Detection of skull expansion with increased intracranial pressure

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A technique is described which uses standard strain-gauge technology to detect skull expansion associated with increased intracranial pressure.

KEY WORDS • intracranial pressure • strain gauge • calvaria • skull expansion

ALL substances deflect with pressure, regardless of their hardness or tensile strength. Even the weight of a fly on a 1-foot diameter steel I beam will deflect the beam. The assumption was therefore made that there should be an expansion of the calvaria when intracranial pressure (ICP) is elevated. An experiment was designed to see if this theoretical movement can be detected in the living state.

Experimental Technique

Instrumentation

A head holder was designed that incorporated two strain gauges,* arranged in series (Fig. 1). The thermal characteristics of these strain gauges were relatively stable. The strain-gauge transducer was part of a Wheatstone bridge (Fig. 2). The bridge was designed to allow off-balance voltage of several microvolts without any fluctuation in the off-balance voltage due to heating in the resistors. It consisted of two 4.2 K, thermally stable, resistors, a voltmeter,† and a variable resistor for balancing the bridge.

The sensitivity of the instrument was such that expansion of the skull of approximately 0.0003 mm would produce a voltage change of 1 μV. This sensitivity can easily be increased by a factor of 50.

Methodology

The skull device was inserted under sterile conditions approximately 1 mm into the outer plate of the calvaria. This point was approximately 6 cm above the external auditory meatus. A base reading was

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* Constantan S R-4 strain gauges, Type FAE-18-12Sg, manufactured by BLH Electronics Inc., Waltham, Massachusetts.
† Hewlett Packard multimeter, Model 3465B, manufactured by Hewlett Packard Co., Waltham, Massachusetts.
taken on the digital voltmeter by balancing the Wheatstone bridge. Any deflection of the meter and its direction was noted. Time was given for the system to stabilize itself. Intracranial pressure was monitored with a Fisher-type intraventricular catheter inserted just anterior to the coronal line, attached to a Statham transducer, and recorded on a Hewlett Packard polygraph.‡

The device was attached to two comatose patients, a 24-year-old woman (Case 1) and a 48-year-old man (Case 2), both with severe brain-stem contusions. The ICP was raised in both cases to between 15 and 20 mm Hg (200 to 260 mm H2O). In Case 1 ICP was raised by bilateral jugular compression five separate times, and in Case 2 by the infusion of 7 to 12 cc of Ringer's lactate solution into the ventricles 14 times. During the tests the off-balance voltage of the Wheatstone bridge was monitored.

Results

In all 19 trials, each time the ICP was elevated to between 15 and 20 mm Hg there was a voltage change which indicated that the skull tong pins were being spread apart. This could only occur with expansion of the cranial vault. As soon as the ICP was allowed to return to normal, the voltage reading returned to its baseline setting. The average voltage change in Case 1 was 12.4 µV, and in Case 2 was 2.6 µV.

‡ Statham P2s DB transducer made by Statham Instruments Co., 2230 Statham Boulevard, Oxnard, California, and Hewlett Packard polygraph, Model 7402A, by Hewlett Packard Co., Waltham, Massachusetts.

Comment

Rigid attachments to the skull (bitemporal or triangular insertion of bolts that project through the scalp) may possibly serve as mechanical support for techniques to detect skull motion and possibly even skull pulsation. These techniques may include electromagnetic interferometry (coherent and non-coherent visible light and ultraviolet light), changes in sound frequency, and holography. Spetzler and Spetzler have already described the holographic changes that appear when the weight of a penny is placed on the vertex of an isolated dry skull.

A definite increase in the bitemporal dimensions of the intact skull was associated with the rise in ICP over 15 mm Hg in our two comatose patients. This increase was detectable with ordinary strain-gauge technology.

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Reference


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