A Microprocessor Controlled Intracranial Pressure Monitor

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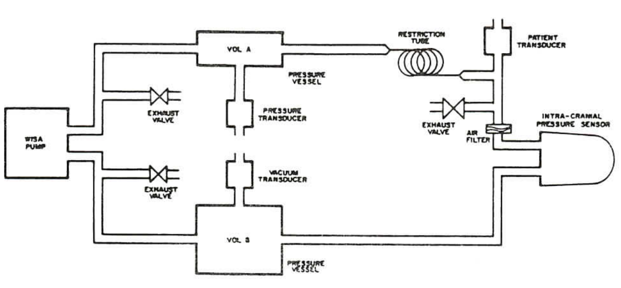
A new intracranial pressure monitor has been developed which utilizes an inexpensive, disposable sensor. The sensor is free from drift and is pneumatically activated, decreasing the electrical shock hazard to the patient. The system provides graphs of both intracranial and cerebral perfusion pressures, retaining memory of the previous 24 hours of data. Both analog and serial digital outputs are included for interfacing with monitoring systems and computers.

Elevated intracranial pressure (ICP) can occur due to head trauma, neurosurgical procedures, encephalitis, hydrocephalus, or drug intoxication. If excessive pressure is allowed to develop inside the head, cerebral circulation is impaired and ischemia results. In addition, the pressure can force the brainstem down through the base of the skull causing death. By detecting the increasing pressure early, it can be controlled by drugs or, in extreme cases, direct drainage.

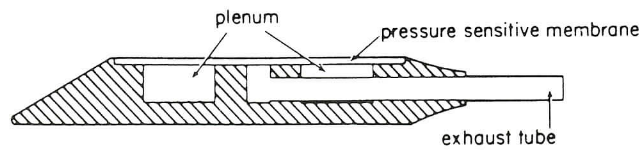
Several methods have been devised for ICP monitoring. Direct monitoring from the ventricles of the brain or subarachnoid spaces (invasive methods) using fluid-filled catheters provides the required data but also opens a path for infection, thereby severely limiting the safe monitoring period to only a few days. The most widely used invasive device is the Richmond screw which measures ICP by tapping the subarachnoid space. The hollow screw is connected via a saline-filled catheter to an external pressure transducer.

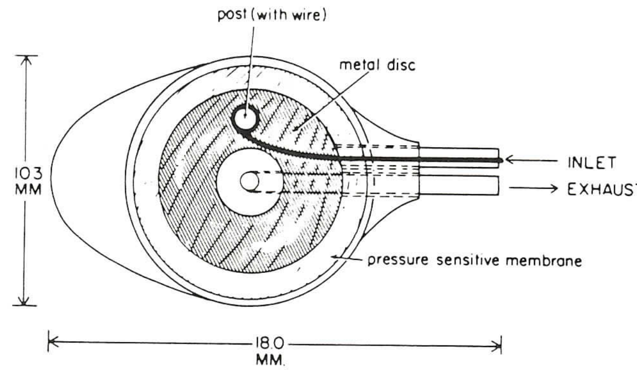
A non-invasive approach involves placing a sensor in the epidural space with the dura left intact. This simplifies the implant procedure and minimizes the risk of infection, allowing a monitoring period of many weeks. A number of non-invasive devices have been used. The most successful uses a fiber-optic detector which senses the displacement of a diaphragm and servo-balances the diaphragm using air pressure. This system suffers from the limitations inherent in a fragile, complex sensor and exhibits a very poor transient response which causes inaccuracies during rapid changes in the ICP resulting from "B" waves and cardiac modulation of the ICP. Other piezo-electric or piezo-resistive sensors require electrical conductors in the brain cavity and exhibit excessive baseline drift.

A new monitor has been developed for the non-invasive measurement of intra-cranial pressure utilizing a pneumatically operated sensor which is not temperature or shock sensitive. In addition, a microprocessor controlled electronics module provides control for the pneumatic system, leak detection, alarms, memory for 24 hours of patient data, CRT display, and hard copy.



Air pressure to power the pneumatic system is generated by a diaphragm pump which supplies at least twice the maximum pressure to be measured. The positive pressure is buffered in chamber 'VOL A' and





the restriction impedes the air flow sufficiently to provide a relatively uniform flow. The air enters the plenum inside the sensor via the inlet and builds up pressure until it slightly exceeds the pressure outside the membrane. The diaphragm then moves outward to unblock the exhaust tube which causes a drop in pressure in the plenum until it equals the outside pressure. The impedance of the exhaust is less than that of the restriction, allowing the pressure in the plenum to decrease. This cycle repeats, thereby maintaining the pressure in the plenum very close to the pressure sensed by the diaphragm. This pressure is read by the patient transducer with only a slight error due to pressure drop in the inlet tube. This error is rendered small by the very small air flow in the system and is a constant value which the microprocessor compensates for. The exhausted air is returned to the pump via the buffer chamber 'VOL B'.

The pneumatic system is completely closed and sealed. Due to the restriction and the very small air flow (40cc/min) which results, the pump sees an almost dead-ended system and moves air from chamber 'VOL B' to chamber 'VOL A' until its capacity is reached. This produces a positive pressure in 'VOL A' and a negative pressure in 'VOL B', the relative magnatude of each pressure being proportional to the inverse of the relative volumes. This provides the pressure sources necessary to make measurements over the range of positive and negative intracranial pressures encountered in clinical practice. The completely closed system also significantly limits the amount of air available to leak out of a damaged sensor to a quantity which is not dangerous to the patient.

The electronic system senses the pressure in the two buffer chambers and is able to detet air leaks and activate alarms, turn off the pump, and exhaust the pressures in the system. The patient sensor is automatically recalibrated every hour and any drift is eliminated. A two hour history of the ICP and cerebral perfusion pressure is displayed on the CRT, which can be scrolled back in time to cover an entire 24 hour record.

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