Project Title	**Smart Shunt For Treatment Of Hydrocephalus**		
Track	**Engineering And Applied Sciences**		
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Team Name	MARS99-SBME		
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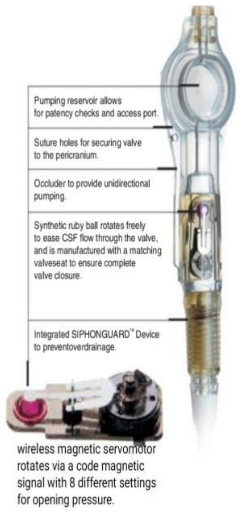
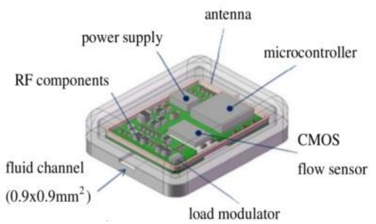
Problem Summary

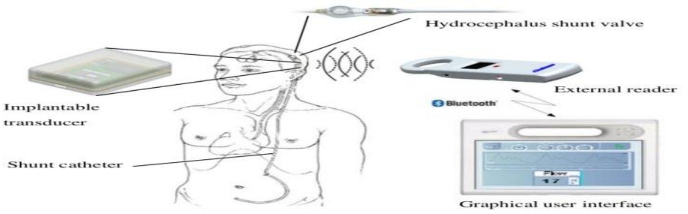
Hydrocephalus is a common congenital disorder of CNS (Central Nervous System) that may be presented in one out of 500 to 2000 children. It is also presented due to aging which cause dementia and gait (Walking) problems. CSF production rate is 20 ml/h if it is not absorbed properly it causes hydrocephalus. The main treatment is a **Shunt** placement (100,000 surgeries per year). Normal ICP in adults range from 5 to 15 mmHg (herniation may occur at 20 mmHg). Shunt blockage in the first year ranges from 20% to 30%. For diagnoses an invasive procedure is used if not sure then surgery for replacement is preferred, but this could be very expensive. ICP capacitive sensing with the kit tool can provide pressure measurement, but the **Smart Shunt** with implantable and biocompatible flow sensor provide an efficient way for diagnosing the blockage of the shunt, over-drainage, and under-drainage with much cheaper, safer, and 24/7 remote monitoring system compared to the current technologies(e.g. MRI, CFD or ultrasound with contrast). These continuous readings could lead to a better understanding of hydrocephalus treatment and better quality of life for the patients. The **Smart Shunt** readings from the tilt sensor combined with ICP pressure sensor data confirm the patient position and the future risks and alert him to change his posture if the ICP or flow rate increase (over drainage) which may be caused by shunt failure and cause coma, stroke, seizure, or even death. The device harvest its power thought RF antenna and additional electronics to power the device and transmit the data through passive telemetry. Smart shunt will provide better care and ease for both the patient and the doctor as it will provide the necessary data for diagnosing the shunt failure, high risk symptoms such as over drainage and increased ICP and separate it from other illnesses like flu reducing the panic and rushing to emergency rooms every time the patient experience headache or feel dizzy. It also will provide accurate readings for future development of the shunt and solving its failure causes.

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 and power to work properly.
- 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.
- The data is stored in the external unit to be processed and viewed by both the patient and the doctor.
- 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 until the vitals are stable.
- The doctor will be alerted to view the data and make adjustment to the valve or tell the patient to go to the hospital if necessary.
- Wireless magnetic servo motor rotate via a coded magnetic signal to adjust the opening pressure of the shunt which can reach eight different setting. These adjustments may be performed automatically.







Achievements and Skills Gained

1. **Basic human anatomy and Physiology, especially Brain anatomy and CSF cycle its main functions, how to model this biological system and the mathematical equations for the fluid dynamics.**
2. **Understanding the hydrocephalus disease and knowing its risks and treatment.**
3. **Shunt hardware design (proximal & distal catheters – connectors – over drainage control devices – different types of valves {slit – miter – diaphragm – ball in cone – flow regulating - adjustable}).**

For The Smart Shunt :

4. **Principle of working for (flow sensor – intracranial pressure sensor – tilt sensor) and reliability on the readings of the sensors with different positions and other factors.**
5. **Power management of the implant and biocompatibility.**
6. **Wireless body communication and telemetry medicine.**
7. **Wireless powering of medical sensors.**
8. **Transducer telemetry electronics (antenna – RF-DC converter – load modulator – DC supply).**
9. **Standard Signal suitable for data transmission between the implant and external unit (FSK signal – pulse width – duty cycle).**

(Cont.)

Project: Smart Shunt For Treatment Of Hydrocephalus

Main Results

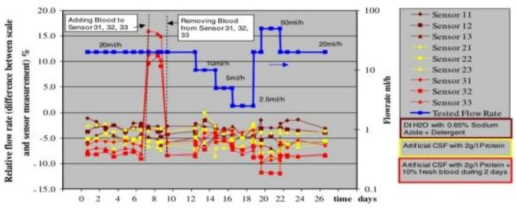


Figure 1 : relative flow rate over 26 days with different scenarios

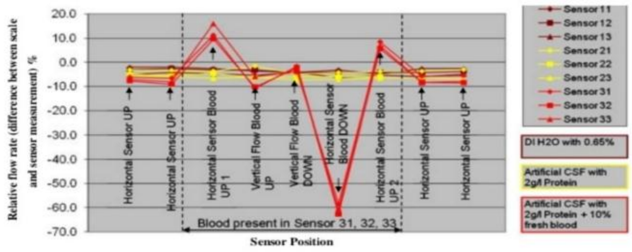


Figure 2 : different positions for the sensor and flow direction

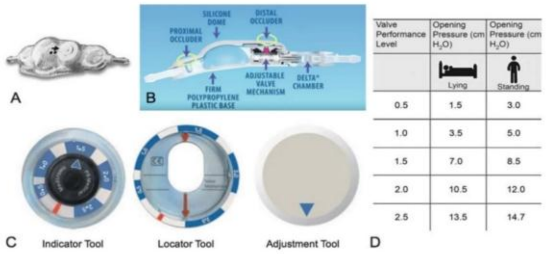


Figure 3: the typical shunt design with opening pressure values on lying and standing

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.

Discussion and Conclusion

- **Figure 1:** Three sensors are used to measure the relative flow rate with reference to flow rate measurement taken by a scale. Different scenarios are presented to improve accuracy, precision, and reliability of the sensor with calibrating the sensor once at 22 ˚ C and also at 37 ˚ C; also different fluids were used with different flow rates.

$$relative\ flow\ rate = \frac{flow\ rate(sensor) -\ flow\ rate(scale)}{flow\ rate(scale)} * 100\ \%$$

22˚C calibrated sensor has offset of -5.4%. 37˚C calibrated sensor has offset of + 6.3%. The compensation average for all relative flow rates is 0.9%. We notice that there is no major difference in the relative flow rate with changing the flow rate from 2.5 ml/h to 50 ml/h all readings are between (0% and 10% offset).
- **Figure 2:** Different orientations for the sensor were made to ensure the reliability of the readings for the patient in different positions combined with tilt sensor data the patient position is confirmed and the opening pressure is adjusted. These results show if there is no blood in the CSF, the orientation of the sensor doesn't affect the readings.
- **Figure 3:** This figure show the main design of the shunt, the adjustment kit, and opening pressure for lying and standing which will be considered to alert the patient and the doctor if there is a risk and also as guidance for simple adjustments.
- **Table 1:** CSF absorption depends on difference between ICP and Dural sinus pressure. Head lower than the heart also affects 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.

References

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Future Work and Suggestions

Suggestions And Main Challenges For:

- **Sensors:** Improve accuracy for low pressures and MRI compatibility.
- **Motor and control mechanism:** Improve power consumption and MRI compatibility.
- **Power source:** Long battery life (avg. 10 years) or rechargeable battery.
- **Communication:** Improve wireless communication, RF antenna technology and Bluetooth.
- **Bio-compatible components.**

Group Photo