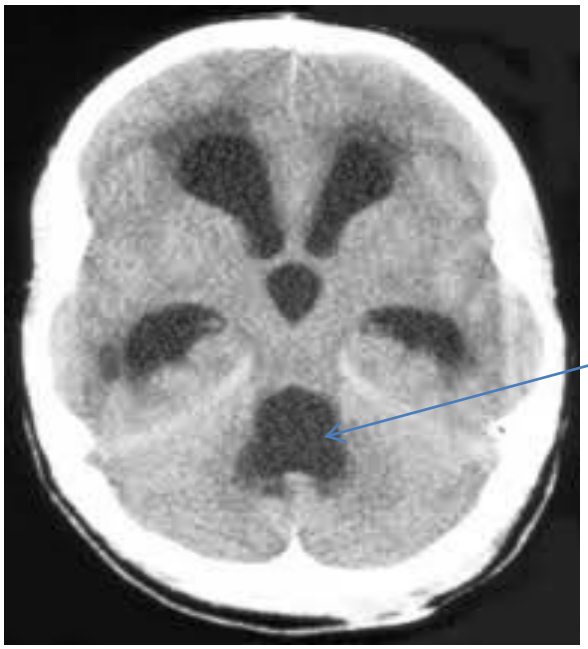
and 25% of **brainstem gliomas**.



5-Arachnoid granulations

Sclerosis or scarring of the arachnoid granulations can occur after **meningitis, subarachnoid hemorrhage, or trauma**.

Occasionally can be seen in cases with disseminated meningeal malignancies**(meningeal carcinomatosis)**



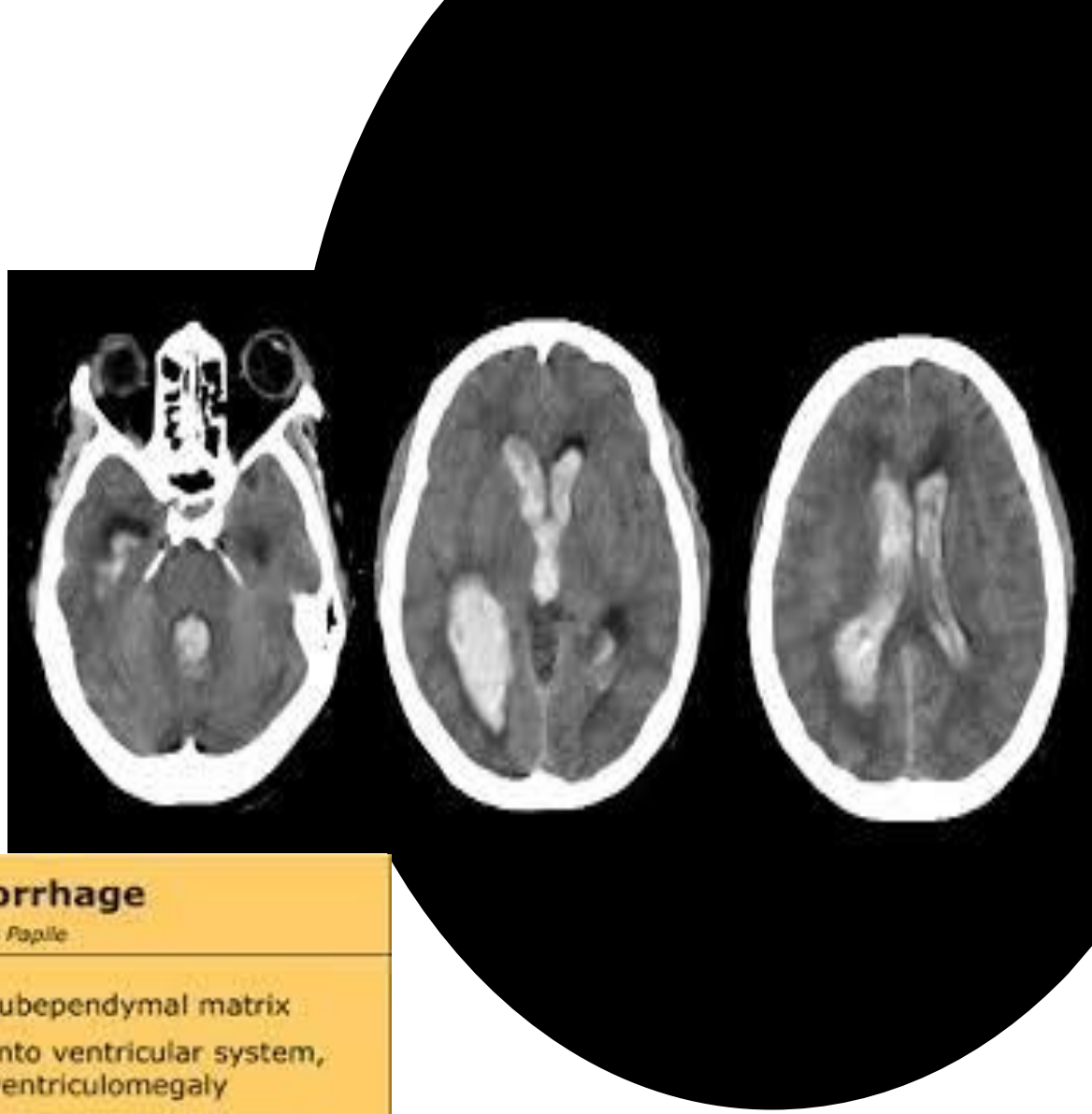
Dilated fourth ventricle

Etiology by age

Premature infants

Hydrocephalus in premature infants is predominantly caused by(intraventricular hemorrhage) IVH. The hemorrhage occurs in the germinal matrix,

Following the resorption of hemorrhage 25% develop hydrocephalus



Intracranial hemorrhage

Classification according to Papile

Grade 1.	Hemorrhage limited to subependymal matrix
Grade 2.	Hemorrhage extending into ventricular system, < 50%, without acute ventriculomegaly
Grade 3.	Hemorrhage extending into ventricular system, with acute dilatation because of flooding of 50% or more of one or both lateral ventricles
Grade 4.	Hemorrhage grade 1, 2 or 3 with extension into brain tissue

Etiology by age

- **Full-term infants**

The common causes of hydrocephalus in full-term infants include

- **Aqueductal stenosis**,
- Chiari II malformation,
- Dandy-Walker syndrome,
- Cerebral malformations (e.g. encephaloceles, holoprosencephaly, and hydranencephaly), arachnoid cysts,
- Neoplasms,

and

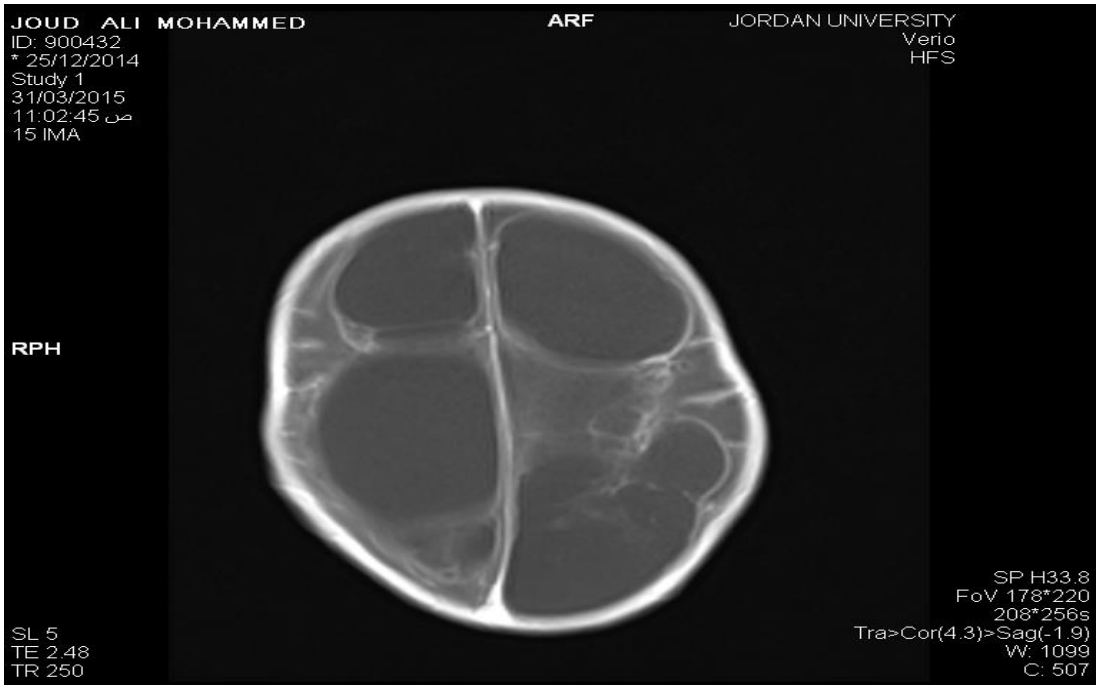
- Vein of Galen malformations.

FULL TERM INFANT

- Aqueduct stenosis
- Chiari malformation
- Dandy walker malformation
- Cerebral malformation ..Encephalocele
- Neoplasm
- Vein of Galen aneurysm

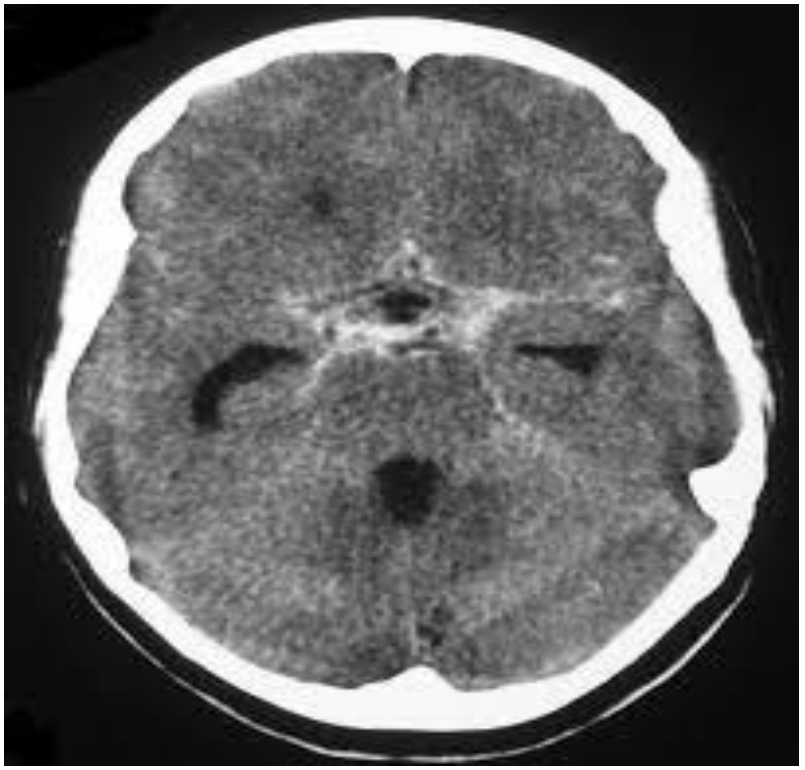
Older children

Hydrocephalus after infancy is usually secondary to trauma, meningitis or neoplasms.



Adults

- 30% idiopathic
- The rest :
  - Subarachnoid hemorrhage
  - Head injury
  - Brain tumors
  - Cranial surgery
  - Aqueduct stenosis
  - Meningitis



SIGNS AND SYMPTOMS

Premature infants	Infants	Toddlers and older
Apnea	Irritability	Headache
Bradycardia	Vomiting	Vomiting
Tense fontanelle	Drowsiness	Lethargy
Distended scalp veins	Macrocephaly	Diplopia
Globoid head shape	Distended scalp veins	Papilledema
Rapid head growth	Frontal bossing Macewen's sign Poor head control Lateral rectus palsy "Setting-sun" sign	Lateral rectus palsy Hyperreflexia/clonus

Full and tense anterior fonatanelle

Dilated scalp veins

Suture widening

Compromised vertical gaze center

Most important Setting sun eyes

3 commonest causes of large head in infants:

1- hydrocephalus

2- chronic subdural hematoma

3- congenital tumors

CLINICAL PRESENTATION

This usually depends on the age of the patient. Children with open skull sutures present differently from older children with closed sutures or from adults. However, and irrespective of age, the presenting signs and symptoms are due to increased intracranial pressure (ICP) and its effects.

1. Presentation in children before suture closure (Figure 68):

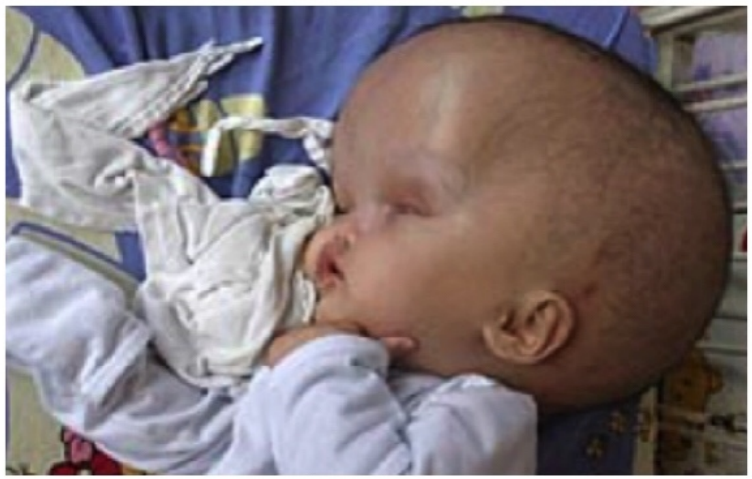


Figure (68): Congenital hydrocephalus

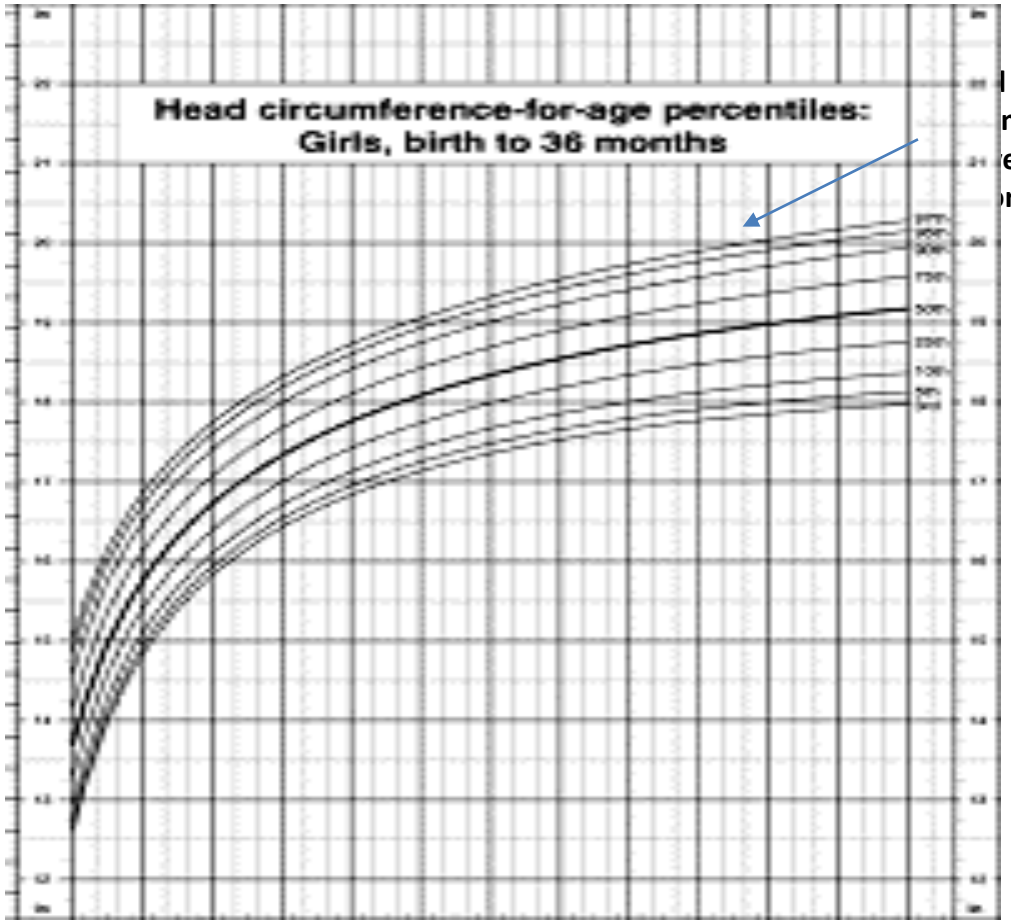
   a. Enlargement of the head, as evidenced by increase in its circumference. Knowledge of the head circumference (HC) at different ages is important in diagnosis. Charts for HC and other parameters are available for both sexes. However, the HC at birth is 35, 36, 37 centimeters for 50^{th}, 75^{th} and 90^{th} percentile lines respectively.

b. Wide, tense bulging fontanel.
c. Shiny stretched scalp.
d. Dilated scalp veins.
e. Frontal bossing
f. Abnormal face to head ratio (Ape face)
g. Limitation of upward gaze (sunset appearance).

2. Presentation in adults and in children after suture closure:
    1. Signs and symptoms of increased ICP (headache, vomiting and visual manifestations).
    2. Signs and symptoms of the causative disease (meningitis, SAH, etc.).
    3. Signs and symptoms of ventricular enlargement (memory problems, difficulty walking and urinary disturbance).

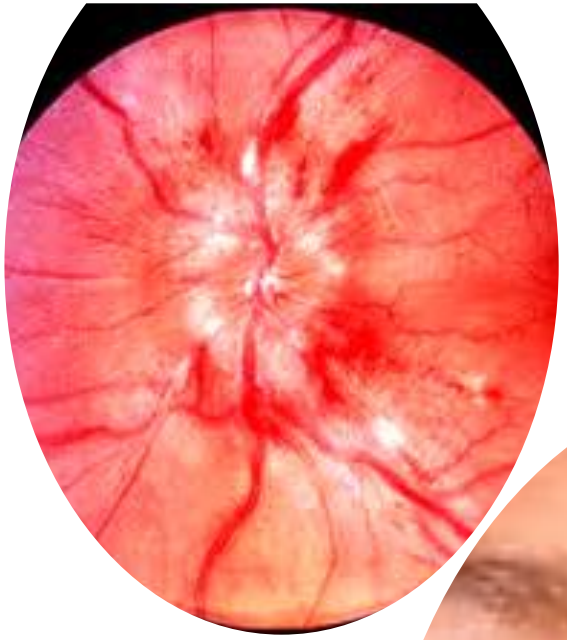
Head circumference

- Normal head circumference for full-term infants is **33-36 cm**at birth.
- Head circumference increases by 2 cm/month during the first 3 months, by 1 cm/month from 4 to 6 months, and by 0.5 cm/month from 7 to 12 months.

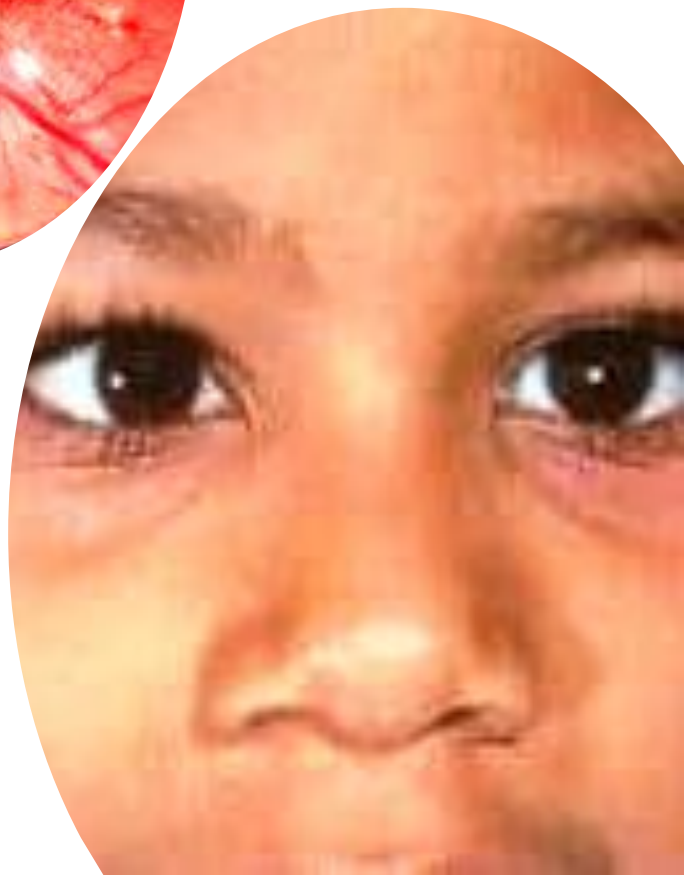


Signs of hydrocephalus in children and adults

- **Fudoscopic examination showing advanced optic disc swelling suggestive of frank papilloedema resulting from intracranial hypertension**



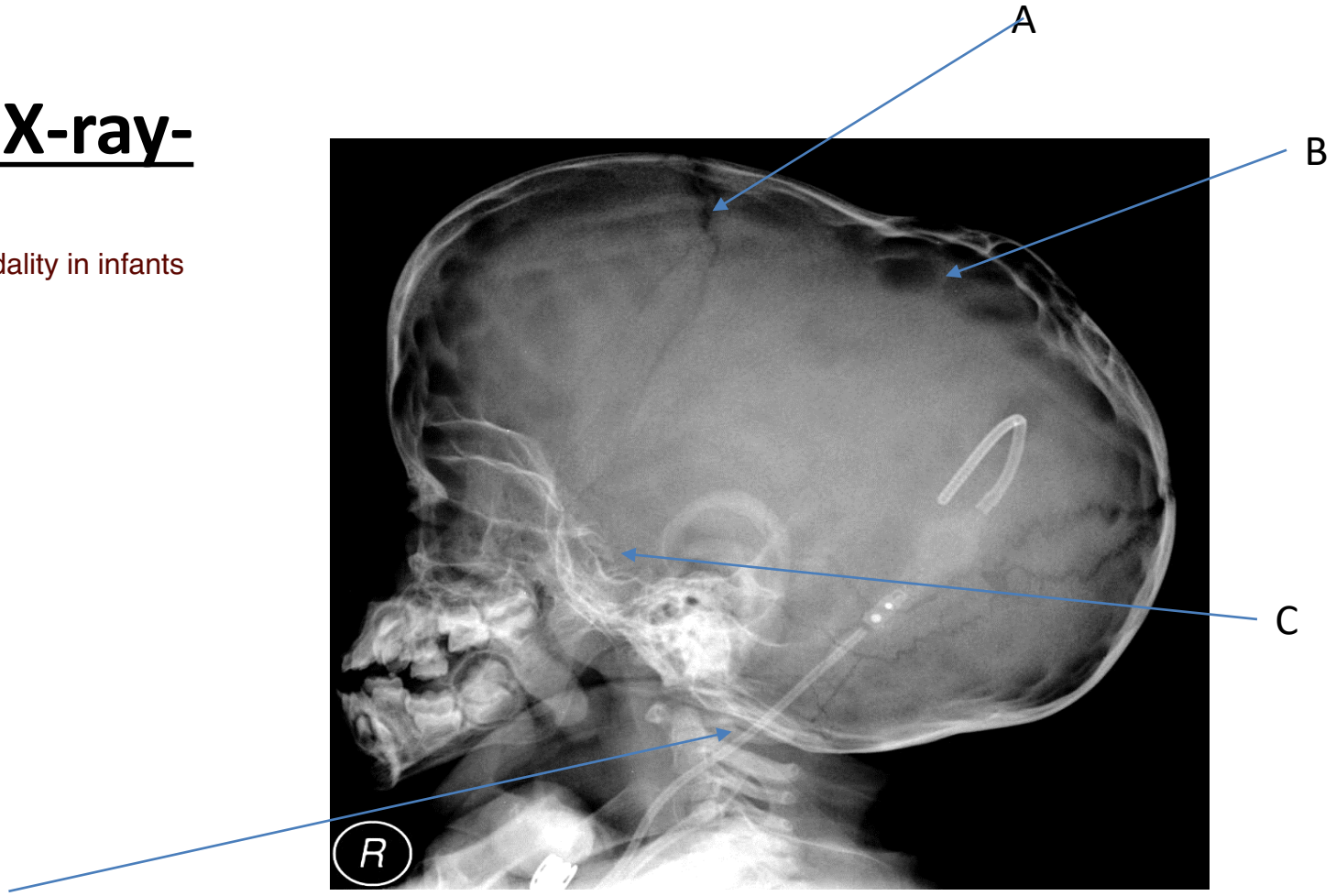
Right abducent nerve palsy



DIAGNOSTIC STUDIES

- **Skull X-ray-**

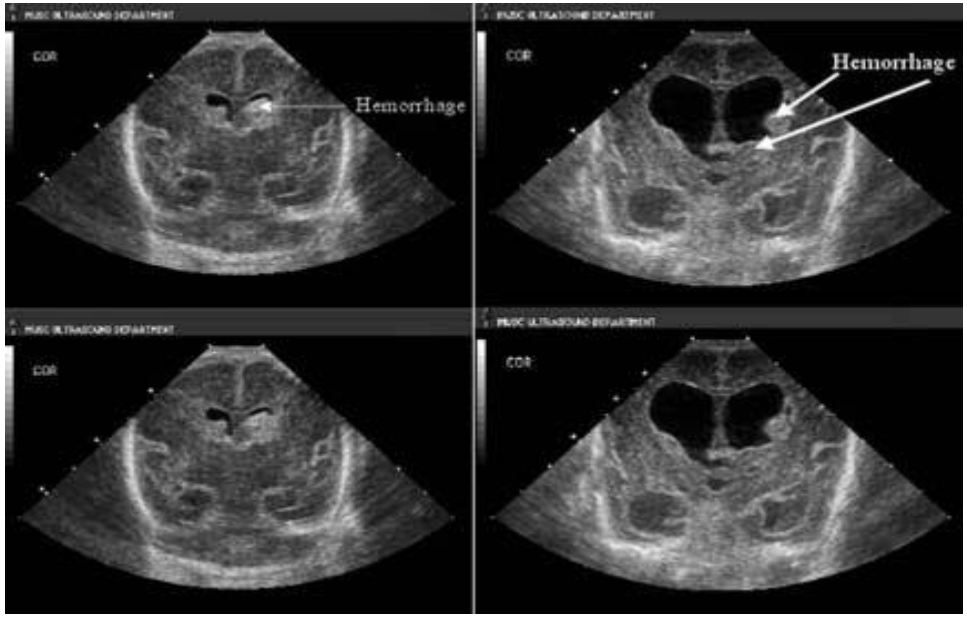
The preferred modality in infants



Cranial ultrasonography

- is particularly useful in the evaluation of premature infants with IVH, as well as the detection and monitoring

  ofventricular size.



CT scanning

- From 1976 to 1986, CT scanning was the definitive method of diagnosing pediatric hydrocephalus.
- limitations: only in the **axial plane**,

Require **irradiation,** and have **less resolution** than MRI.

IMAGING

Computerized tomography (CT) or magnetic resonance (MRI) is the mainstay of diagnosis. Either will reveal the presence of the hydrocephalus itself (Figure 69), and may reveal the cause in a large percentage of cases especially when there is obstruction by a mass, or a congenital anomaly. One has to take care in using CT in children due to the untoward effects of radiation on their developing brain [63], in these cases ultrasound could be used, but requires experience.

Especially when < 6 months y.o

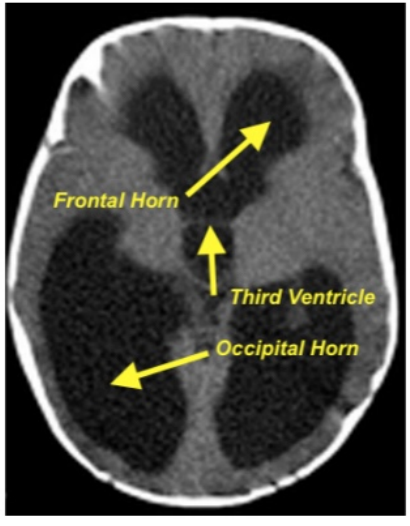
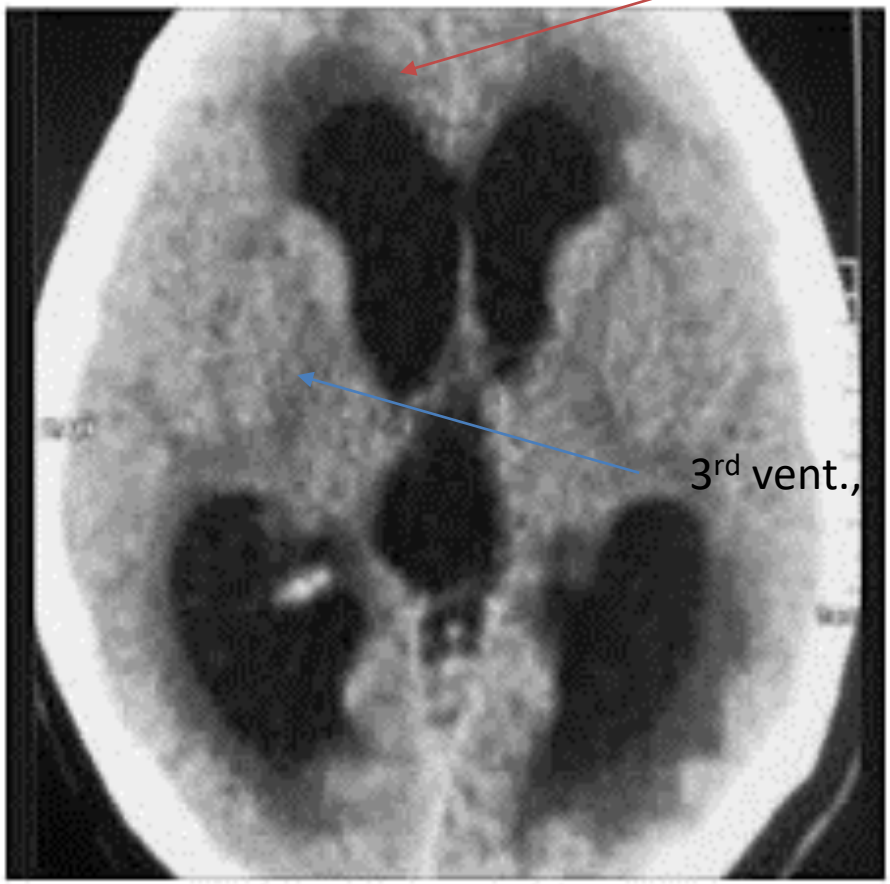


Figure (69): CT showing Congenital Hydrocephalus

A sign of non-compensated hydrocephalus

Periventricular fluids

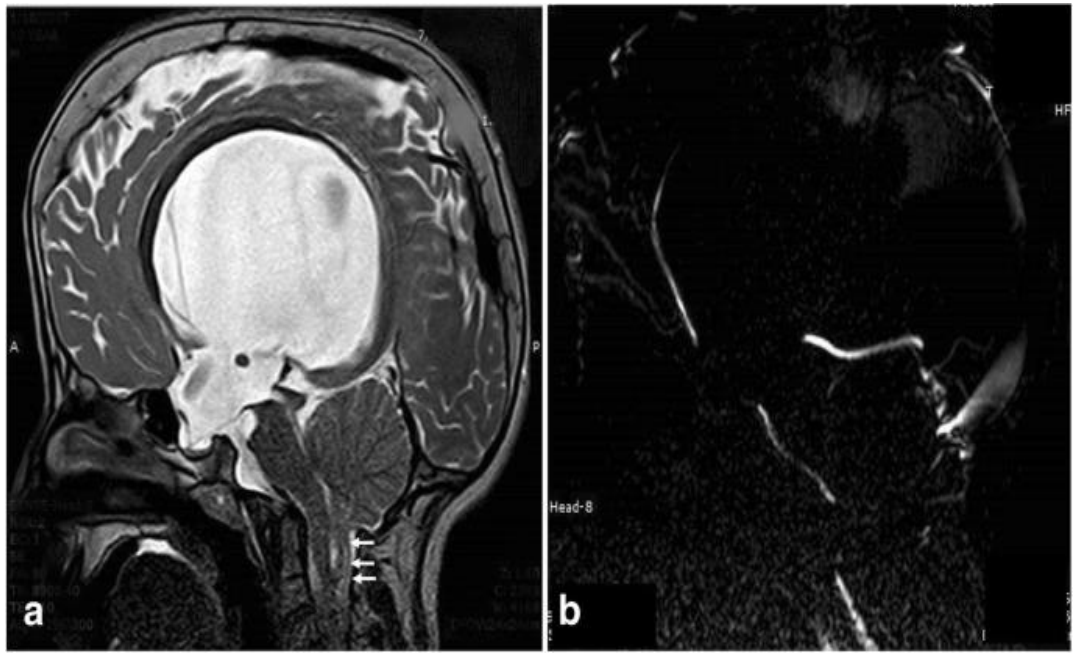


Brain MRI

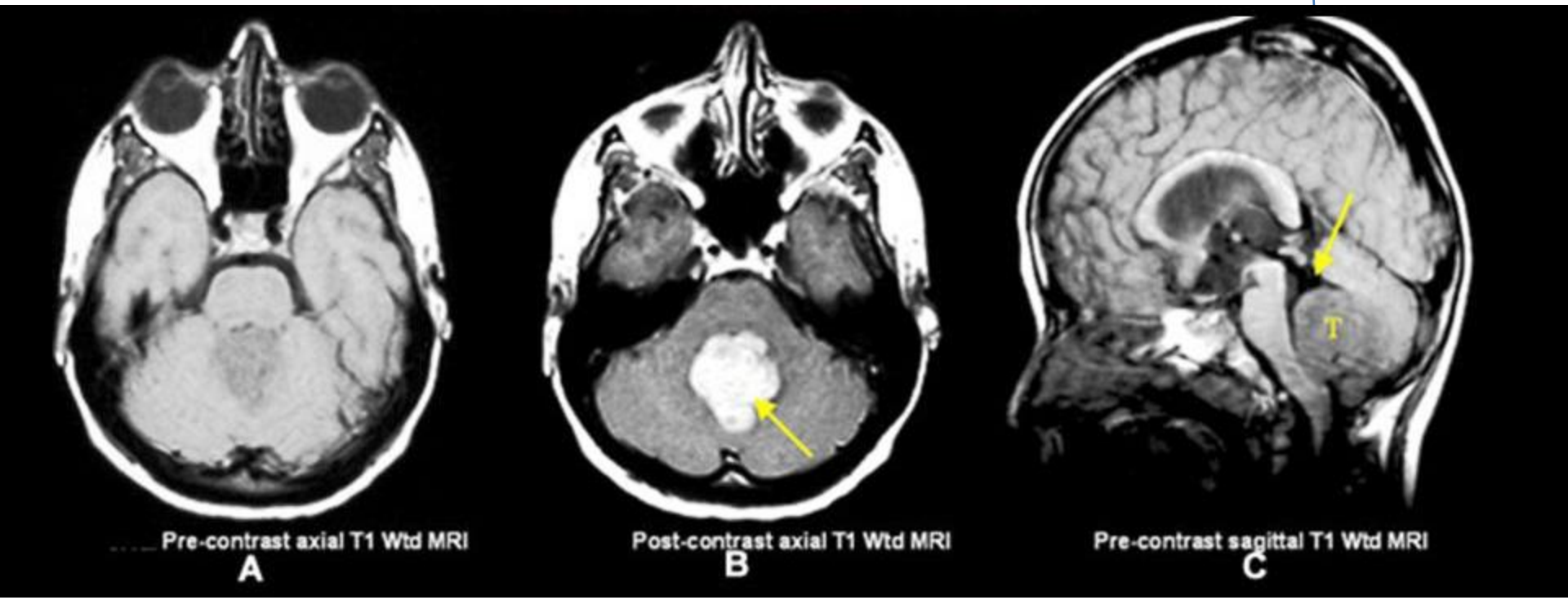
1- compensation
2- communication
3- cause
4- Evans ratio (the ratio of the maximal width of the frontal horns to the maximum inner skull diameter)

Since 1986,

- can project the brain in axial,coronal, and sagittal projections.
- MRI can detect transependymal resorption and low-grade gliomas more clearly.
- as well as determine CSF flow across the aqueduct.



The same previous infant, MRI was done postoperatively after V-P shunt insertion.
You can notice the reduction of the size of the ventricles with the posterior fossa tumor that caused the non communicating hydrocephalus



treatment

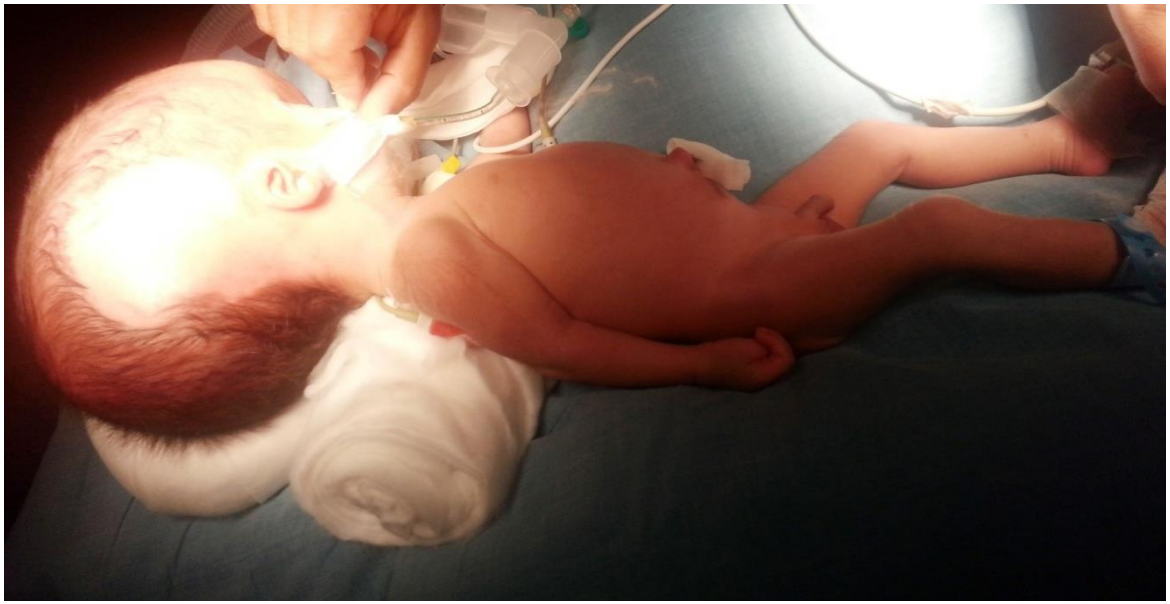
- The goal is:

1. Optimal neurological outcome Optimize not normalize
2. Preservation of cosmosis

- Normal sized ventricles should not be considered the goal

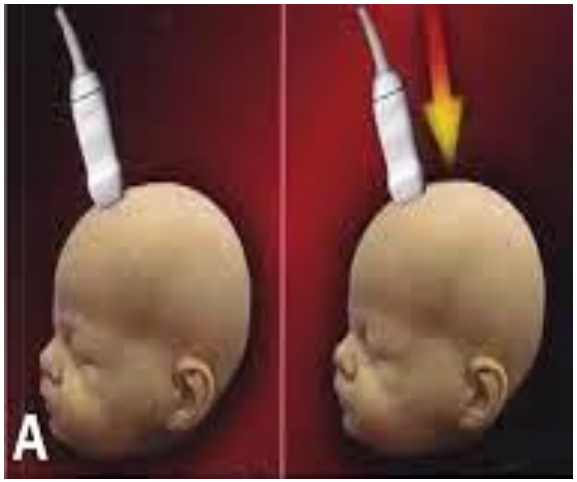
1. Non surgical
2. Surgical

➢ Shunting
➢ Non shunting

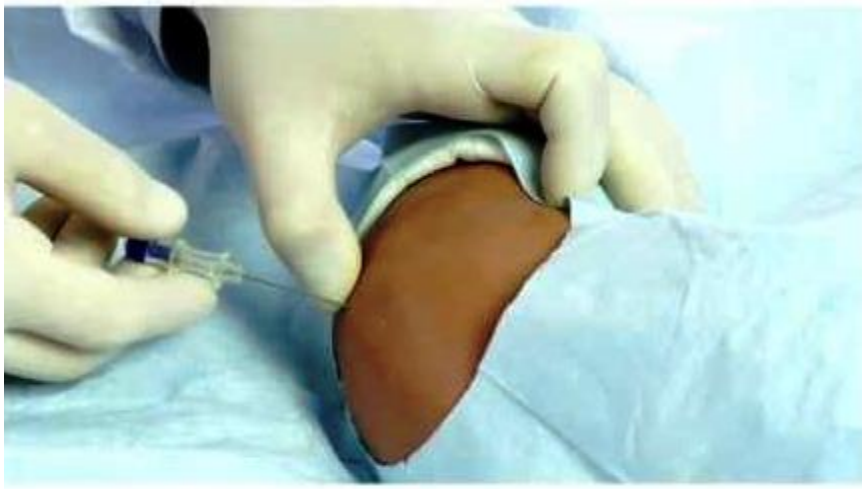


Non surgical

- Not defintive treatment. Temporary measure until we do the surgery
- Acetazolamide and frusamide
- Serial LP or ventricular tap
- Head rapping ,radioactive gold…..



Transfontanelle u/s preparing for tapping of the ventricles



Lumbar puncture to drain the CSF

Surgical – non-shunting options

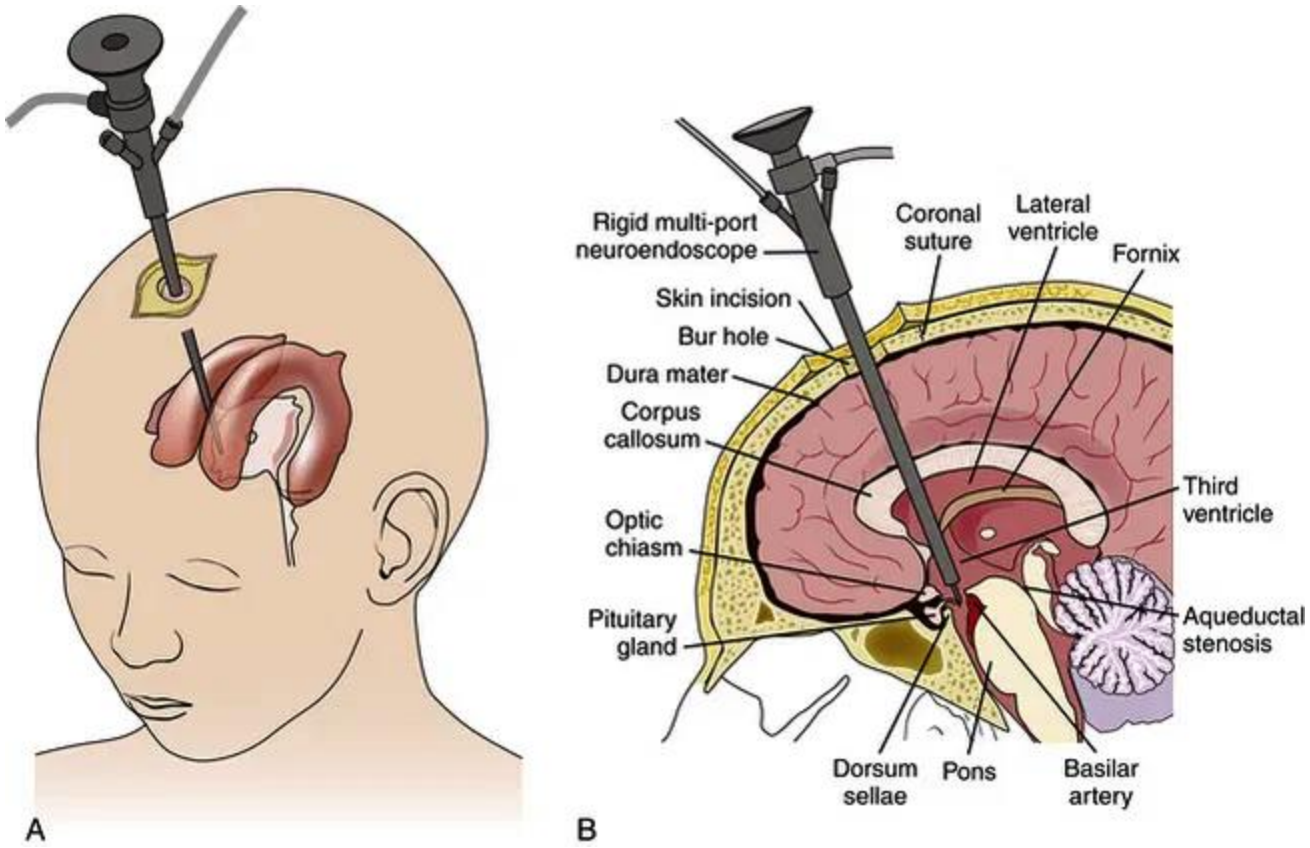
1-Whenever possible, the obstructing lesion that causes the

hydrocephalus should be ***surgically removed.***

2-For CSF obstruction at or distal to the aqueduct, a potential surgical treatment is the ***endoscopic third ventriculostomy(ETV).***

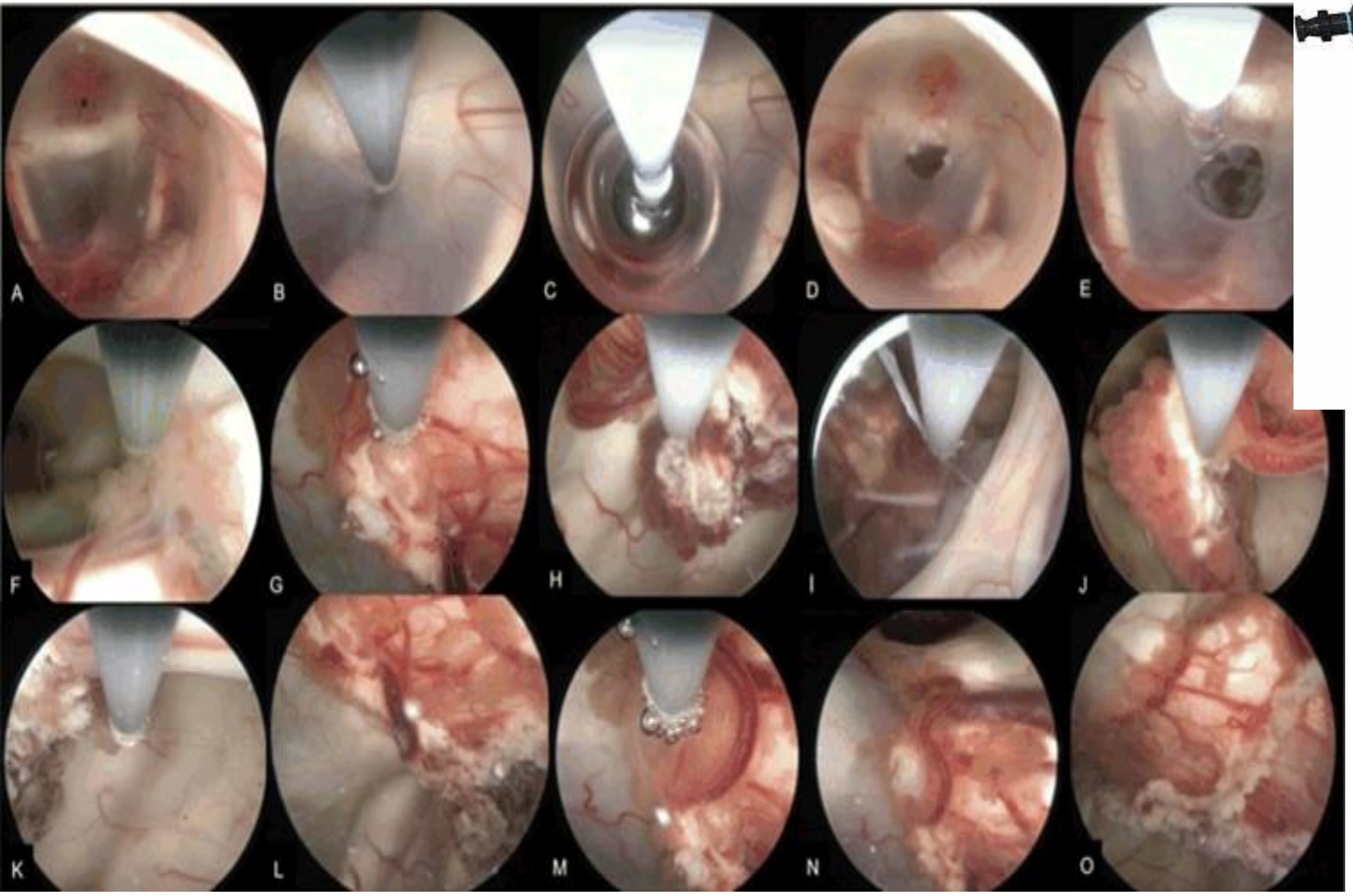
By surgically creating an opening at the floor of the third ventricle, CSF can be diverted without placing a shunt. Kamikawa and associates reported a 75% success rate for ETVamong 44 pediatric patients with hydrocephalus secondary to aqueductal stenosis; Other

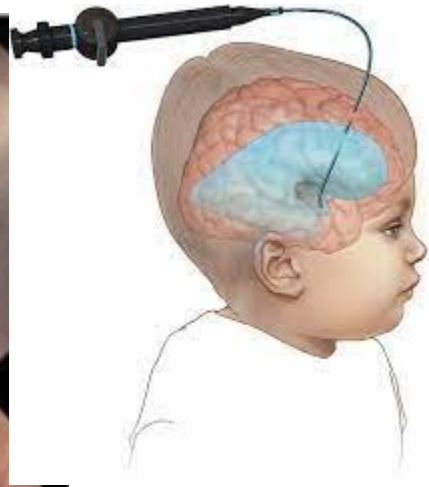
Endoscopic Third Ventriculostomy(ETV)



Flexible endoscope

ETV-CPC-choroid plexus coagulation





Surgical - CSF shunts

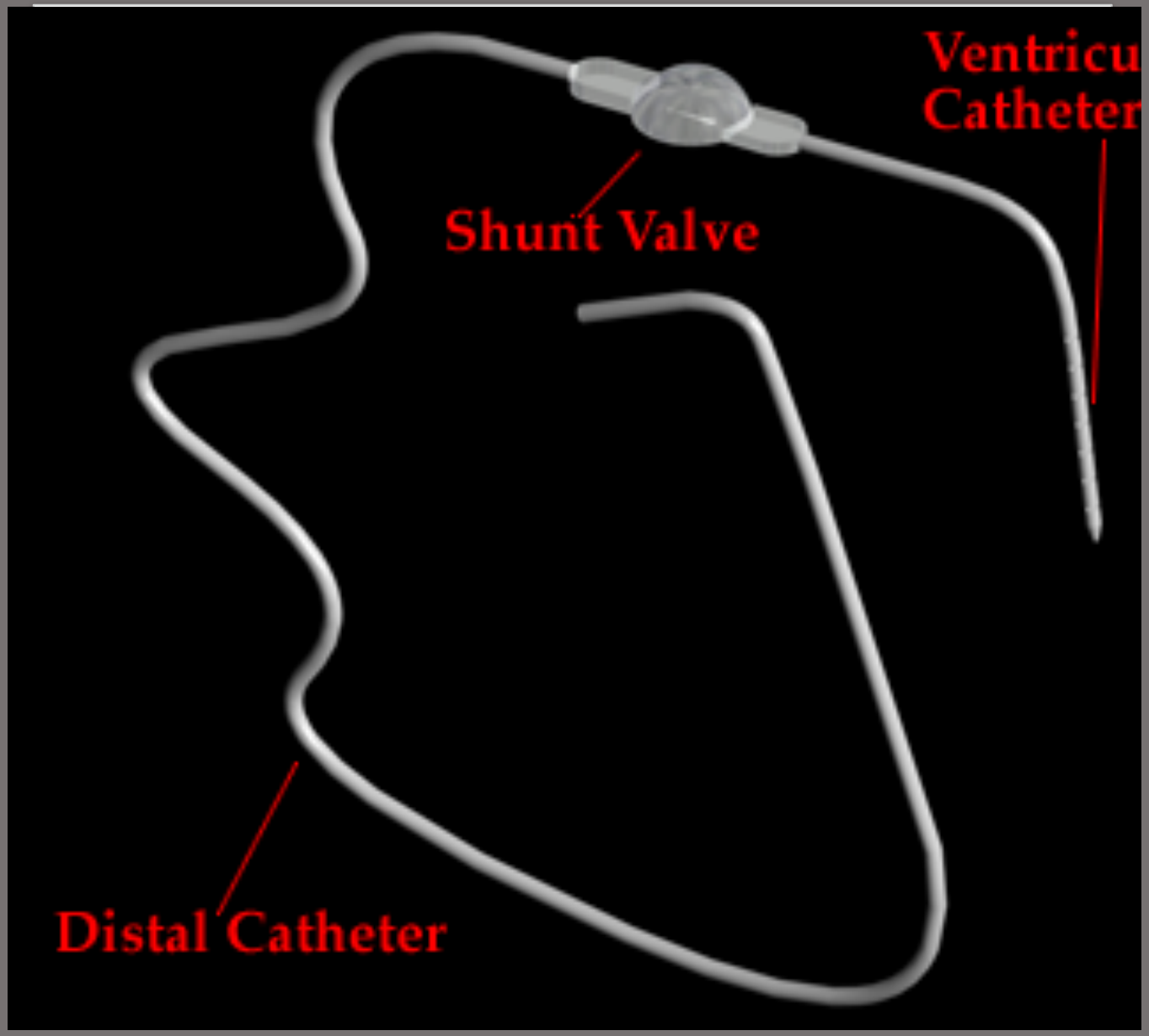
- CSF shunts are usually silastic tubes that divert CSF from the ventricles to other body cavities (i.e. peritoneal, atrium or pleural

space), where normal physiologic processes can absorb the fluid.

SHUNTING CSF

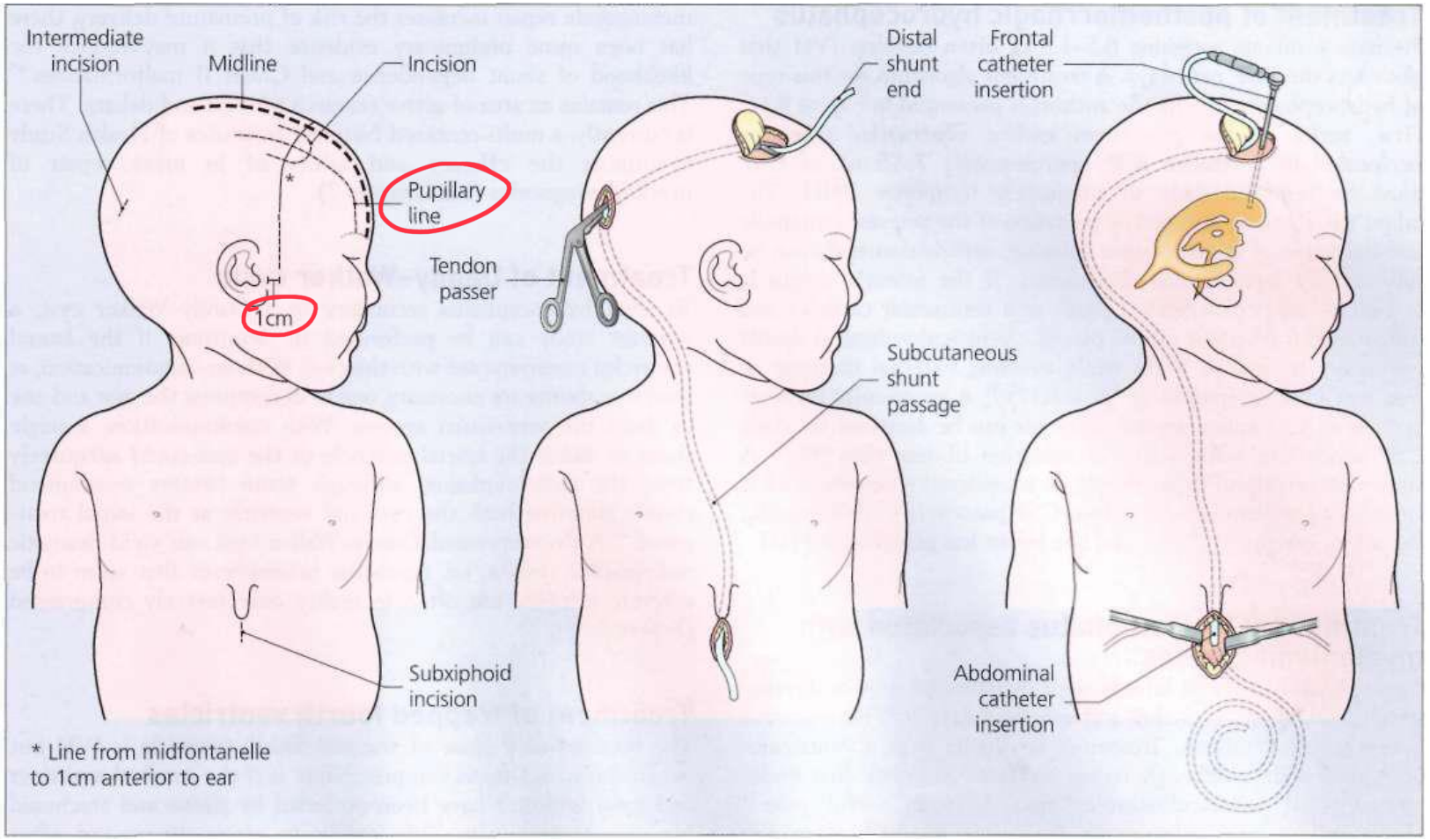
Ventricular CSF is usually shunted using a pressure-operated valve, with anti-syphon device and containing a sampling chamber. The shunt is composed of the valve, a proximal (ventricular) catheter and a distal catheter, which are assembled during surgery. The proximal catheter is usually inserted via a burr hole in the right posterior parietal region into the posterior horn of the lateral ventricle. It can also be inserted into the frontal horn. The ventricular catheter is then attached to the valve outside the skull. Once this is done, the distal catheter is tunneled under the skin to its destination. Its proximal end is connected to the free end of the valve and its distal end is inserted in the required destination

The destination of the distal end will indicate the type of the shunting procedure, namely (ventriculo-peritoneal) if the shunting was to the peritoneal cavity and this is the most commonly used type, or (ventriculo-atrial), if it is to the right atrium, or (ventriculo-jugular), if it is to the jugular vein, and lastly (ventriculo-pleural), when it is to the pleural cavity. This last location is not favored, due to the negative pressure inside the pleural cavity, which may “suck” CSF resulting in low ICP and consequent hemorrhage.



Components of the shunt

Surgical techniques



Placement of a frontal ventriculoperitoneal shunt. Patient positioned and coordinates marked; subcutaneous shunt passage; ventricular catheter insertion; peritoneal catheter insertion.

Shunt complications

Shunt complications and failures remain a significant problem in treating hydrocephalus.

(1) mechanical failure of the device,

(2) functional failure because of too much or too little flow of CSF(malfunction), and

(3) infection of the CSF or the shunt device.

Shunt complications

	Uncommon complications			
Common complications	Cranial	Subcutaneous	Peritoneal	Atrial
Infection	Subdural hygroma	Shunt migration	Peritonitis	Endocarditis
Obstruction	Subdural hematoma	Shunt disconnection	Pseudocysts	Nephritis
Inadequate flow or overdrainage	Hemiparesis Hematoma	Shunt fracture	Perforation Hernias	

Commonest

Shunt Infection

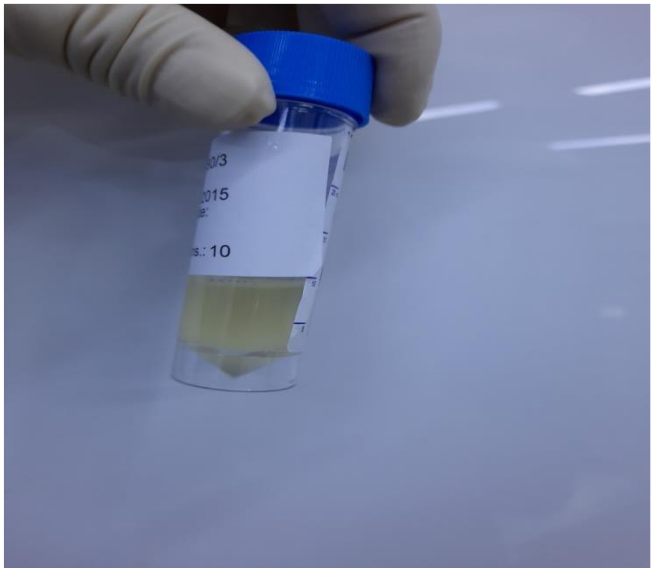
Infection > pleocytosis > failure of the shunt

- In general, approximately 1-15% of all shunting procedures are complicated by infection.

Premature infants have an increased risk.

- Evident within 1 month of placement. Nearly 90% of all shunt infections are recognized within 12 months
- it is believed that most bacteria are introduced at the time of surgery.
- ***Staphylococcus epidermidis*** *causes approximately 60% of* shunt infections, ***Staphylococcus aureus*** *is responsible for 30%, and* coliform bacteria, propionibacteria, streptococci, or *Haemophilus influenzae cause the remainder.*

- **Diagnosis** is confirmed by CSF sampling from the shunt reservoir ;with the findings of leukocytosis and positive culture .
- **Treatment** usually involves
  - the removal of the infected shunt
  - and placement of an EVD. The patient is then treated
  - with the appropriate intravenous antibiotics, based on culture and sensitivity results.
- When the infection is cleared, i.e. (1) at least 3 consecutive daily CSF cultures that are negative, (2) CSF white blood cell count < 50, and (3) CSF protein < 500 mg/dL, a new shunt system is implanted, and the EVD is removed.



COMPLICATIONS OF SHUNTING

All complications will lead to non-functioning of the shunt, requiring a change of the shunt itself in most of the times. The following are the commonest complications:

INFECTION: This is a serious complication, not only because of the meningitis or ventriculitis, which accompanies it, but also due to the difficulty in treatment**.** Infection has been attributed usually to the patient own skin organisms (staph aureus or epidermidis) and is proportionally linked to the length of the surgical procedure. It usually occurs within two weeks; however, infection could occur at a much later time. The patient may come with signs of meningitis like fever, lethargy and headache. Infants and children may have poor feeding and irritability [7-9].

Examination may reveal signs of meningitis or alteration of level of consciousness, a full bulging fontanel if not closed. The child will be feverish. The shunt may be functioning or not. Examination of the abdomen may reveal tenderness. Special attention should be paid to the operation site and examined for signs of infection or skin ulceration.

A blood CBC should be taken, and this may show increased WBCs. The shunt should be tapped through its capsule (chamber) and a specimen collected. The CSF examination should be directed at analysis and culture. Neutrophils are usually found in the CSF, the proteins may be high, and occasionally the sugar is low.

CT scanning has no role in the diagnosis of infection, unless one is not sure or wants to check for ventriculitis.

Treating the infection of the shunt is difficult; there is some debate about the ideal method of management. All agree that antibiotic, which crosses the BBB, should be administered empirically.

Then either one of the following could be done:

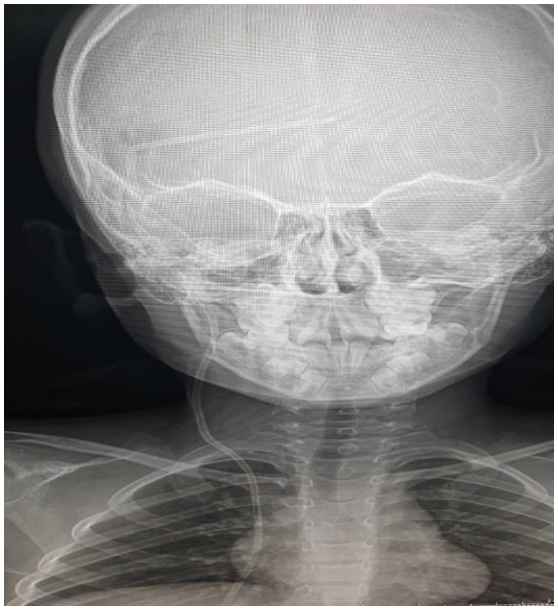
a) Exteriorize the distal end into a sterile bag outside the body, and continue antibiotics according to the results of sensitivity until all infection clears, then a new shunt is inserted to replace the old one which is removed, or,

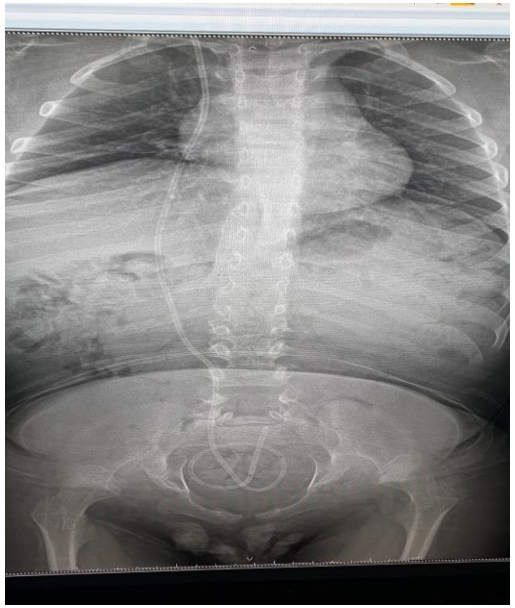
b) Remove the whole shunt from the beginning, on the presumption that any foreign material is usually the site for colonization by organisms and replace it with an external ventricular drain (EVD), or by repeated ventricular taps as appropriate.

Once the infection had cleared as indicated by three consecutive negative cultures or three normal CSF analyses, a new shunt is usually placed. If there were problems with the original absorbing surface (peritoneum or circulation) then a new destination is found. (I.e. change peritoneal into atrial or atrial into pleural etc.)

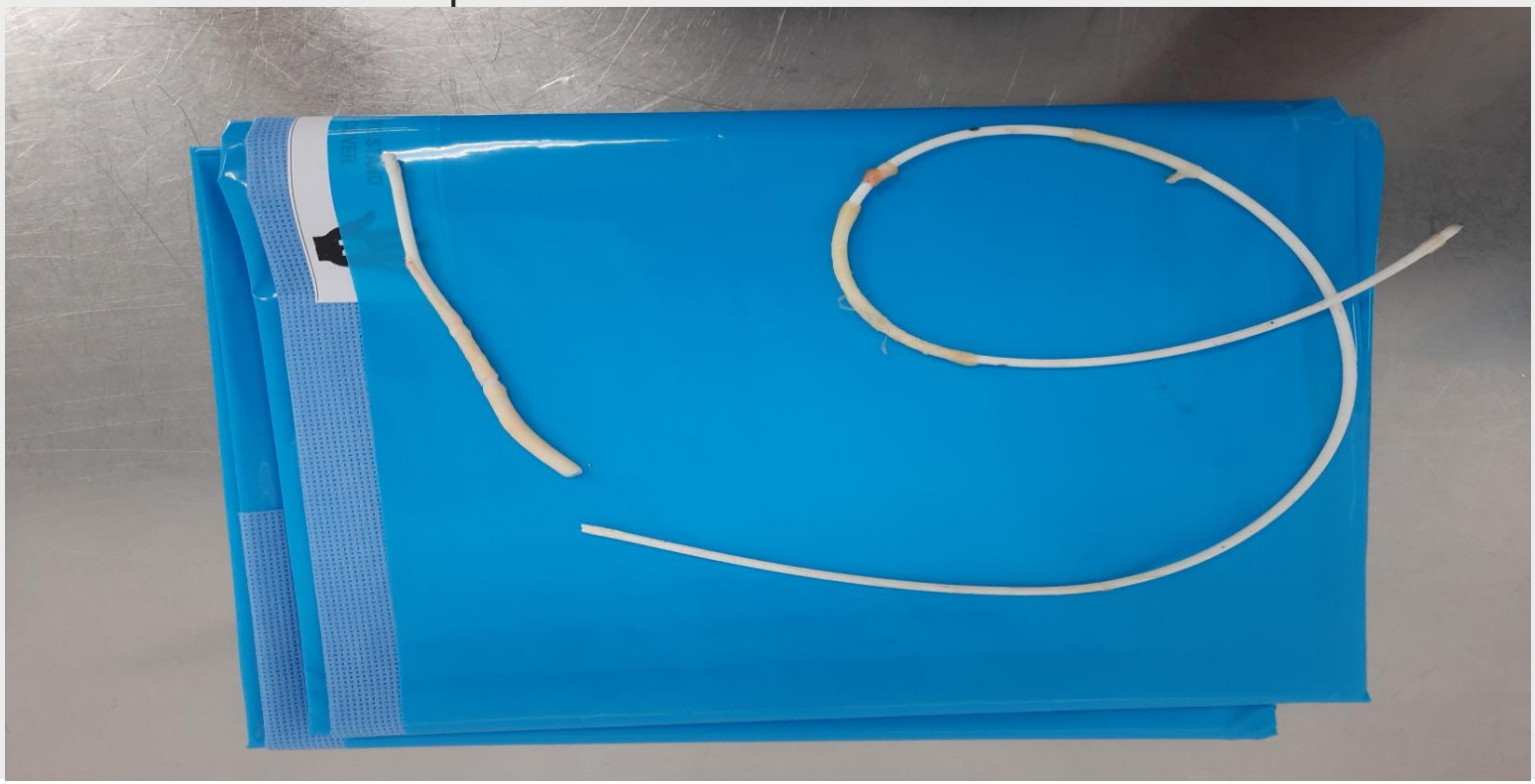
shunt obstruction

- A child with a shunt malfunction often presents with signs and symptoms of increased ICP.
- Children with a shunt malfunction usually present with headache, irritability, lethargy, nausea, and/or vomiting.
- The shunt itself can be examined for evidence of obstruction..
- A head CT, as well as shunt survey Xrays





- Shunt obstructions/malfunctions are treated by replacing the occluded or nonfunctioning components, or by replacing the entire system.



MALFUNCTIONING, here either the proximal or the distal end is not working properly (blocked or not adequate). This could be due to obstruction of the proximal end by debris or choroid plexus.

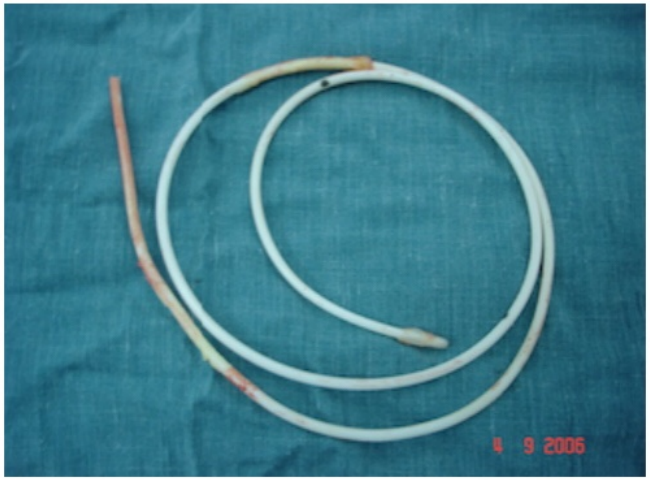


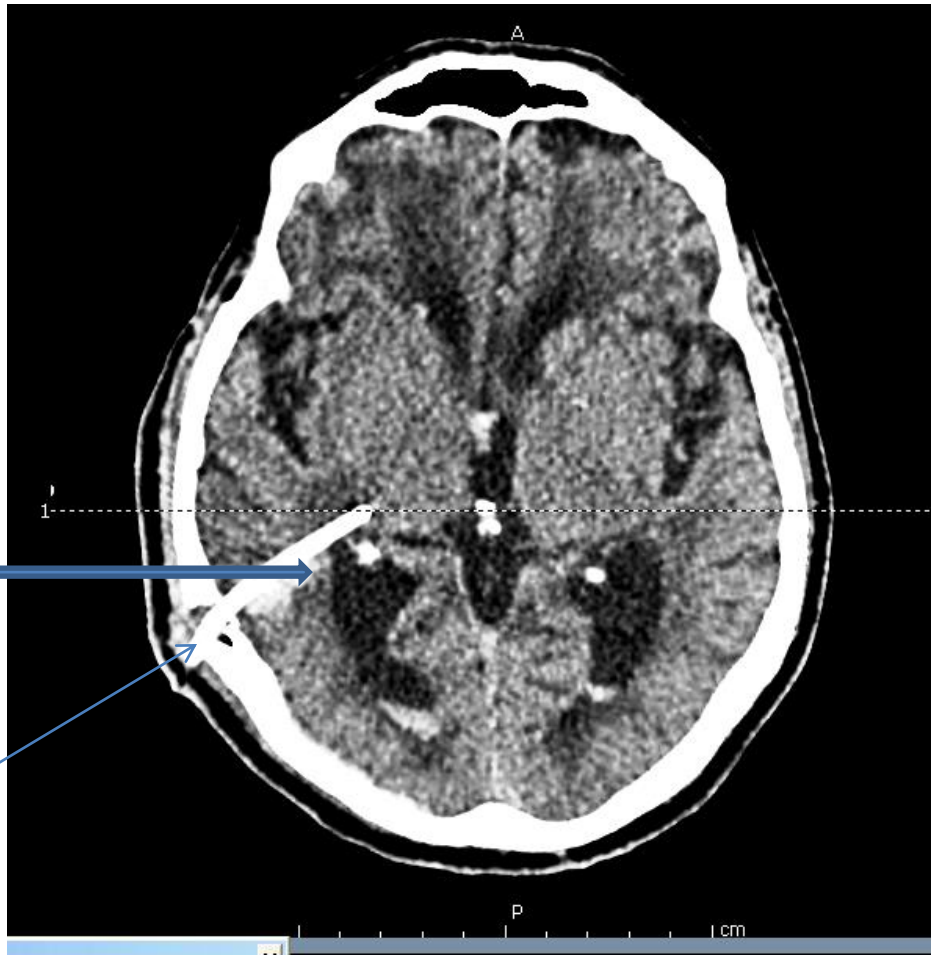
Figure (70): Shunt tubing obstructed by adherent tissue.

Problems of the distal end include closure by omental adhesions (Figure 70), the formation of a cyst or kinking. The patient will be lethargic, vomiting and irritable, if he is old enough he may complain of headache, he will have no fever and no signs of infection. CT will usually reveal enlargement of the ventricles.

Testing the valve will usually indicate which end is obstructed. If pressing the chamber of the valve empties it, but it does not refill then

the proximal end is obstructed. But if the pressure fails to empty the chamber, then the distal end is obstructed. One only needs to deal with the non-functioning end, by replacement. If the whole shunt seems not adequate then it should be replaced with the correct one.

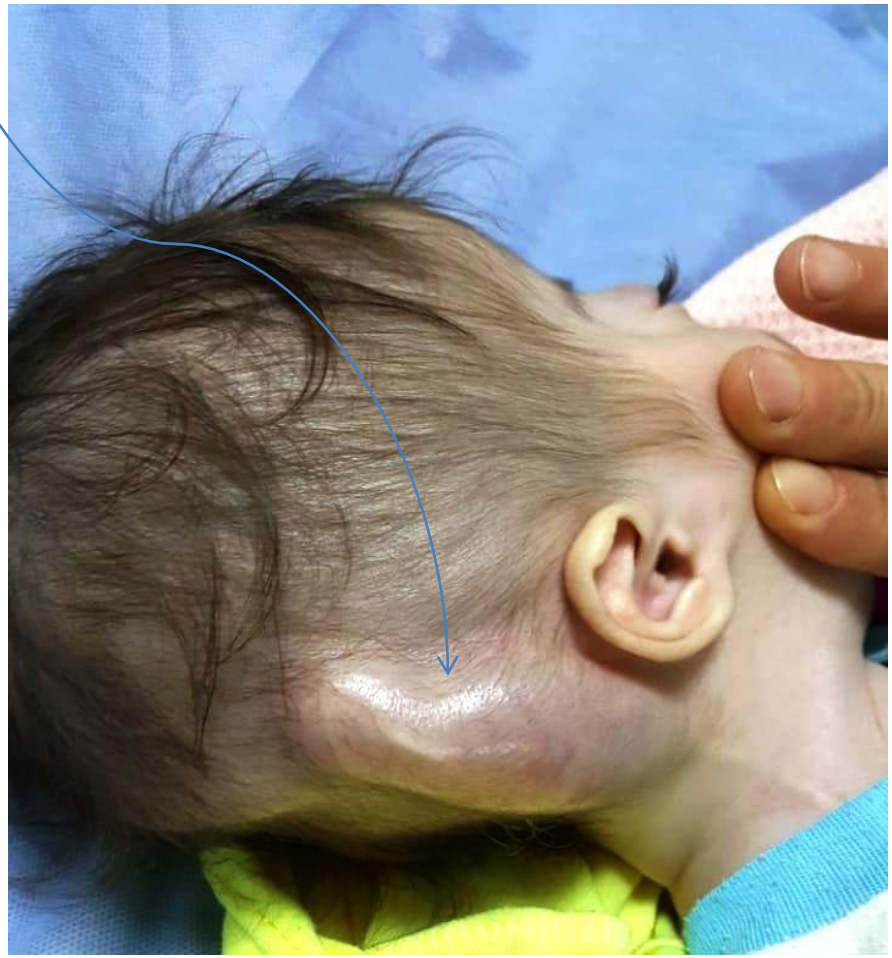
Hematoma at sit of shunt insertion



Intracerebral Hematoma around the catheter

Ventricular catheter

Swelling around the valve of the shunt highly suggestive of shunt malfunction



OTHER COMPLICATIONS include:

1. Fracture or disconnection of the shunt
2. Volvulus, intestinal obstruction and intestinal perforation (ventriculo-peritoneal shunts)
3. Ascites, hydrocele, hernia (ventriculo-peritoneal shunts)
4. Migration into the vascular compartment (atrial and jugular shunts).
5. Peritoneal cysts (ventriculo-peritoneal shunts)
6. Need to lengthen the shunt (all types).
7. Over drainage (all types).

Chronic or normal pressure hydrocephalus (NPH)

Chronic hydrocephalus of adulthood presents more insidiously, often weeks or even years after the inciting cause, sometimes without apparent cause at all.

. The affected patient exhibits a combination of **motor** dysfunction, **urinary** incontinence, and **Dementia** the so called Hakim -Adams triad.

The early motor signs are most prominent in the lower extremities and are related to difficulty initiating walking, the so-called"magnet gait" phenomenon.

. Advanced cases show frontal release signs, such as suck and grasp reflexes.

Parkinsonian and other dyskinesias have been described. In the early stages of hydrocephalus, the patient is well aware of the urge

to void, but urinary incontinence results from an uninhibited bladder and a gait-induced inability to reach the bathroom in time.

SPECIAL TYPES OF HYDROCEPHALUS

Normal Pressure Hydrocephalus

Occurs usually in people over 50 years of age, producing symptoms mimicking those of dementia, i.e.: memory disturbance, gait disturbance and loss of bladder control. It may occur after head trauma, sub arachnoid hemorrhage or occasionally infection.

The differential diagnosis of this entity is dementia and chronic subdural hematoma, because all three produce the triad of memory problems, gait disturbance and loss of control over urination.

Usually the diagnosis of dilatation of ventricles is confirmed by CT. Improvements of symptoms may result following withdrawal of CSF via a spinal tap. However, some surgeons resort to the insertion of a ventricular catheter (EVD) and perform ICP monitoring overnight to record the abnormal pressure wave (plateau), which occur in the early hours of the morning and are diagnostic.

The treatment of this type of hydrocephalus requires shunting using a normal pressure valve. Shunting usually leads to dramatic

improvement in gait, but the least to improve is the memory disturbance.

Hydrocephalus ex-vacuo

Develops when some of the brain substance is lost or becomes gliosed as after infarcts or simply with brain atrophy in elderly. Here the resultant space is taken over by dilatation of the ventricle or ventricles. This type of hydrocephalus may show no symptoms and signs and may require no treatment.