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Gravity- and Pressure-Controlled Valve System for Controlling Cerebrospinal Fluid in the Ventricular System

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Technology description

Hydrocephalus is a disorder in which a subject’ s body produces cerebrospinal fluid (CSF) at a rate faster than the venous system is able to absorb the fluid. The increase in intracranial pressure (ICP) caused by the excess fluid can lead to a number of uncomfortable and potentially dangerous neurological symptoms and conditions including headache, cerebral edema, seizures, brain herniation and death. Traditional treatment for hydrocephalus uses “shunts” made of flexible tubing inserted into the ventricular system to drain the excess fluid from the ventricular system to another body cavity such as the peritoneal cavity, from which it is absorbed back into the circulatory system. However, in at least 10 percent of cases, CSF drainage shunts lead to slit ventricle syndrome, where the ventricular system is overdrained, resulting in abnormally low ICPs and causing debilitating headaches and, in severe cases, dural hemorrhage. Over time, the ventricular system can cycle through very low pressures followed by obstruction, which causes very high pressures, eventually reaching a state in which the shunt becomes permanently obstructed and fails. In this state, ICP can rise to dangerous levels and the shunt must be replaced on an urgent basis.

The root causes of slit ventricle syndrome are not understood. A gravity-induced siphoning effect is thought to play a role, but current anti-siphoning valves often fail to prevent or to reverse slit ventricle syndrome. The reason for failure has up to the present time been a mystery. An improved understanding of the root causes of slit ventricle syndrome would be highly desirable, as well as a system and a method of controlling CSF drainage from the ventricular system that avoids overdrainage of CSF. UW–Madison researchers have developed a system that allows drainage of excess CSF and prevents CSF overdrainage. A key insight is that cardiac pulsations can be transmitted inside the shunt tubing, creating a pulsatile pressure wave that propagates down the tubing. When this pressure wave hits a pressure differential valve, it can force the valve open during the systolic phase of the pressure wave, pumping some CSF through the valve with each systolic phase. In this way, CSF can be pumped across a valve as long as the peak pressure within the shunt tubing exceeds the preset pressure differential threshold for that valve, even if the mean pressure is below that same threshold. Overdrainage then occurs. The improved system and valve design prevent slit ventricle syndrome by addressing both gravity siphon effects and cardiac pulsations.

The improved system consists of tubing that leads from the ventricular system into a valve system that has two arms, a forward flow arm and a return flow arm. A one-way low threshold pressure differential valve is located in the forward flow arm. CSF that passes this first valve can either exit the valve system through a one-way higher threshold exit valve that leads into the peritoneal cavity, or it can flow through the return flow arm via a one-way low threshold valve that returns CSF back to the inlet side of the valve system. By choosing appropriate pressure differentials for the three valves, one can bracket the pressures on the inlet side between a set minimum and maximum value. If the ICP rises above the set maximum, then CSF will flow through the inlet valve and out the exit valve. If the ICP drops below the set minimum, then CSF will flow through the return valve and back towards the inlet side of the valve system, thus preventing overdrainage. The high threshold pressure differential exit valve also incorporates a gravity compensation unit that negates the gravity siphoning effect, regardless of the orientation of the patient. Thus, the net effect is to allow for drainage of excess CSF while preventing overdrainage due to either the cardiac pulsation or gravity siphon effect.
The Wisconsin Alumni Research Foundation (WARF) is seeking commercial partners interested in developing a valve system that inhibits cerebrospinal fluid overdrainage, which leads to slit ventricle syndrome.

Application area

Cerebrospinal fluid shunt devices

Advantages

Addresses gravity siphon effects as well as cardiac pulsation effects on ICP that can lead to CSF overdrainage

Institution

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