Prolonged Measurement of Experimental Intracranial Pressure Using a Subminiature Absolute Pressure Transducer*

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Studies of the normal physiology of intracranial pressure and its pathophysiology in nervous system disease have been significantly hampered in the past by the limitations of the available measuring and recording methods. These measurements are of great value in both experimental and clinical investigations, and the need for improved techniques persists. Current technological research in physics and engineering is continually making available new devices and principles applicable to biological problems. We are describing one such application of an industrial capsule transducer to measurements of intracranial pressure.

Historical Review

The earlier pressure-measuring devices involved connecting the subarachnoid space or the ventricular lumen with a simple water, mercury, or spring manometer; they suffered from a high degree of variance, artifact, and inaccuracy. The more sophisticated mechanical devices that followed still had four types of shortcomings. First, an appreciable amount of fluid was usually removed from the system both in making the measurements, and as leakage, thus directly affecting the pressure itself. Second, the measurements were coarse, depending on mechanical linkage, and lacked effective amplification. Third, blockage of the system by choroid plexus, arachnoid membrane, nerve roots, or the brain itself occurred frequently, yet was often difficult to detect, particularly when the blockage was partial. Fourth, long-term measurements showed important additional artifacts, some transient, such as those produced by movements of the subject or the connecting tubing, others more permanent, such as those introduced by gravity or by changes in temperature and barometric pressure in systems sensitive to such influences. There was also the practical problem of setting up a reliable drift-free automatic device to record long-term measurements over days or weeks without attendance.

The first and second shortcomings were recognized by Lagergren in 1937 when he reviewed all the techniques for cerebrospinal fluid pressure measurement up to that time and described his own continuously-recording optical manometer system. Further technical improvements were provided by Guillaume and Janny, who in 1951 devised a magnetic pressure transducer and optical recorder system and made a series of original observations on continuously-recorded human intraventricular pressure. Since 1960, a variety of relatively sensitive, low-displacement electromanometers have become commercially available. These, when coupled with the increasingly available laboratory oscillographs, have minimized the problems of fluid displacement, sensitivity, and adequate amplification, and were summarized by Lundberg. Verdura, et al., have recently reported a useful experimental modification for animals with small ventricles in which silicone-rubber catheters were placed in the subarachnoid space anterior to the upper cervical spinal cord and medulla of dogs and then connected to the external transducer.

To overcome blockage and thus make the measuring system independent of the patency of subarachnoid or ventricular spaces, Rothballer discarded open catheters and used a very small (50 to 200 μl capacity) intracranial balloon of polyethylene or latex. It was placed in the subdural space and con-

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connected to an especially low displacement extracranial transducer* by means of fluid-filled tubing. This system proved suitable for long-term measurements in both man and animals if it remained absolutely leak-free, but was still subject to some movement and gravity artifacts.

More recently, Hulme and Cooper† have reported the development of a special pressure transducer fixed to a stainless-steel support screwed into the edges of a burr hole. Also, Numoto, et al.,‡ have described a small intracranial switch device which consists of a 9-mm diameter silastic envelope enclosing two gold electrodes and the poles of a simple switch, connected externally by wires passing through polyvinyl tubing. The internal pressure introduced via the tubing is just sufficient to separate the contacts, thus opening the switch; this is taken as equal to the external (intracranial) pressure. This method measures discontinuously and does not record. Both of these last two methods require a separate surgical operation for the removal of the measuring device.

Thus, although the problems of fluid displacement, leakage, insufficient amplification, and certain artifacts have been separately overcome, there is still no one device embodying all such features, which at the same time is small, removable without separate operation, and capable of continuous, unsupervised measurement and recording. It seemed to us that if the pressure transducer itself could be sufficiently miniaturized to be placed intracranially and connected externally through wires to a continuous recorder, these problems might be eliminated. The following is a description of such a device.

Materials and Method

Transducer. We have adapted for intracranial pressure measurement a capsule pressure transducer originally developed industrially† for studying the pressure changes at the leading edges of helicopter blades. It consists of a hollow beryllium-copper disc 0.5 mm thick, 6.35 mm in diameter, and weighing 0.14 gm (Fig. 1). One of the disc ends is a flat movable diaphragm of 0.028 sq in. The internal sensing element is a special four-arm bridge, bonded-foil strain gauge. The gauge is designed to take maximum advantage of the strain imposed upon the diaphragm, with two arms of the bridge in compression and the other two arms in tension. Two lead wires enter and leave through a supported neck; for intracranial use, the transducer and adjacent leads are coated with silastic rubber. When the thin diaphragm is subjected to an external pressure (or vacuum), the transducer measures absolute pressure in the range between 26 to 35 inches of mercury (8,970 to 12,075 mm of water), with a reserve capacity of withstand- ing 23 to 38 inches of mercury (7,935 to 13,110 mm of water) without damage to the instrument. This is adequate for measuring intracranial pressure, since the extremes of barometric pressure recorded (in the New York City area) lie between 28.37 and 31.06 inches of mercury (9,787.65 to 10,715.70 mm of water). Thus, the transducer can respond to an additional 1,973.1 mm of water above the highest barometric pressure likely to be encountered. It is unlikely that the intracranial pressure will reach, much less exceed, this value. The specifications are listed in Table 1.

The power supply and control box designed for the Statham pressure transducer

* Statham model P23Dc: displacement, 30 µl/100 mm Hg; output, 5 mV/100 mm Hg at 10 V activation.
† Scientific Advances, Inc., Columbus, Ohio.

Fig. 1. Subminiature absolute pressure transducer. The lower view is a photograph of the transducer, lead wires, and the miniature plug, with a centimeter scale for comparison. The upper picture is a higher magnification (X9) view of the transducer itself, showing its shape and contour.