16. Hydrocephalus shunts
Shunt technology

- Closing mechanism: Ball on spring versus silicone membrane or mitre valves
- Programmable valves
- Preventing overdrainage
From Hydrocephalus to .... complications

Hydrocephalus

Diagnosis

Shunting

Complications

Hydrodynamic properties of shunts
Cambridge Shunt Evaluation Laboratory
Membrane valves:
Ball on spring valves
The **SinuShunt** is the classic differential pressure mitre valve designed to drain cerebrospinal fluid from brain ventricles to the cranial transversal venous sinus. Its opening pressure is intended to be close to 0 mm Hg and hydrodynamic resistance close to physiological resistance to CSF outflow (8 mm Hg/(ml/min)). With such parameters shunt is intended to restore physiological conditions to CSF outflow.

**Schematic diagram of the SinuShunt (provided by the manufacturer)**

1. Connector  
2. One way valves  
3. Pre-chamber  
4. Resistance tube  
5. Distal catheter
‘Autoregulation’ valve- OrbisSigma

- stabilizes flow, not a pressure
- prevents overdrainage
- contraindicated in patients suffering from intermittent (vasogenic) ICP waves

[Diagram showing the components of the valve: INLET, CASE, NOTCHED PIN, SEAT, DIAPHRAGM, OUTLET]

[Graph showing the relationship between flow and pressure with a specified region of flow stabilisation]
Codman-Medos Programmable Valve
- 18 precise steps of programming
- low resistance
- may overdrain
- may be reprogrammed accidentally
- small particles may damage opening-closing properties
Strata Valve: ‘Ball-On-Spring’ adjustable valve + Delta Siphon Controlling Device
All valves work on the same principle: magnetically movable rotor changes pre-load of spring supporting ball in cone.

Sophy Valve

Schematic diagram of construction of Sophysa Polaris Valve (Figure scanned from the leaflet provided by the manufacturer). 1: inlet connector, 2: semicircular spring; 3 & 12: radiopaque setting identification points, 4: rotor, 5: ruby axis, 6: micromagnet, 7: outlet, 8: fixation holes, 9: ruby ball, 10: adjustment lugs, 11: safety stop.
**ProGAV**: The unit consists of two parts: programmable ball-on-spring valve (A,B) and shunt-assistant which increases opening pressure in vertical position to prevent overdrainage (C). Programming is achieved by turning of the rotor, which controls pre-load of cantilevered spring (E). Possible adjustment is continuous from 0 to 20 cm of water.
Problems with posture-related overdrainage

Shunting to peritoneal space or to heart
Pressure in upright position may be grossly negative in upright position

Reasons for Revision

Adult (17+)
- Fracture
- Disconnection
- Migration
- Infection
- Overdrainage
- Underdrainage

Child (0-16)
- Fracture
- Disconnection
- Migration
- Infection
- Overdrainage
- Underdrainage


Thanks to Dr. HK Richards

U.K. Shunt Registry
Preventing Overdrainage

Medtronik PS Medical Delta Valve
(with siphon control device)
Hayer-Shulte Anti-Siphon Device
Gravitational devices:

example - Chhabra Shunt
Siphon prevention

ShuntAssistant

C
The Valve switches from low opening pressure in horizontal position to high pressure opening valve in vertical body position. There are 9 combinations of operating pressure (3 horizontal and 3 vertical).

Schematic diagram of the DualSwitch Valve.
1. Titanium casing
2. Silicone diaphragm supported by flat spring. Left- low tension; Right-high tension spring
3. Closing ball
4. Outlet chambers. Right chamber (outlet from high-pressure valve) is always open. Left chamber (outlet from the low-pressure valve) is open only in horizontal position.
5. Heavy tantalum ball blocking low pressure valve in vertical position.
Programmable Shunt Assistant: ProSA

Schematic diagram of construction of proSA (Figure copied from the Manufacturer web-page).
1-inlet connector, 2-outlet connector; 3- sapphire ball, 4- weight, 5- bow spring 6-rotor with micro magnets, 7- outlet,
Codman Hakim: Siphon Guard

Two channels: middle-low resistance and spiral outer-high resistance – around 40 mmHg/(ml/min). Switching may be unreliable.
Switching is unstable—it may happen on different flow levels.
The valve may be programmed and its performance level may be verified with very simple hand tools.
Tests were performed using: constant flow of 0.3 ml/min at different programming levels (below), flow increasing from 0 to 1.5 ml/min in triangular pattern (upper right) using computer-controlled infusion pump, or with fluid flowing out of high container over longer period (usually 4-6 hours) – right lower corner
Scattering of the pressure-flow curves

Pressure-flow curves depend on operational pressure of the valve.

Valve may generate pressure waves
Pulsations of pressure before and past the shunt
Relationship between operating pressure (y-axis) and peak-to-peak pulse amplitude (x-axis).
Influence of the peritoneal drain

Programming of the valve has been checked both using pressure-flow and flow-pressure tests. Good agreement of the pressure-flow curves with the nominal data has been recorded. The following graphs illustrate flow-pressure curves of the valve set at different performance levels.

Valve has five distinct operating performance levels.

Closing pressure values and 95% confidence limits are presented in graphical form below.
Adjusting Performance Level

Hakim-Programmable

Miethke-ProGAV

Strata

Sophy

Polaris
Magnetic field interactions in adjustable hydrocephalus shunts

Laboratory investigation

ANDREA LAVINIO, M.D.,1,2 SALLY HARDING, PH.D.,3 FLOOR VAN DER BOOGAARD, M.D.,1 MAREK CZOSNYKA, PH.D.,1,4 PETER SMIELEWSKI, PH.D.,1 HUGH K. RICHARDS, PH.D.,1 JOHN D. PICKARD, F.MED.SCI.,1,3 AND ZOFIA H. CZOSNYKA, PH.D.1,4

1United Kingdom Shunt Evaluation Laboratory, 2Neurosurgery Unit, Department of Clinical Neurosciences; 3Wolfson Brain Imaging Centre, University of Cambridge, United Kingdom; and 2Institute of Anaesthesiology and Intensive Care Medicine, University of Brescia, Italy

Object. Exposing patients with ventricular shunts to magnetic fields and MR imaging procedures poses a significant risk of unintentional changes in shunt settings. Shunt valves can also generate considerable imaging artifacts. The purpose of this study was to determine the magnetic field safety and MR imaging compatibility of 5 adjustable models of hydrocephalus shunts.

Methods. The Codman Hakim (regular and with SiphonGuard), Miethke ProGAV, Medtronic Strata, Sophysa Sophy and Polaris programmable valves were tested in a low-intensity magnetic field, and then translational attraction (TA), magnetic torque (MT), and volume of artifacts on T1-weighted spin echo (SE) and gradient echo (GE) pulse sequences in a 3-T MR imaging unit were measured.
Two stages of examination: First- low intensity field
All programmable valves are sensitive to external magnetic field (> 10 mT)
Strata valve
**Sophysa valve**

- **Probability of switch**
- **Magnetic field [mT]**

Graph showing the probability of switch across different magnetic field values, with shaded areas indicating unstable and stable positions.
Medos-Hakim valve

Probability of switch

Magnetic field [mT]
Every day life devices generating (electro-)magnetic fields

<table>
<thead>
<tr>
<th>Device</th>
<th>Measured flux density [mT]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical shaver/cooker</td>
<td>1.0</td>
</tr>
<tr>
<td>Loudspeaker boxes</td>
<td>2.2</td>
</tr>
<tr>
<td>Hair dryer (30-cm distance)</td>
<td>2.5</td>
</tr>
<tr>
<td>Headphones</td>
<td>7.0-23.0</td>
</tr>
<tr>
<td>Attached cord receiver</td>
<td>8.5</td>
</tr>
<tr>
<td>Cellular telephone</td>
<td>17.5</td>
</tr>
<tr>
<td>Cab of electrical railway engines</td>
<td>Up to 50</td>
</tr>
<tr>
<td>Induction heating systems [50Hz-10kHz]</td>
<td>4.5 up to 130</td>
</tr>
</tbody>
</table>
Distortion of Gradient-Echo image:
Distortion of T1 image
Message to take home

• All shunts are pressure-passive
• Adjustability - reasonable aim helping to minimize revision rate
• Majority of valves have unphysiologically low resistance (when open)
• Few offer reasonable prevention against posture-related overdrainage
• Adjustable valves distort MRI image
• Most of adjustable valves (except ProGAV and Polaris) may be accidentally re-adjusted by external magnetic field
• Prizes vary: from 300 to 1600 GBP