Radio Telemetry for the Measurement of Intracranial Pressure*

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Periodic long-term measurement of intracranial pressure is desirable in many neurosurgical conditions. Perhaps one of the more troublesome diseases from this standpoint is hydrocephalus. The status of such a disease requires repeated evaluation over a prolonged period, but the hazards of violating the ventricular or lumbar subarachnoid cerebrospinal fluid system with repeated needle punctures are formidable. The application of radio telemetry techniques to the general problem of intracranial pressure has been suggested by MacKay. The application of telemetry to physiologic problems has resulted in the development of many useful systems. Pressure in the human bladder and gastrointestinal tract has been studied on a short-term basis with active transmitters powered by a chemical battery. Small active transmitters have been constructed that will continue to function for at least a year, but this is a relatively short time in terms of disease processes of neurosurgical concern.

Passive transmitters that are energized from an external radio frequency energy source rather than by chemical batteries have been developed in a variety of forms. Relatively large units operating at low radio frequencies have been successfully implanted in the body with pulse-ringing techniques. Another approach in passive transmitter development has been to use a transistor as a rectifier for radio frequency energy from a transmitter outside the body serving as an energy source, storing the energy on a capacitor, and then using the same transistor as an oscillator to re-radiate the energy of the charged capacitor as a frequency modulated signal.

Small passive transmitters which are mechanically simple have been developed for studies of intraocular pressure in the experimental animal. One unit, which Collins has named a "miniature passive pressure transensor," consists of a short piece of polyethylene-covered glass tubing with mylar diaphragms attached to each end in a drum-like fashion. Within the unit there is a pair of parallel coaxial spiral copper coils attached to the inner surface of the diaphragms. The coils constitute a resonant circuit in which the frequency is a function of the spacing between the coils which in turn is a function of the pressure on the diaphragms. The transensor, following implantation in the eye, is sensed externally by a sweeping grid-dip circuit. The output of the sensing circuit is integrated with respect to time, and the output of the integrator is then fed to a pen writer as a continuous record of intraocular pressure.

This telemetry system has many features which are highly desirable for development in neurosurgery. The transensors are small, have few parts to fail, and have a long, useful life. The method needs modification for use in long-term (years) measurement of intracranial pressure by radio telemetry. We wished particularly to measure the cerebrospinal fluid ventricular pressure wave form and study its relationship to the ventriculomegaly of hydrocephalus. The method is also applicable to the study of mean intracranial pressure in problems of intracranial mass lesions. Biological safety and physical limitations of materials and design must, however, be recognized as limiting factors in the development of transensors for human use.

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Radio Telemetry to Measure CSF Pressure

Materials and Methods

The transensor developed for neurosurgical use combines the functions of a transducer and a passive radio transmitter (Fig. 1). Electrically it consists of a parallel-tuned circuit containing a capacitance and an inductance. The capacitor has one fixed plate and one plate which is a flexible stainless steel diaphragm. The diaphragm is separated from the fixed plate by an air space of 0.5 mm. The effective diameter of the diaphragm is 8 mm. The stainless steel plates are resistance-welded to a coil of the same material to complete the tuned circuit. The typical working frequency of these units is 70 MHz. The steel components were mounted in a machined acrylic (methyl methacrylate) case with an epoxy resin. A cover for the diaphragm and a ring to insulate the inductor and provide mechanical support for the transensor on the skull were also attached to the case with epoxy resin. A nylon tubular connection was attached to the diaphragm cover and served as the pressure input of the system. The assembled transensor was dipped in Insul-x and baked for one hour at 120° C. Insul-x, a synthetic polymer, has been useful for insulating depth electrodes in neurophysiological studies.

Completed units were soaked in saline solution for 2 weeks to test for leaks. The units were then sterilized in ethylene oxide. A standard perforated silicone rubber ventricular catheter (such as is used in the Pudenz-Heyer shunt) was connected from the lateral ventricle to the nylon tubular connector at the time of surgery (Fig. 2). The transensor case was mounted in a burr hole ½ inch in diameter in the same manner as an Ommaya reservoir. The scalp was closed over the transensor in routine fashion (Fig. 3). Healing was uneventful.

When implanted, the transensor frequency varied with the ventricular pressure. The frequency variations of the transensor could be detected through the intact scalp. A vari-