Smart Shunt For Treatment Of Hydrocephalus

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Objectives

The smart shunt will provide ease for both the patient and the doctor by providing necessary data for diagnosis. The shunt failure or over drainage will be separated from normal illness, such as Flu.

- Providing accurate data for future developments and designs.
- Protecting the patient from over drainage risks.
- Protecting the patient from ICP increase risks.
- Alerting the patient to change his posture.
- Wireless communication and live data transmission for both the patient and the doctor.
- Allowing automatic adjustments for the opening pressure.
- Allowing the doctor to perform adjustments on the value without the patient rushing to the emergency room every single time.
- Protect the patient from experiencing coma, stroke, seizure or even death

Methodology

The sensors will be implanted near the shunt sealed to distal catheter. The device will harvest power to work from external unit with the help of RF technology. Telemetry electronics, load modulator, RF-DC converter are used in the implant to supply the circuit with the required voltage. Feedback between the implant and the external unit will regulate the data transmission and RF transmission rates to keep the temperature at an optimal rates, Pressure, flow, and tilt data are transmitted to the external unit with Bluetooth to be processed. If any of the readings exceed the normal limits, the patient will be alerted and given some instruction like sitting or lying down for a period of time. The doctor will be alerted to view the data and make adjustment to the valve or tell the patient to go to the hospital. These adjustments may be performed automatically.

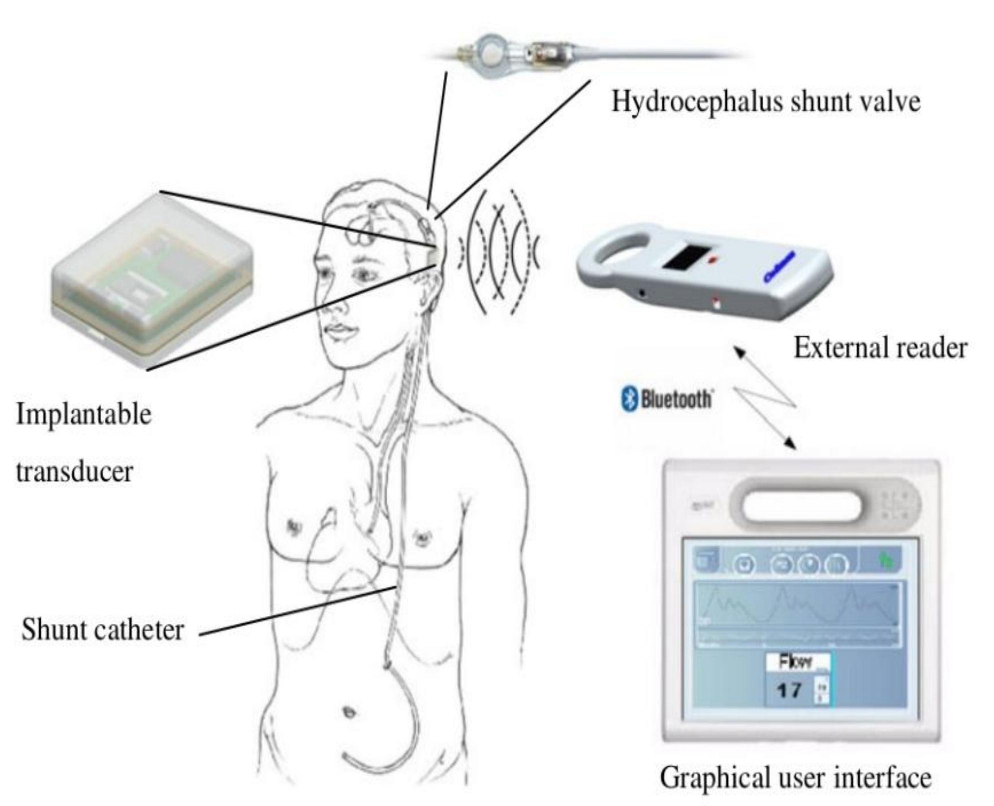


Fig1: Implant and external unit communication over Bluetooth

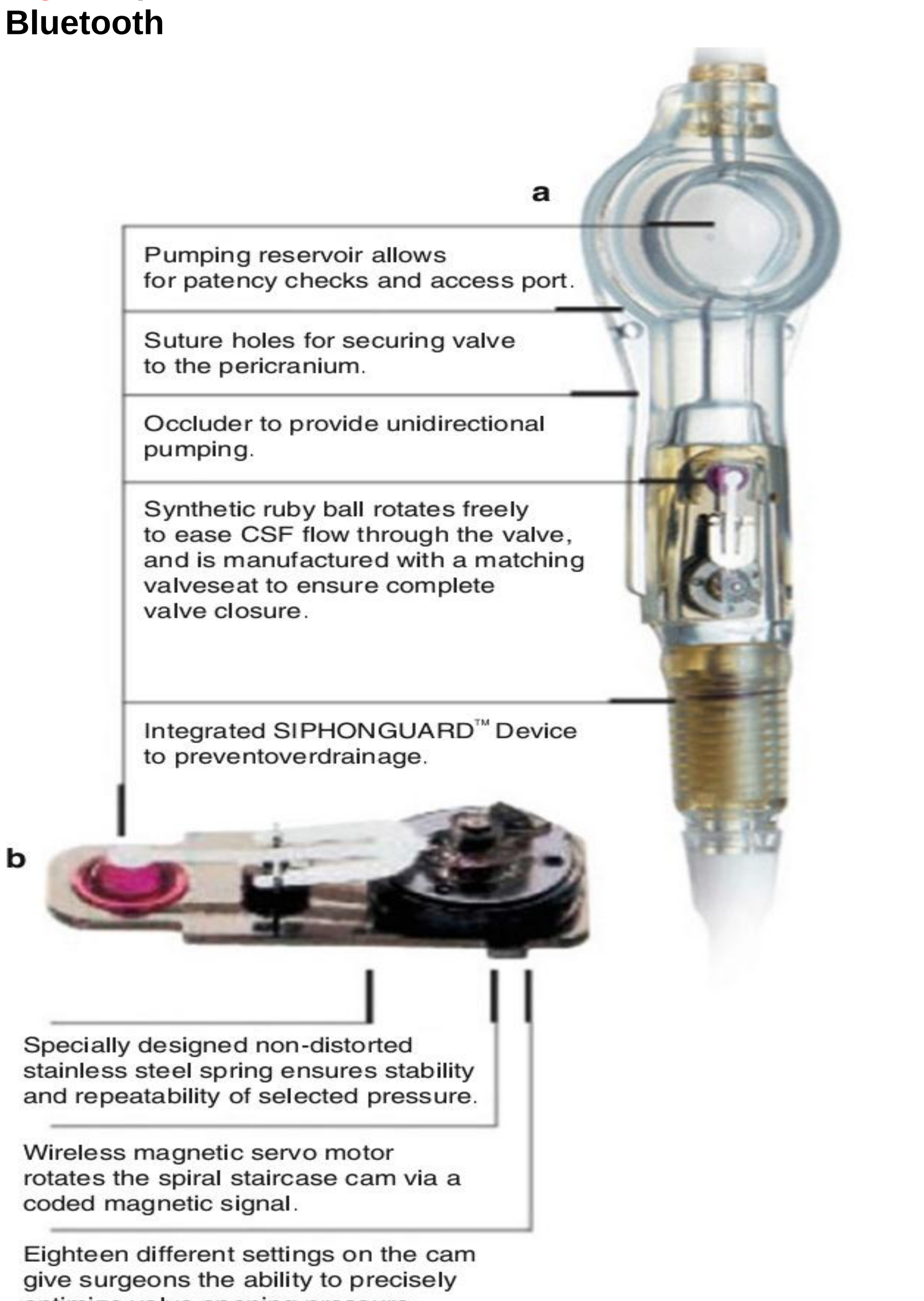


Fig2: shunt with a wireless programmable servo motor for adjusting opening pressure

Materials & Sensors

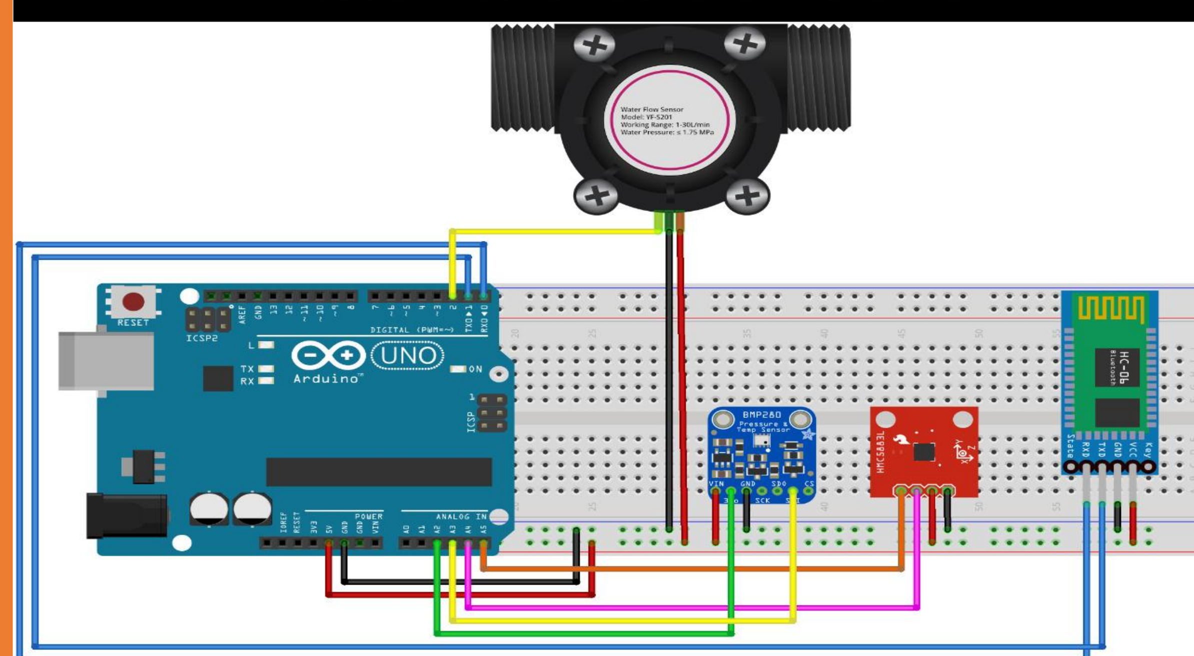


Fig3: schematic with meme pressure sensor, flow sensor tilt sensor, Bluetooth module, and arduino

1. Flow Sensor

Theory of operation

It is based on the amount of heat removed from a heat temperature sensor. It is modeled using heat transfer in liquids. R2 act as a heater and R1 & R3 act as temperature sensors to determine the velocity of the flow and its direction.

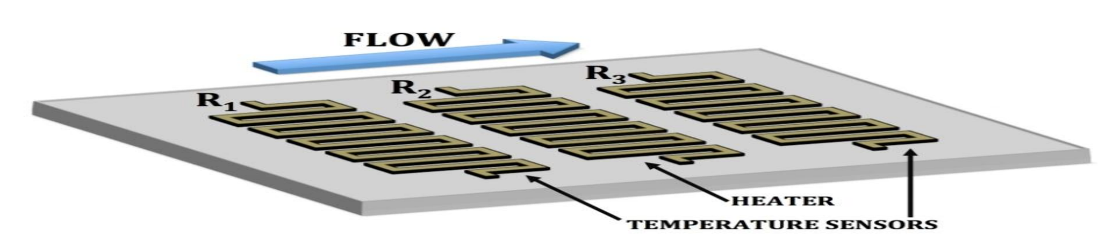


Fig4: calorimetric flow sensor

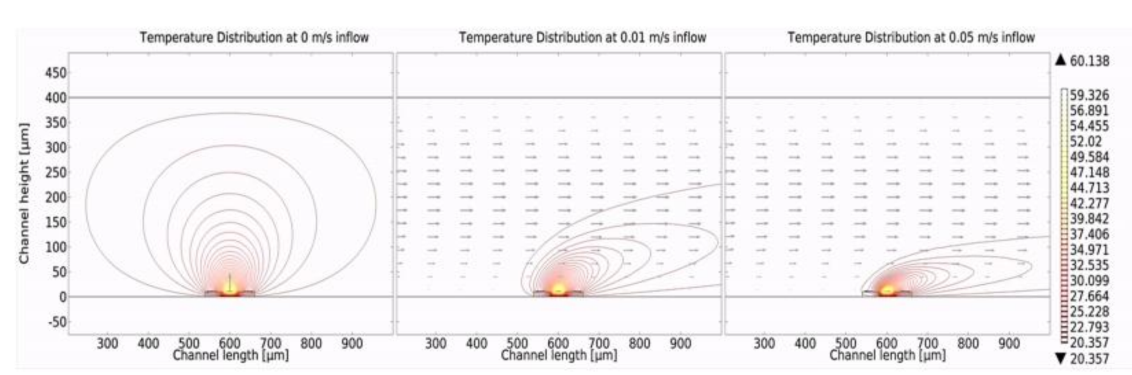


Fig5: temperature distribution with different flow rates

Sensor Electronics And Block Diagrams

- **Calorimetric flow sensor (based on thermal anemometer principle).**
- **Microprocessor.**
- **RF section.**

The CMOS chip contain the sensor and all necessary electronics

- **ADC.**
- **Linearization amplifier.**
- **Temperature compensation.**
- **Calibration memory.**
- **Power supply.**
- **Antenna.**
- **Load Modulator.**
- **Flow channel**

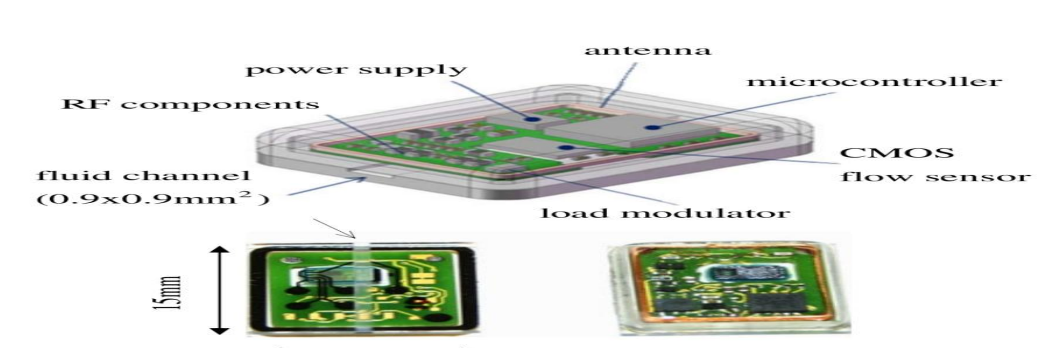


Fig6: components of flow sensor

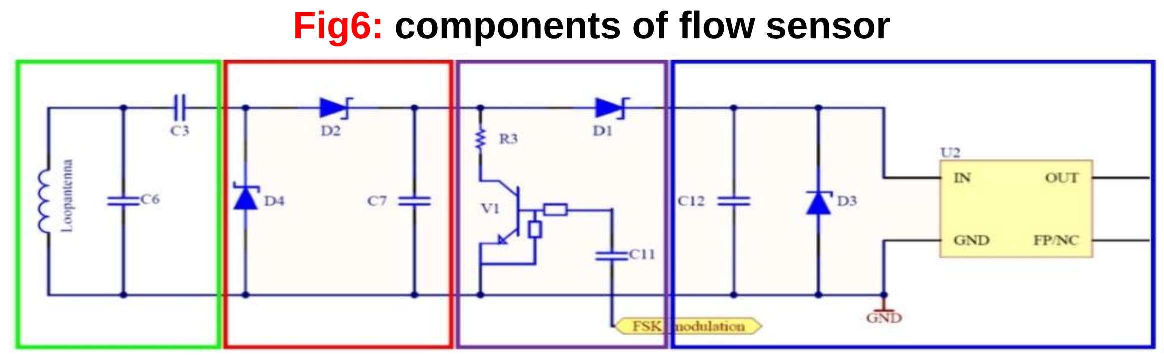


Fig7: Green box: loop antenna and impedance matching. Red box: RF-DC converter. Purple box: load modulator. Blue box Dc supply.

Power Management & Data Transmission In All Sensors Depend On Circuit Shown In Fig6.

- **RF-DC converter output is passed to voltage regulator which is used to supply 3.3 V to the CMOS flow sensor.**
- **Minimum energy for the implant is 19.17 mW**
  - **16.3 mW by the CMOS sensor.**
  - **2.87 mW by the microcontroller.**
- **Large capacitor used in DC supply unit (C12) to stable the power supply during load modulation.**
- **In load modulator:**
  - **R3 is small and limited by collector current to ensure maximum load modulation amplitude.**
  - **C11 is used to adjust the modulation pulse.**
- **If pulse width is large, energy dissipation in R3 is increased and the range of telemetry is reduced.**
- **If the pulse width is small, the FSK signal will not be detected by the external unit.**
- **15% to 20% duty cycle has the best results.**
- **Diodes is used instead of inductivity used in most telemetry to reduce the thickness of the implant.**

2. Pressure Sensor

Theory of operation

two conducting layers are deposited on a diaphragm to create a capacitor. pressure added change the spacing between the two layers which change the capacitance. the change is measured by adding the sensor with a tuned circuit that change its frequency with pressure. additional electronics added turn it to an oscillator which is optimal for wireless data transmission with the help of antenna technology.

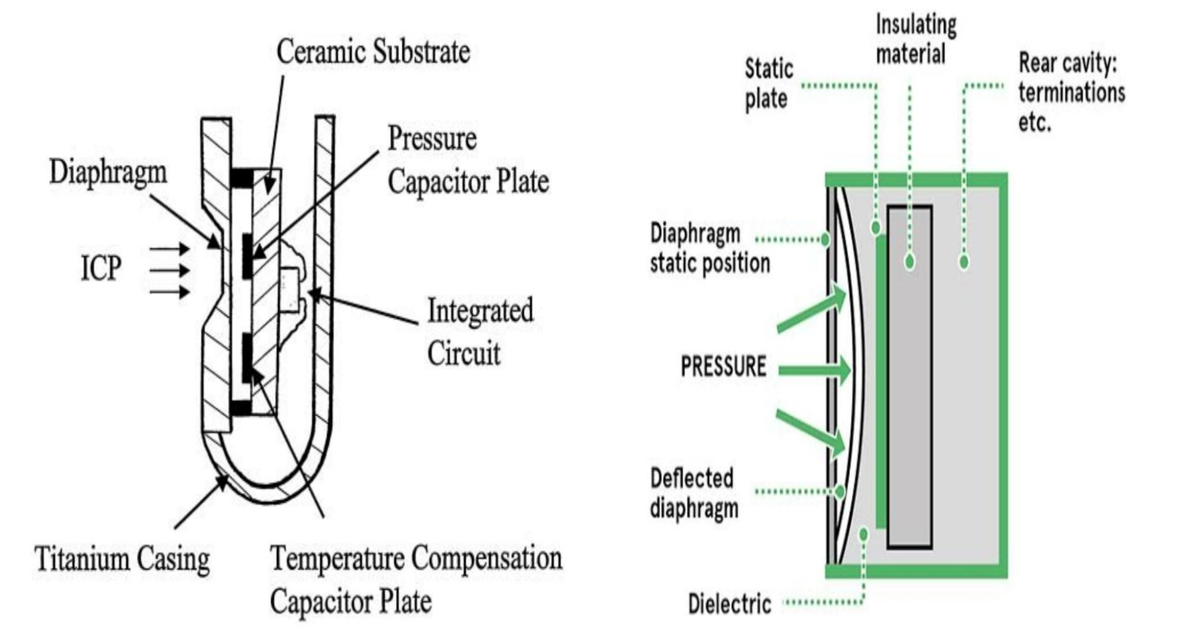


Fig8: ICP sensor placement in the shunt and working principle

3. Tilt Sensor

Theory of operation

When rotation occurs in a certain direction, gravity forces the moving rod to go toward the first fixed bar while moving away from the other. This causes the change in capacitance to occur, and there are increasing on the side that the moving rod moves toward, and decreasing on the other side, then The differential capacitance |Cright-Cleft|.

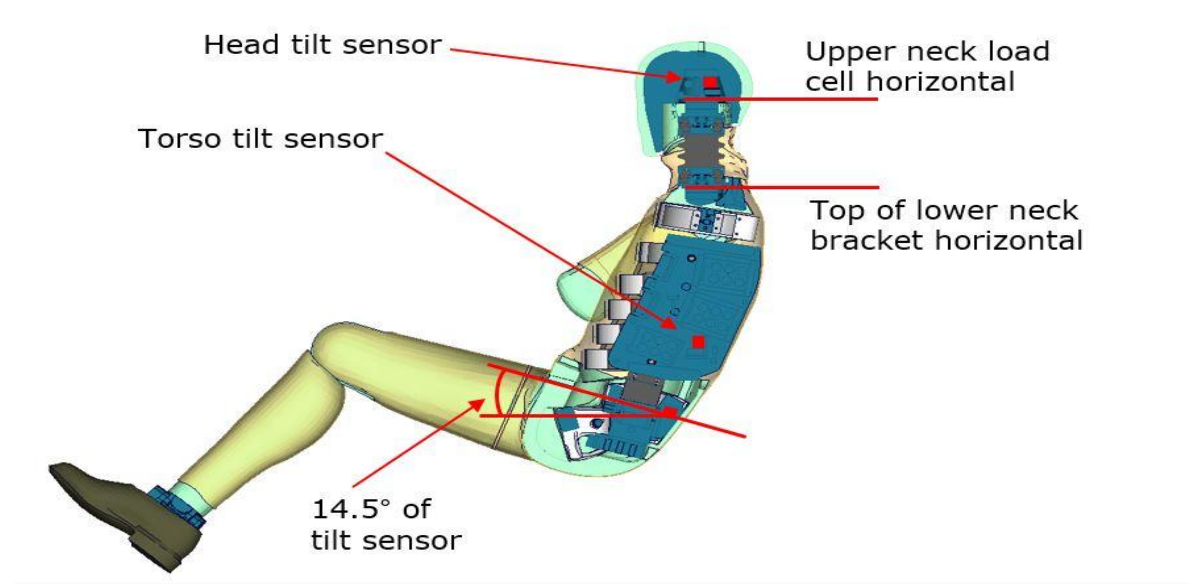


Fig9: Tilt sensor to determine the posture of the patient.

Results

CSF absorption depend on difference between ICP and Dural sinus pressure. Head lower than the heart also affect absorption. If the head is down by 20 degree for 10 min , LVP and SSP increase but return back to normal quickly in the horizontal position. ICP increase 3 times more than normal if the head is inverted. Tabel1 show the corresponding CSF and blood

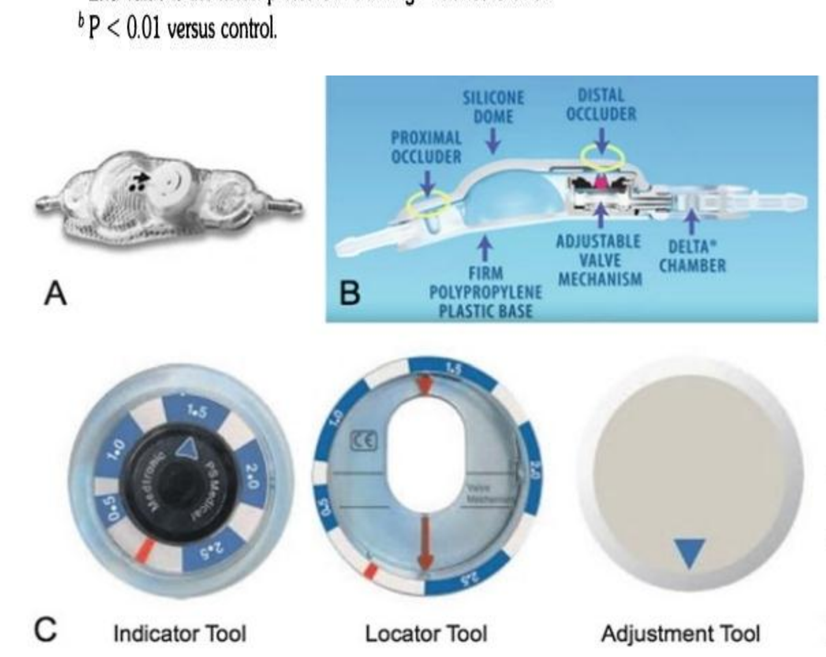
Table 1. Effect of Head-Down Tilt on Cerebrospinal Fluid and Blood Pressures.[a]

	Horizontal Position (Control)	Head-Down Tilt (min) 10	20	40	60	80	100	120	Return to Horizontal Position
LVP	4 ± 0	12 ± 1[b]	11 ± 1[b]	11 ± 1[b]	11 ± 1[b]	11 ± 1[b]	11 ± 1[b]	12 ± 1[b]	4 ± 1
SSP	−2 ± 0	5 ± 0[b]	5 ± 0[b]	5 ± 0[b]	5 ± 0[b]	5 ± 0[b]	5 ± 0[b]	5 ± 0[b]	−2 ± 0
ECSFP	7 ± 1	9 ± 0	8 ± 1	8 ± 1	8 ± 1	8 ± 1	9 ± 1	9 ± 1	7 ± 1
MAP	83 ± 3	93 ± 2[b]	93 ± 4[b]	93 ± 4[b]	94 ± 5[b]	90 ± 8	89 ± 8	89 ± 8	84 ± 5

LVP, lateral ventricular pressure; SSP, sagittal sinus pressure; ECSFP, effective cerebral spinal fluid pressure; MAP, mean arterial pressure.

[a] End value is the mean pressure in mm Hg ± standard error.

[b] $P < 0.01$ versus control.



Valve Performance Level	Opening Pressure (cm H_2O) Lying	Opening Pressure (cm H_2O) Standing
0.5	1.5	3.0
1.0	3.5	5.0
1.5	7.0	8.5
2.0	10.5	12.0
2.5	13.5	14.7

Fig10: valve different opening pressure while standing and lying

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