Prototype for a Neural Horizontal Semicircular Canal Prosthesis

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Spatial orientation, which affects balance and vision, is greatly affected by the vestibular system found in each inner ear. This system includes three semicircular canals and two otolith organs. These five components perform complex measurements related to spatial orientation, which includes angular velocity and linear acceleration about 3 axes. This information is utilized by the nervous system to determine the motion and orientation of the head. Loss of vestibular function can result in balance difficulties, nystagmus and blurred vision.

A prototype for a semicircular canal prosthesis is currently being tested on animals. Since it is just the first step to a complete solution, it only concentrates on the horizontal plane, allowing for one dimension of rotation. If successful, it will lead to the establishment of a vestibular prosthesis that can perform all of the functions of a normal system.

The horizontal semicircular canal prosthesis mimics the normal function by sending a broad range of frequencies through electrical stimulation. A piezoelectric vibrating gyroscope senses the angular velocity of the head. This measurement is then amplified, filtered and converted from analog to digital. The final result is then converted to stimulation frequency via a look-up table. Electric pulses at the corresponding frequency are then delivered to the vestibular nerve. This is done using platinum wire electrodes which are surgically implanted near the nerve.

The first prototype was built to be tested on guinea pigs. The device is meant to be mounted on top of the animal's head. The circuit components include: an angular rate sensor (GYROSTAR Model ENC-05E), a CMOS microcontroller (PIC16F84-04/SO), a current source, a power supply (batteries), resistors and capacitors. Surface mount technology was utilized so that the size and weight of the device are minimal.

The prosthesis was firmly attached to the guinea pigs skull by a surgically attached head bolt. A second surgery was required to implant a pair of electrodes in each ear, near the vestibular nerve. A "ground" wire was also inserted into surface muscles.

Two types of experiments were conducted. In the first, the head remained stationary while the device was rotated. Therefore, electrical stimulation was the only source of information regarding spatial orientation. In the second experiment, the semicircular canal was surgically plugged. The first experiment had a greater gain than the second but both trials showed that the animal adapted to the new device after a day.

Eye movement and nystagmus were measured to determine the animal's response to the stimulation. So far, nystagmus is almost completely relieved and eye movement is detected. These successful test results helped to determine that the next step should be clinical tests on humans.