SHUNT TECHNOLOGIES

Introduction

- Controversial topic – which shunt is best?
- Confusion- how it works?
- Knowing the principles will help in intelligent selection of device.

History

Hippocrates

- First attempted ventricular puncture for HCP

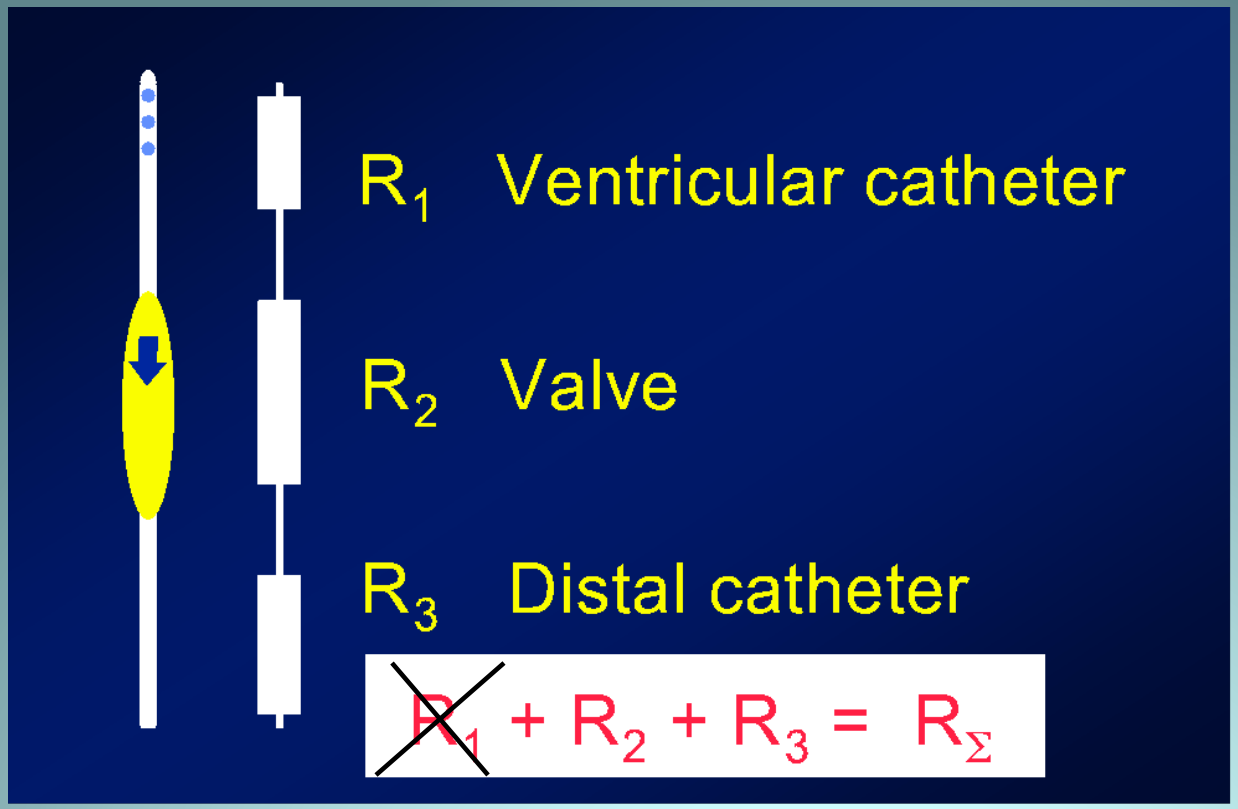
VP shunt = 1908

Nulsen and Spitz

Pudenz

- Ventriculojugular shunt –spring & ball.
- Used silicone tubing

Shunt Resistances are Additive ?



R1 is negligible

Shunt Hydrodynamics

Flow rate = P/R
- P = Driving pressure
- R = Resistance to flow

Resistance from **shunt tubing**(Rt.)
- Length and inner diameter of the tubing(L)
- Viscosity of the CSF .
- Rt= $8nL/\pi r^4$ (Poiseuille's law)
- n = coefficient of absolute viscosity.

Resistance from **valve components** (Rv.)
- Its not constant in the range of physiologic flow rates & a curved flow relationship is seen.

Hydrodynamics contd.

The pressure gradient driving the flow in a ventriculoperitoneal shunt system is determined by-

$\Delta P = IVP + h\rho g - OPV - DCP$

ρ = density.
OPV = opening pressure of the valve.
DCP = distal cavity pressure.

Applied importance

$Rt = 8\eta L / \pi r^4$

- Kinking can reduce flow significantly.
- Shortening distal catheter will alter dynamics.
- Air bubbles can cause failure.
- For higher density CSF, low pressure systems work better.

ρgh

- Higher flow rate in sitting and standing position= "Siphoning"

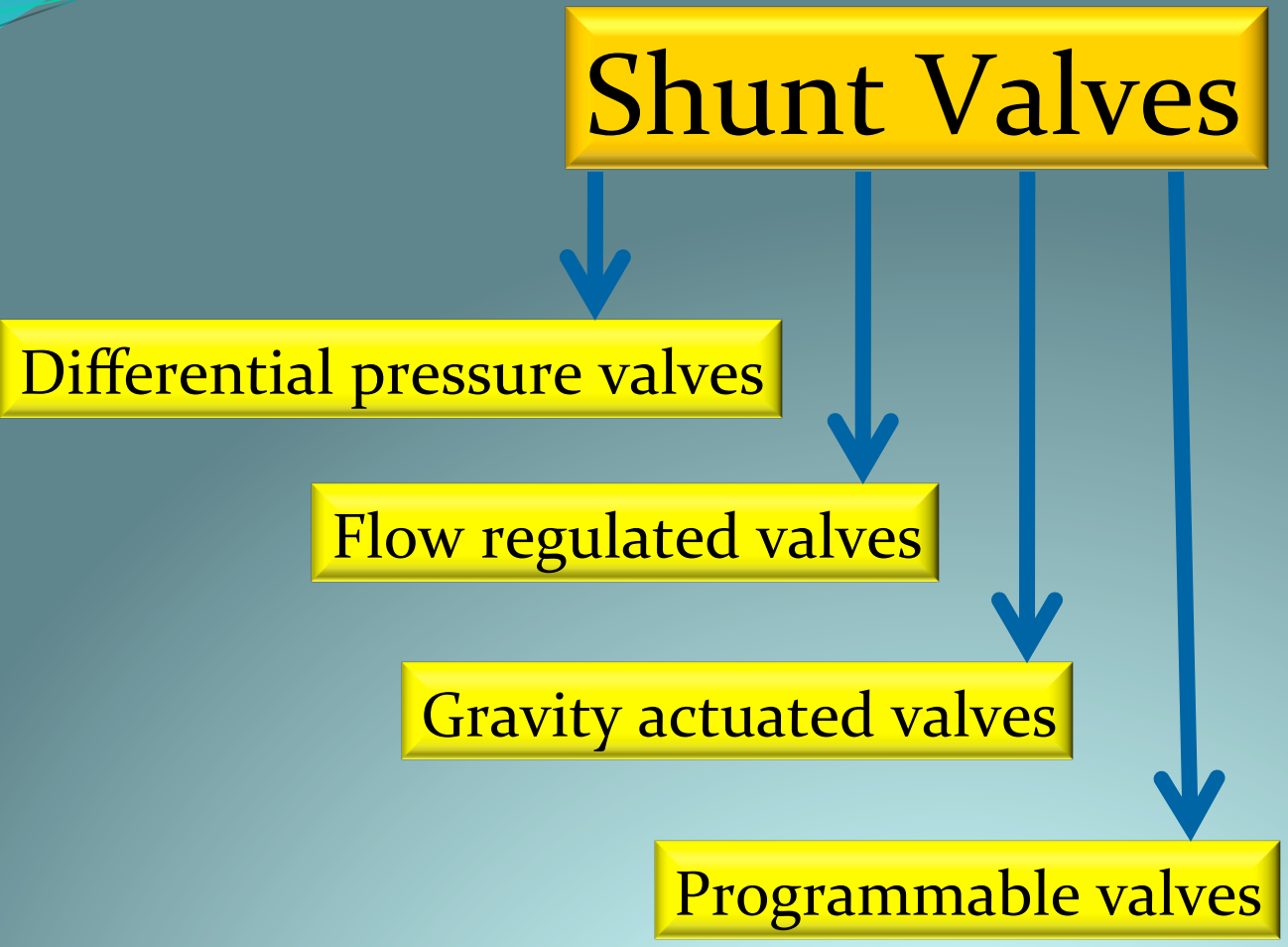
Biomaterials

Biomaterials currently used include:

- **Silicone elastomer** – catheters, valve housings / suture clamps, siphon devices, etc.
- **Polypropylene/Polysulfone/Nylon/Polyethersulfone** – valve housings/seats, needle stops, connectors, reservoirs.
- **Ruby/Sapphire** – valve pins, balls, seats
- **Titanium/Stainless Steel** – valve housings, needle stops
- **Tantalum** – radiopaque markers.
- **Barium** – radiopaciofier (homogenous or stripe).

Shunt Systems

- Shunt systems come in a variety of configurations and models but they have similar functional components:
  - Valve Mechanisms – flow or differential
  - Fixed, programmable, or variable settings
  - Catheters
    - Ventricular (proximal)
    - Peritoneal/Atria (distal)
  - Accessories
    - Reservoirs, Siphon Devices
    - Connectors, Filters, Pumping Chambers


Shunt Valves
Differential pressure valves
Flow regulated valves
Gravity actuated valves
Programmable valves

Differential pressure valve

- Slit valves
- Miter valve
- Diaphragm v.
- Ball in cone valve

Defined by their opening and closing pressure.
As the IVP goes above the valve opening pressure, the valve opens to allow egress of CSF at a rate determined by the resistance of the system, until the pressure falls below the closing pressure and flow of CSF ceases.

Slit valves

Proximal slit valves

Holter Hausner valve

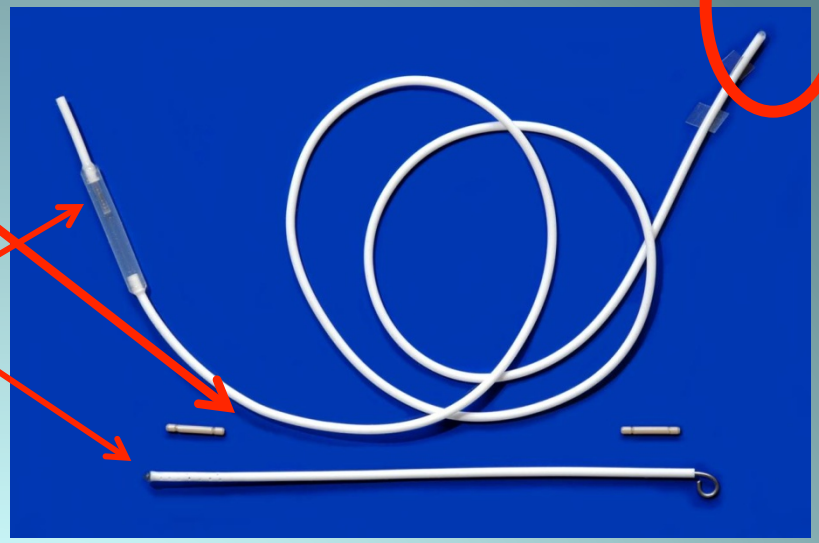
Distal slit valves

Codman unishunt valve
Chhabra shunt.

They offer the least resistance to flow and in fact no significant difference in resistance can be measured between a tube with a distal slit valve and an equally long open ended tube.

Chhabra shunt

- Slit and spring valve system.
  - The systems are available in 2 ball, 3 ball, 4 ball range.
  - Catheters contain barium sulfate for x-ray detectability.
  - The ventricular catheter has tantalum tip.
  - Regulating valve contains a stainless steel sleeve and balls and a sapphire ball.



Diaphragm valve

- Most commonly used type of valve.
- Involve the deflection of a silicone membrane in response to pressure in order to allow flow of CSF

Diaphragm valve

Ceredrain

Ref: www.lifecarehll.com

Basic Valve Features

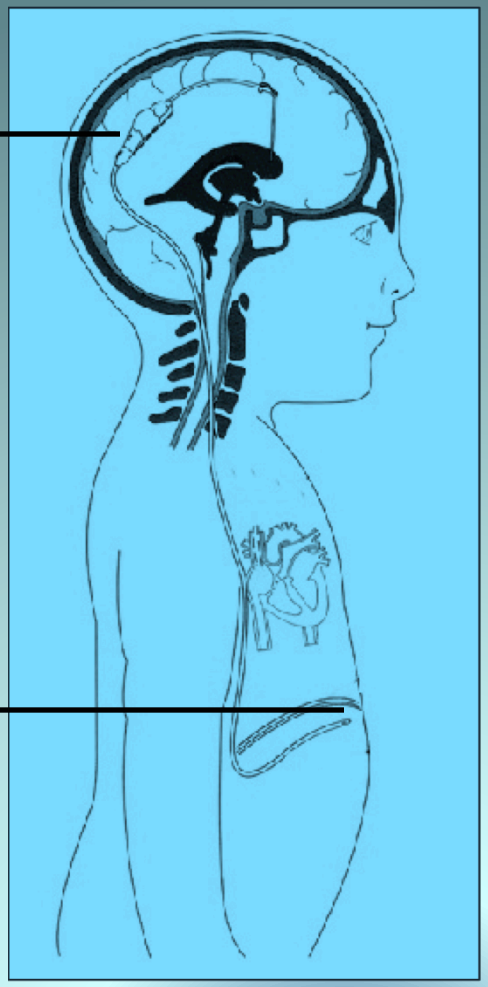
- Valve mechanism of dissimilar materials
  - Differential pressure mechanism
    - When the sum of inlet and outlet pressure exceed a threshold value, valve opens and drains
- Central reservoir for percutaneous CSF access
- Plastic base for rigidity and stability
- Non-metallic design

Button Valve

- For neonatal use (premature infants)
- Profile: 4 mm
- Requires use of separate reservoir
- No occluders

Differential Pressure Valve

In Reality



8 cm H_2o (valve) + -48 cm H_2o (distal catheter) =-40 cm H_2o

IVP (Ventricles)

Shunt
Overdrains

IVP = -40 cm H_2o
Siphoning

Flow Regulated Valves

Contoured synthetic ruby flow control pin that fits inside a movable ruby ring

As the pressure increases , the ruby ring is deflected downwards, the ruby ring is tapered the flow aperture decreases which increases resistance and reduces flow.

If the pressure is further increased the ruby ring is further deflected down until resistance is lowered to allow rapid increase in flow rate.

Flow Regulated Valves

Advantage
Flow regulated valves are less likely to be associated with siphoning and over drainage

Disadvantages
- Due to small orifice high chances of obstruction.
- High resistance has a propensity to cause fluid collections under the scalp in young children unless they are nursed upright with a compressive dressing

Gravity Actuated Valves

They attempt to prohibit or reduce siphoning by increasing opening pressure with the assistance of gravity.

Inlet valve = ball spring valve and does not change resistance with position

Outlet valve has a synthetic ruby ball that sits in a conical seat and there are three stainless steel balls that sit on top of it which weigh it down in upright position and fall away in recumbent position.

Programmable valves

•They are externally adjustable differential pressure valves.

• Surgeon has the option of altering the opening pressure with an external device and thus altering the need for surgical shunt revision.

• They are also **susceptible to siphoning**.

Programmable valves

They have an adjustable ball and spring mechanism. A step motor assembly.
Radiopaque markers.
Motor assembly can be adjusted with externally applied magnets.

Platform Stops

- Platform stops inhibit rotor movement from one platform to the next
- Need extra strong magnet to lift the rotor over the stop to the new platform

StrataVarius

- Handheld instrument designed to be ambidextrous
- Battery powered device (2-AA)
  - 100 uses
  - Power-down after 3 minutes of idle time.
- LCD readout screen
- Portal for valve palpation and magnetic adjustment
- Magnet is 2 times stronger

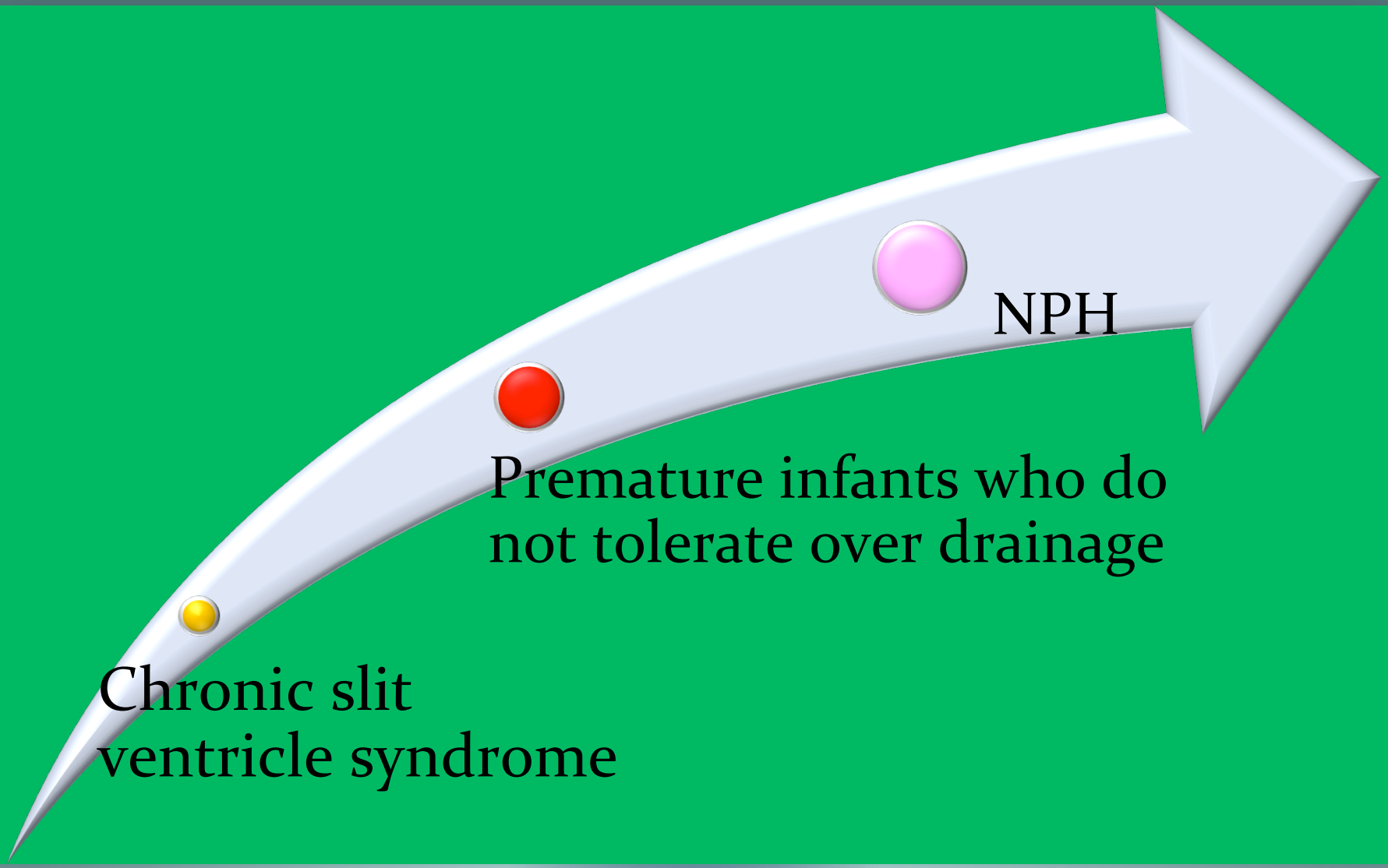
MRI Studies

- **Safe for use**; "MRI Conditional"
  - no movement of valve in tissue pocket
  - no selective heating
  - no effect on valve performance

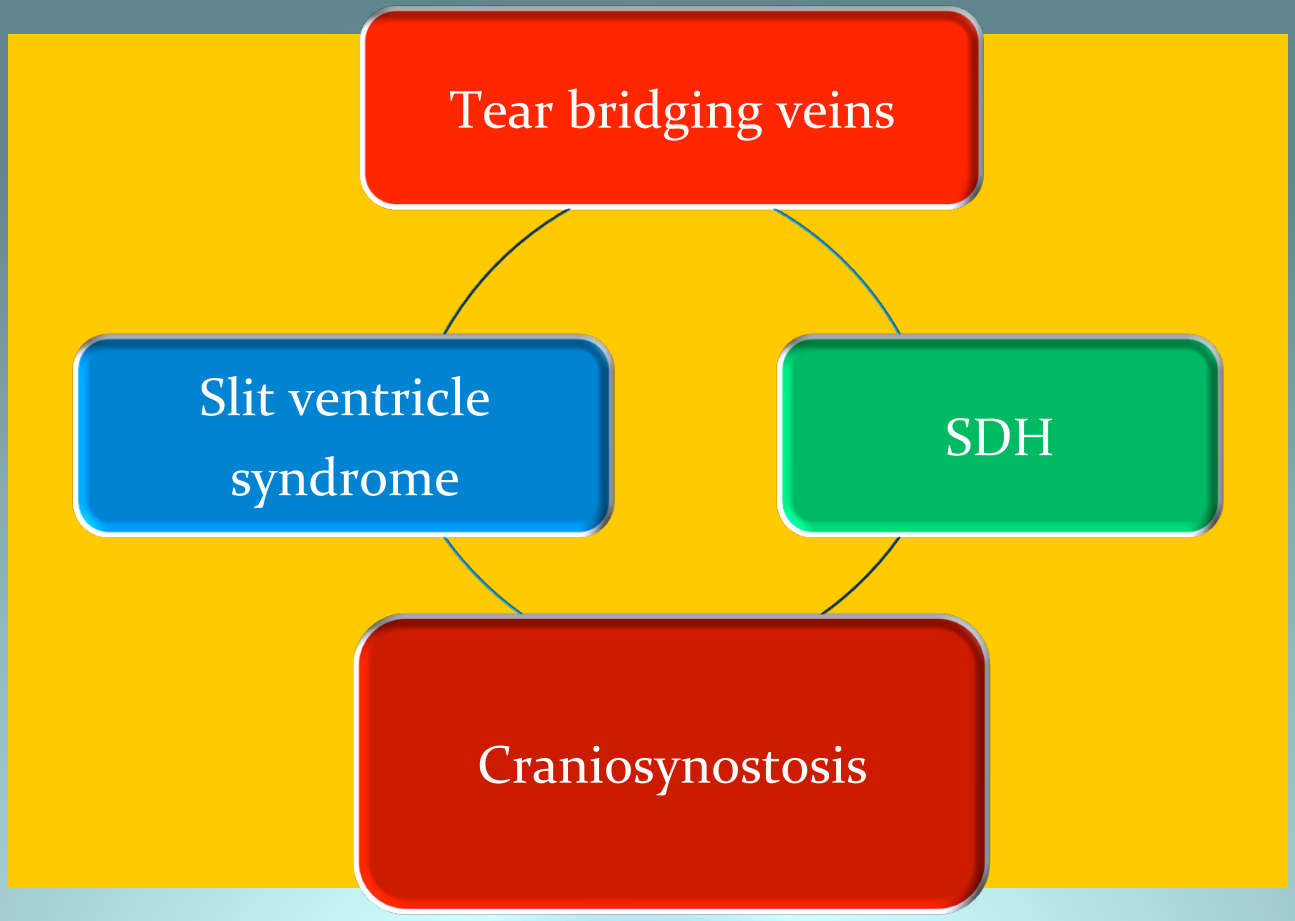
MUST **Reprogram after each MRI**

MRI will change the pressure setting

Indications for Programmable valve



Effects of siphoning



To prevent siphoning

Change the shunt valve to one with higher opening pressure

Use antisiphon device

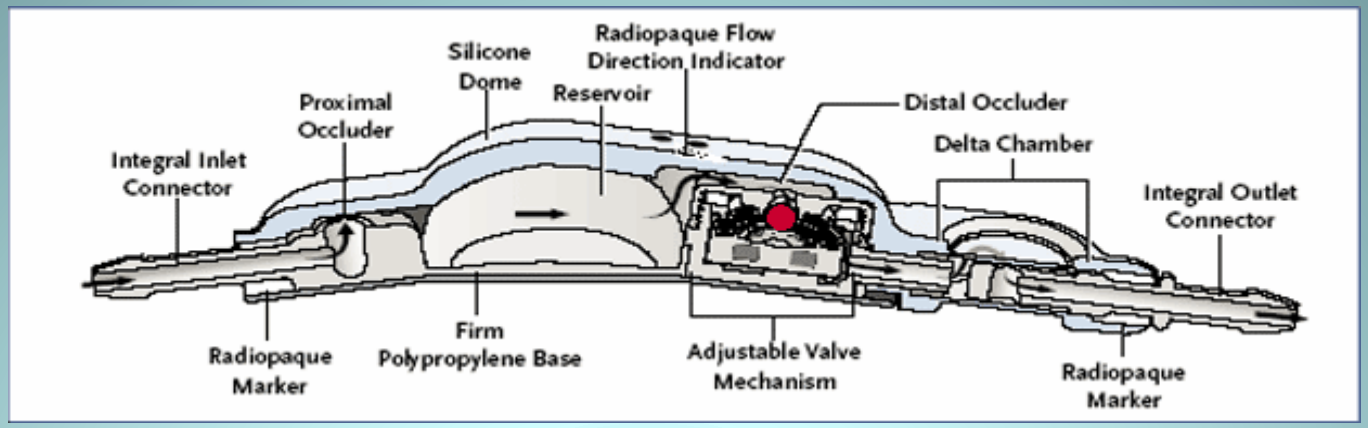
Will only delay ventricular collapse
But will not prevent it.

Antisiphon device

Has a small diaphragm that reduces the flow of CSF when the pressure inside the shunt falls below the atmospheric pressure

Delta Chamber

- The Delta Chamber uses a hydrodynamic leverage ratio of 20:1 to reduce the effect of negative hydrostatic pressure, and allow the valve to operate in its specified Performance Level, regardless of body posture.



http://ebtplus.co.kr/images/product_img63.gif

Delta Valve Message

- The Delta chamber senses both positive inlet pressure, and negative outlet pressure, and manages both.
- The Delta chamber manages negative outlet pressure without adding significant resistance to the shunt.
- The dissimilar material and recessed design of the Delta chamber diaphragms help to minimize the risk of compression from overlying tissue.

Siphon / Flow Control

SiphonGuard™ is a unique device designed to reduce the risk of CSF overdrainage complications.

- Rugged
  - No encapsulation or external pressure influence – flow not totally blocked
  - Avoids damage due to errant needle
- Unaffected by implant location
- Available as an integrated or stand alone device.
- Device is always open unlike other on and off devices.

Codman-nonprogrammable.jpg

Advancements in biomaterials

- Antibiotic impregnated shunt tubings.
- Coated silicone tubings for converting them into hydrophilic and more lubricious material.

Antibiotic impregnated shunts

»Bacteria In Shunting

›Most common bacteria in shunt infections?

← ‹*S. epidermidis*

‹*S. aureus*

‹*Coryneformis*

‹*Streptococci*

‹*Enterococci*

Account for approx. 77% of shunt infections.

Internal or External ?

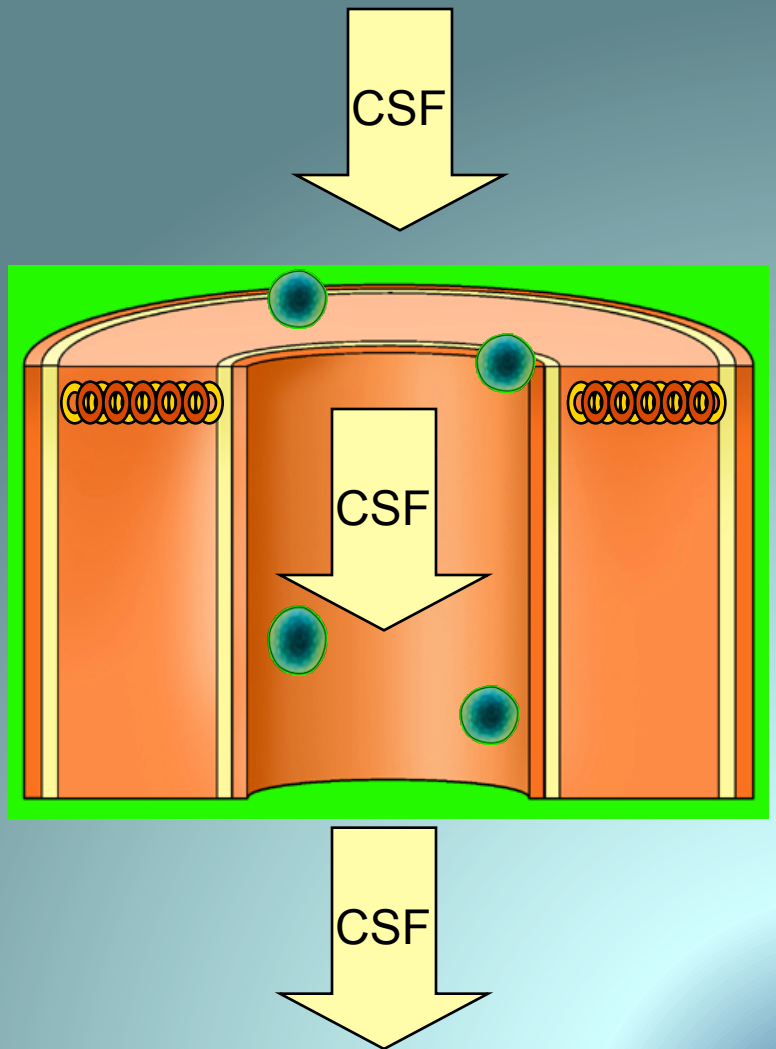
» *Internal* » *Majority* » *S. epidermidis or Coryneformis*	» *External* » *Minority* » *Wound infection complicated by foreign body* » *S. aureus*

Contd..

Internal Shunt Infection

- *The organisms start to multiply*
- *And they produce extracellular slime*
- *This can, in time, completely block the shunt*

Contd..
How Do They Work?



Due to the concentration difference between the catheter and the external environment, there is a positive diffusion gradient which causes the drugs to slowly diffuse out of the silicone.

The concentration of drugs at the surface of the catheter is high enough to inhibit colonization.

Precaution

Pre Implant Technique

- *Surgeon should not pre soak Bactiseal in saline or antibiotic solutions prior to implantation because the diffusion process will be activated.*

Reduction in infection

- Significant reduction in shunt infection rate with antibiotic impregnated shunt.(from 6.5% to 1.2%).
- P value- 0.0015.

Chris X et al, dept of NS, Vic. Australia.

J. Of clinical neurosciences JUNE 2007.

BioGlide

- BioGlide is a covalently-bonded hydrogel that aids with ease of insertion, reduces bacterial adhesion, and absorbs water-soluble antibiotic solutions
- Created to address the issue of “infection”

BioGlide

- **We can say:**
  - Hydrophilic, lubricious surface facilitates insertion
  - Smoother surface than non BioGlide treated surface

- **We should be cautious saying:**
  - Reduced Bacterial Adhesion
  - Absorption of Antibiotics

Specific requirements

Posthemorrhagic hydrocephalus of the premature

Pressure differential valve of ball-in-cup or diaphragm design

High brain turgor patients (achondroplasia, Crouzons, others)

High pressure shunts
May even need valves in series.

Low brain turgor patients (NPH)

LP shunt with ASD

Cost of various shunt systems

No.	Name	Rupees
1	Codman programmable	45,000
2	Medtronic programmable	39,000
3.	Diamond (vygon)	17,000
4.	Bactiseal	12,000
5.	Phoenix(vygon)	5,000
6.	Ceredrain	1,300
7.	Chhabra	1,240

Indian Scenario

- “The inexpensive Chhabra shunt in comparison to Codman shunt had no statistically significant diff in outcome”**(J Neurosurgery {peds 4}102:358-362,2005)**

Valve design trials

- "Multicentre randomized trials of CSF shunt valve design have failed to demonstrate any difference among the valves in cases of shunt failure."

1. *DRAKE Jm et al-RCT of CSF valve design in pediatric pts. Neurosurgery 43:294-305. 1999*
2. *Pollack et al- RCT of a programmable valve versus a conventional valve for patients with HCP. Neurosurgery 45:1399-1408,1999.*

- *Exception = Antibiotic impregnated shunt.*

Unmet Medical Needs
Shunting

- "Smart Shunting"
  - Intracranial Pressure Sensing
  - CSF Shunt Flow Sensing
  - Internal Feedback Control
- Reduction of Shunt Infection Rates
- Self-healing properties and the ability to elongate with patient growth, may be characteristic of future biomaterials.