301-23 - Excellence - shunt_valve - Executive Summary

Executive Summary: Tong BME Design Award, BME 301

Hydrocephalus Shunt Valve

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Hydrocephalus is caused by the insufficient drainage of cerebrospinal fluid from the skull, resulting in high intracranial pressures (ICP) that can damage the brain. It affects three in every 2000 individuals at birth, and is the most common reason for brain surgery in children and infants. Total average medical expenditures on hydrocephalus exceed $1 billion per year, and over 40,000 operations are conducted annually to attempt to correct the symptoms of hydrocephalus. (*hydroassoc.org*) Roughly 30% of individuals with hydrocephalus will experience intellectual disability at some point in their life (*nhfonline.org*).

Implanted shunt valves treat the resulting high ICP of hydrocephalus by removing CSF from the interior of the blood-brain barrier. Most commercial shunt valves function *via* pressure differentials between the intracranial space and the abdomen (Drake, James M., et al.). A common mode of failure observed in these valves is the formation of a blockage known as a proximal occlusion at the junction of tubing and the valve itself. Proximal occlusion has been observed to be indirectly related to problems with valve overdrainage due to a siphoning effect. Even with the development of programmable differential pressure valve systems, top of the line shunt valves display failure rates of 81% within 12 years of implantation (Sainte-Rose et. al.).

To alleviate overdrainage seen in commercial differential pressure devices, the proposed device regulates fluid flow utilizing the pressure differences between ambient and intracranial pressures. The device consists of an upper fluid reservoir for storing inflowing CSF and a lower fluid reservoir which counterbalances the ICP using ambient pressure from surrounding tissues and a support spring. A piston separates the two reservoirs. When the ICP inside the upper reservoir overcomes the ambient pressure and spring force, the piston is forced down, uncovering an outflow port, and the CSF is drained. The ICP is returned to standard physiological levels and the piston closes again, preventing overdrainage. The design behaves viscoelastically according to the Kelvin-Voigt model to prevent “jackhammering,” repetitive piston movement caused by every tiny shift in ICP. This behavior reduces the fatigue experienced by the components, ensuring that the device opens only when intracranial pressure reaches a certain average threshold.

This design presents a novel approach to control ICP in shunt valves designed for hydrocephalus. If commercialized, the ease of fabrication and increased durability of valves employing ambient pressure present a myriad of possibilities in future shunt valve constructs. To construct the large-scale prototype, the team calculated the spring constants of several springs, dictating placement of the outflow on the prototype, and used the Reynolds number to calculate the scaled dimensions and the corresponding fluid flow in the large scale prototype.