HYDROCEPHALUS I

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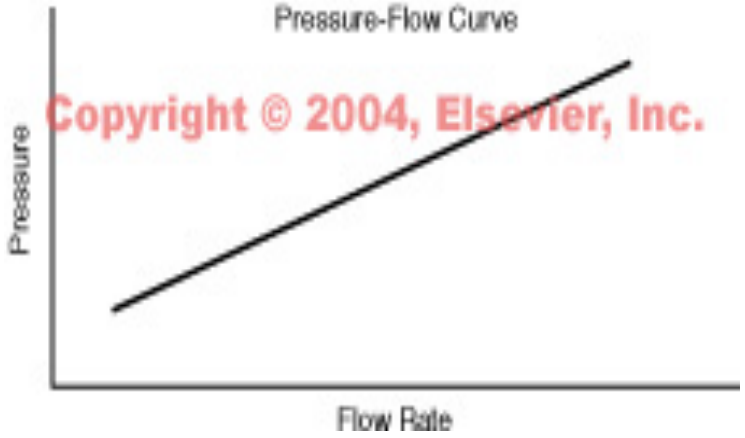
Physiology of CSF Shunt Devices

- Hydrodynamics of shunt systems: Defines the flow (Q) of CSF in the shunt
- $Q = \Delta P / R$
- ΔP = Driving pressure
- R = Resistance.
- Most cases of hydrocephalus: Pathologic increase of hydrodynamic Resistance.
- Shunt provides a low-resistance pathway for CSF diversion.

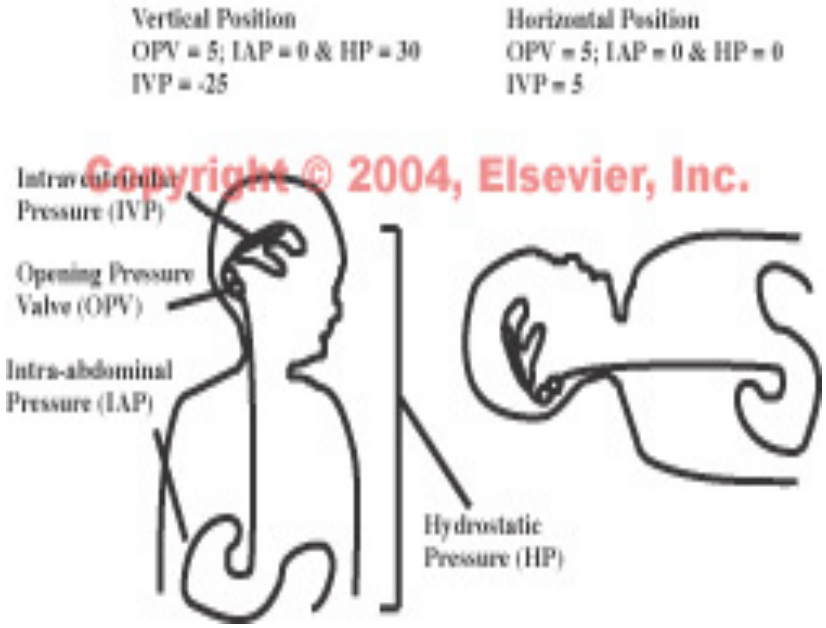
Physiology of CSF Shunt Devices

- R = RT + RV
- RT = 8ηL / πr4 (Poiseuille's law)
- RT remains constant producing a linear pressure V/S flow curve for the tubing.



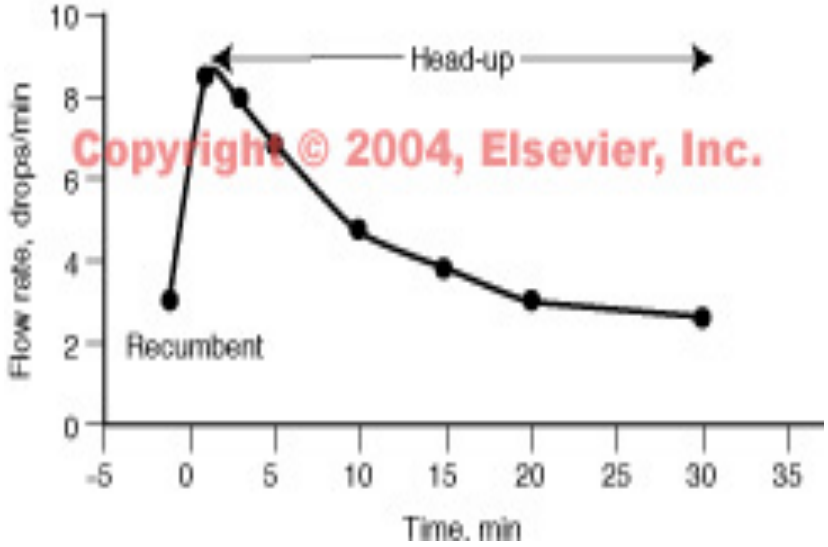
Physiology of CSF Shunt Devices

- $\Delta P = IVP + \rho \dot{g} \hat{h} - OPV - DCP$
- IVP = Intraventricular pressure.
- Hydrostatic pressure = density X gravitational constant X vertical height difference between proximal and distal ends.
- OPV = Opening pressure-valve.
- DCP = Distal cavity pressure.



SIPHONING

- Increase in flow when pt moves from the recumbent to the upright position.
- Difference in the height of the ventricular catheter and distal catheter.
- Difference in hydrostatic pressure.
- Does not happen in the normal brain.



SIPHONING

- Effects:
  Low-pressure symptoms.
  Tearing of bridging veins.
  Subdural hematomas.
  Premature closing of cranial sutures Slit-ventricle syndrome.
- Raising of opening pressure will not prevent it.
- Hydrostatic pressure upright position = 25-50 cm H2O.
- OP low-pressure valve = 1-4 cm H2O
- OP high-pressure valve = 8-10 cm H2O

SHUNT VALVES

- Differential pressure valves:
  Static valves.
  Programmable valves.
- Flow-regulated valves.
- Siphon-resistive (antisiphon) valves
- Gravity-actuated valves.

Differential Pressure Valves

- Goal: Prevent climbing and falling of IVP.
- DPVs are determined by their opening and closing pressure.
- Resistance of the entire shunt systems determines the flow when valve is open.
- Categories:
  Very low < 1 cm H2O.
  Low 1-4 cm H2O.
  Medium 4-8 cm H2O.
  High > 8 cm H2O.

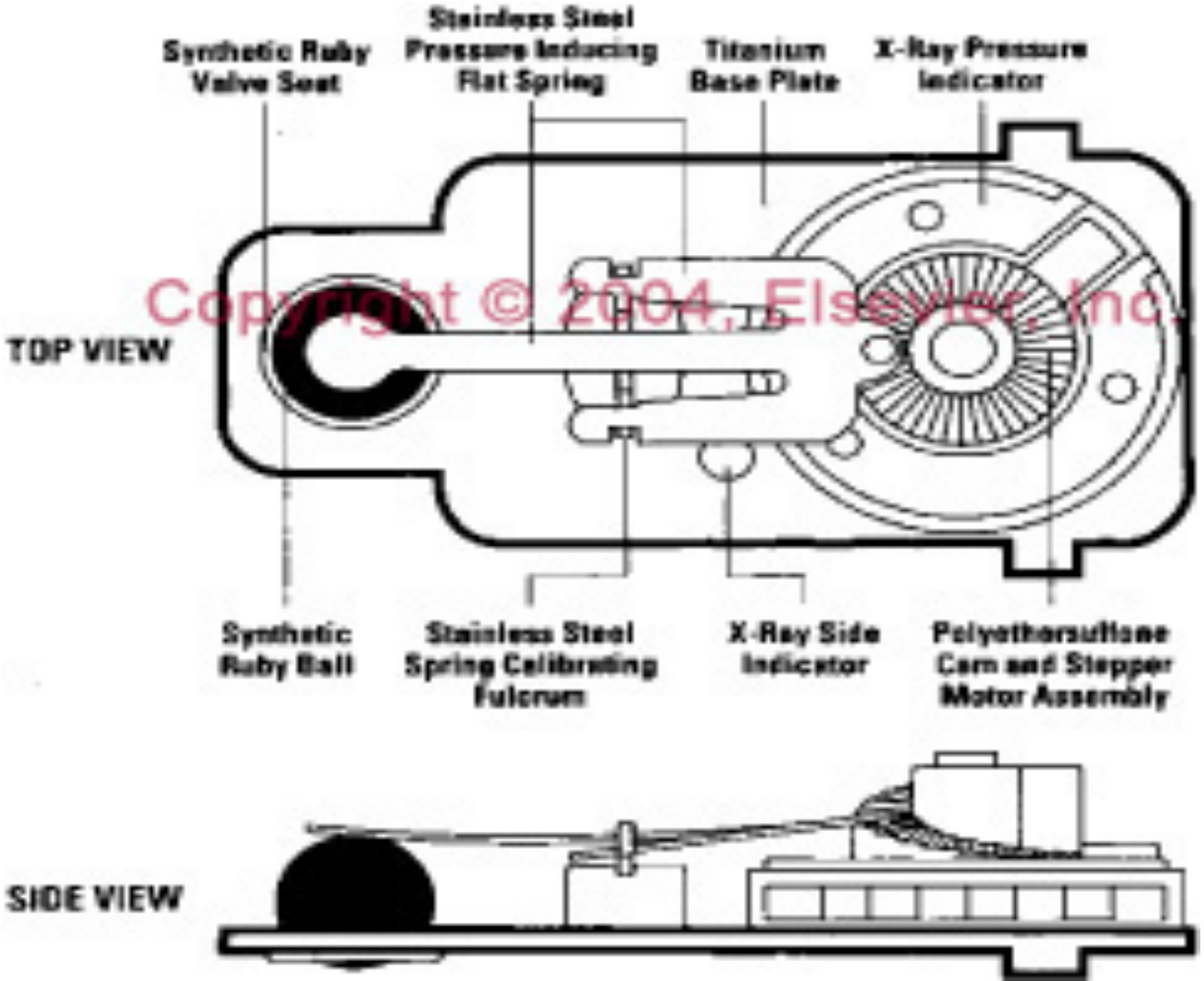
Differential Pressure Valves

- Slit valves:
  Proximal end: Holter-Hausner valve
  Distal end: Codman Unishunt.
  Lowest resistance to flow.
- Diaphragm valves:
  Most common of DPVs
  Deflection of a silicone membrane to allow flow of CSF.
- Programmable valves

Programmable Valves

- Externally adjustable differential pressure valves.
- Pressure may be adjusted without a surgical revision.
- Expensive.
- Indications:
  Overdrainage or underdrainage.
  Arachnoid cysts.
  NPH.
- Examples:
  Codman Medos programmable valve
  Sophy programmable pressure valve.
- Contain magnets:
  Produce artifact on MRI.
  May be reprogrammed by a magnetic field.

Codman Medos Programmable Valve

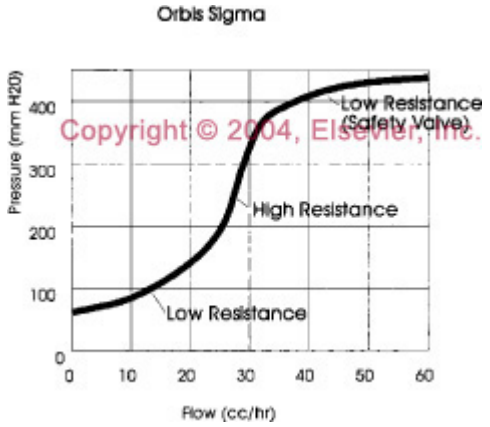


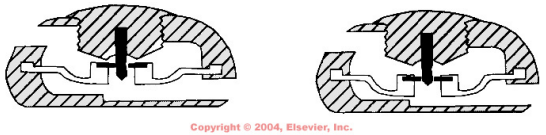
Codman Medos Programmable Valve

FLOW-REGULATED VALVES

Increase the R when ΔP increases → Constant Q.

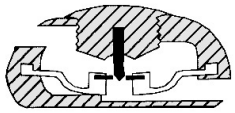
- ΔP controls the R.
- Pressure-controlled, variable resistance, constant-flow valves.
- Pressure-flow curves: sigmoid shape.
- Reduce siphoning and overdrainage.
- Risk of obstruction: small orifices.
- Orbis Sigma valve.





Low Resistance

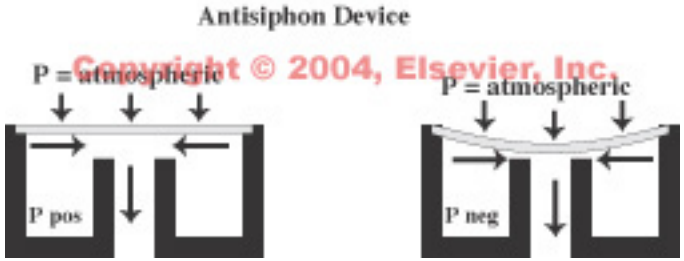
High Resistance



Low Resistance at High Pressure
(safety pressure release)

Antisiphon Devices

- Reduce the overdrainage.
- Diaphragm that reduces the flow of CSF when pressure inside the shunt < atmospheric pressure.
- PS Medical Delta valve.



Valve Design Trials

- MRT of CSF shunt valve design in pediatric hydrocephalus.
- 344 patients.
- 12 North American or European centres.
- Evaluated valves: standard differential pressure valve, Delta valve, and Orbis-Sigma valve.
- Follow-up: 1 year.
- Results: No differences in shunt obstruction, overdrainage, loculations of the cerebral ventricles, and infection.
- Drake JM, Neurosurgery 43:294-305, 1998.

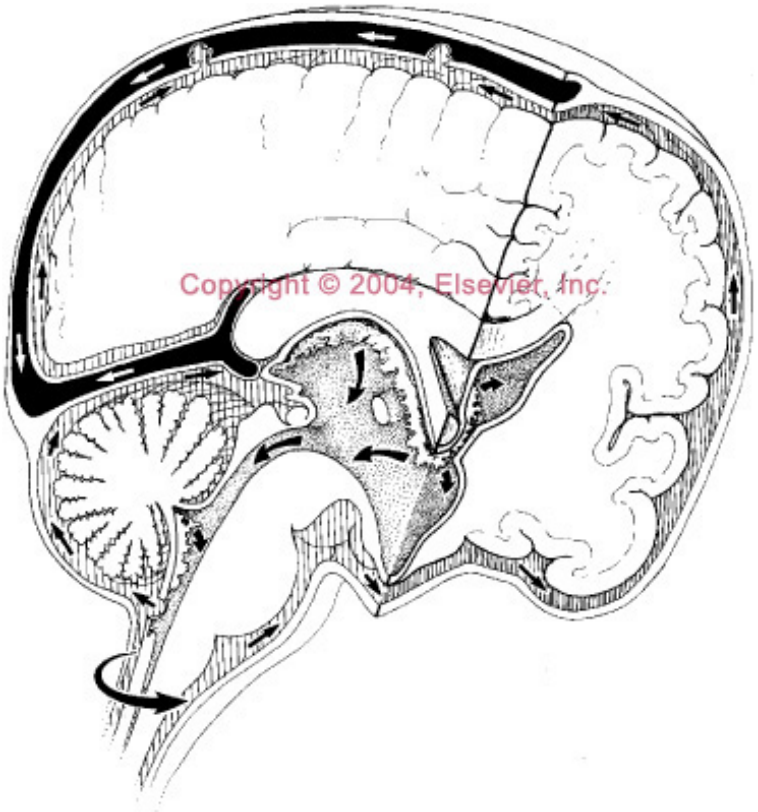
Hydrocephalus in Children

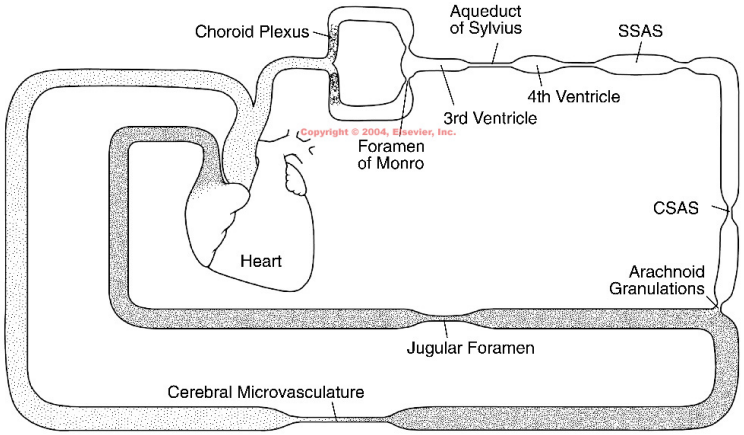
- Definition: Excess of CSF accumulated within the ventricular system with a secondary increase of ICP.
- It is not a disease; results from various conditions affecting fetus, infant, and child.

Normal Dynamics of CSF

- CSF production rate: 0.33 mL/min.
- Choroid plexus production:
  Energy-requiring process.
  Enzime carbonic anhydrase.
  May be blocked by acetazolamide (Diamox®).
  50%-80% of the total CSF.
- By-product of cerebral and white matter metabolism

Normal Dynamics of CSF





Classification

- Dandy's classification:
  Communicating.
  Noncommunicating.
- Ransohoff's classification:
  Intraventricular obstructive
  Extraventricular obstructive.
- Intraventricular: Foramen of Monro, aqueduct of Sylvius, and oulet foramina of the fourth ventricule.
- Extraventricular: Basal cisterns, arachnoid villi, and venous outflow.

Obstruction of One Foramen of Monro

- Unilateral monoventricular hydrocephalus may be congenital or acquired.
- Congenital:
  Rare
  Usually missed in infancy.
  Rapid increase of head.
  P.E.: Contralateral increase of tone

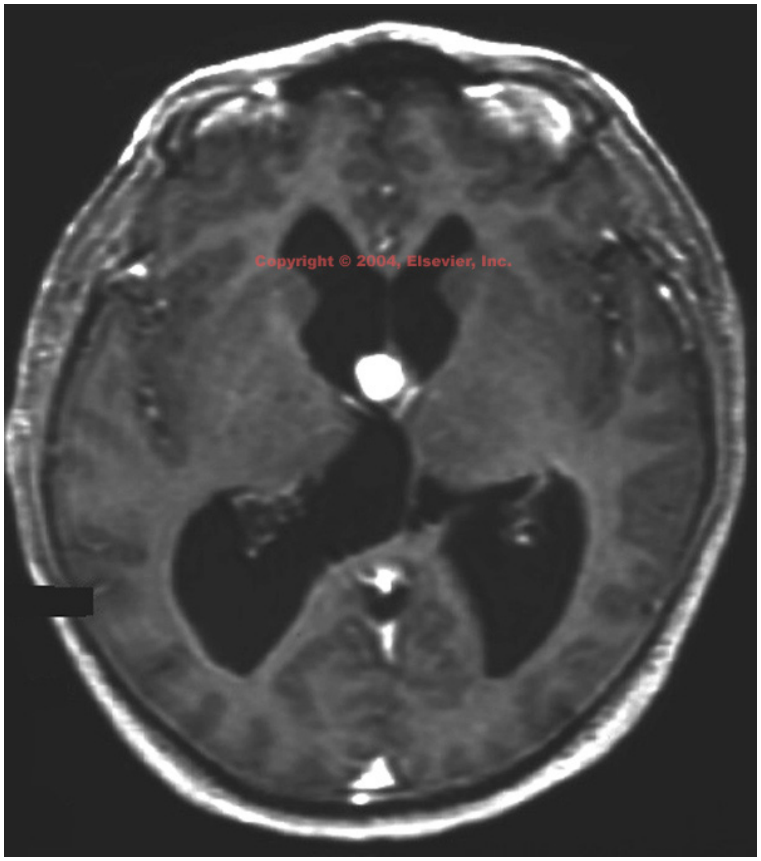
Obstruction of One Foramen of Monro

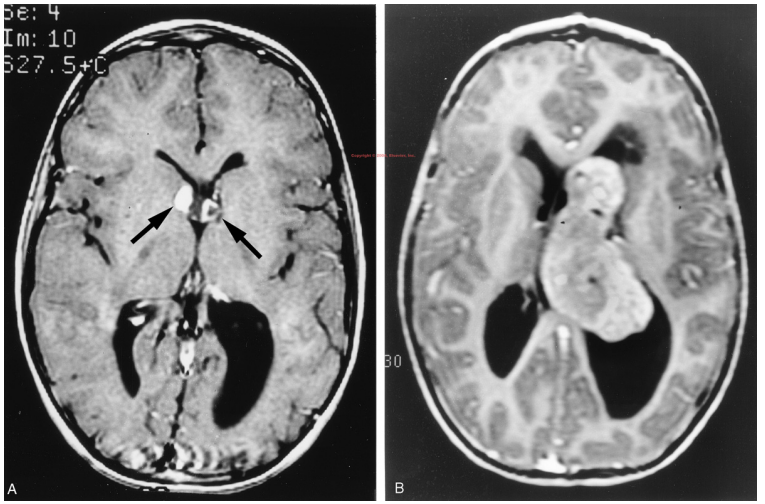
- Acquired

  Tumours: Subependymal giant cell astrocytomas (tuberous sclerosis), craniopharyngiomas, opticohypothalamic astrocytomas, choroid plexus papillomas, and germinomas.

  Inflammatory processes.

Colloid Cyst and Subependymal Giant Cell Astrocytoma.





Treatment

- Congenital:
  Shunt the affected ventricle ± endoscopic septum pellucidotomy
  Reconstitution of cortical mantle.
- Biventricular hydrocephalus and III ventricular mass.
  Severely ill pt. → Bilateral shunts.
- Tumour resection as much as possible.

Obstruction of the Aqueduct of Sylvius

- Congenital:
  Second most common cause of hydrocephalus diagnosed in utero.
  Can occur in families – sex linked condition.
- Acquired:
  Infectious processes.
  Tumours: Tectal plate astrocytoma, pineal region tumours, posterior fossa tumours (medulloblastomas, cerebellar astrocytomas, ependymomas, and choroid plexus tumours).

Treatment

- Prenatal:
  Medical counselling about outcome
  Other abnormalities.
  Variable outcomes: ⅓ vegetative, ⅓ developmental delays, and ⅓ normal.
  If delivery, when? "point of no return" → brain mantle < 1 cm.
- Birth to 1 year: VP shunt.
- Beyond 1 year: Endoscopic third ventriculostomy (ETV) – Success rate 70%

Treatment

- Acquired: EVD – Maximal tumour ressecction.
- Shunt malfunction: very rapid deterioration – ventricular catheter.
  Shunt revision V/S ETV.
  ETV: Success rate – 80%.

Obstruction of the Outlet Foramina of the Fourth Ventricle.

- Requires obstruction of three foramina.
- MRI: Marked enlargement of IV ventricle + mod. enlargement of lat. Ventricles + syringomielia.
- Most common cause: infection.
- Associated to Chiari I and II malf. Arachnoid scarring + mechanical compression.
  History of taumatic delivery.
- Most dramatic form: Dandy-Walker malformation

Obstruction of the Outlet Foramina of the Fourth Ventricle.

- Dandy-Walker mal
  Vermis agenesia
  Failure OF open.

Treatment

- Define if the aqueduct of sylvius is open.
- Stent placed in the aqueduct.