Experimental Study of Patterns of Brain Distortion and Ischemia Produced by an Intracranial Mass*

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EXPANDING intracranial masses can cause neuronal dysfunction by several possible mechanisms. A rapidly expanding mass lesion may produce vascular compression and ischemia of brain tissue adjacent to the lesion. Brain substance remote from the mass also can be rendered ischemic because of the particular vulnerability of its blood supply to distortion and compression. A notable example is compression of the posterior cerebral artery against the edge of the tentorium. A third mechanism to be considered is alteration of the electrical and chemical properties of neurons by distortion of their architectural arrangement. This is particularly pertinent in evaluating the significance of brainstem displacement and distortion.

The purposes of the present investigation were to study displacement and distortion of the brain and intracranial vascular compression produced by acute expansion of an extracerebral balloon, and to correlate these effects with pressure measurements from various intracranial compartments. Particular attention was directed to gross morphological changes in the brain stem.

Experimental Methods

Experiments were performed in adult cats and rhesus monkeys anesthetized with intravenous pentobarbital (Diabutal, 30 mg/kg). Twelve cats were used to study transmission of pressure through the brain. The animals were placed in a stereotaxic headholder, and small recording balloons were inserted into the cerebral hemispheres. Each balloon was injected with a small volume of water (0.2–0.4 ml). Baseline pressures varied among the recording balloons, so adjustments in volume were made until pressures in all balloons rose equally in response to injection of saline into the cisterna magna. Pressure differences recorded with subsequent inflations of an extracerebral injection balloon were considered to be valid if a cisternal injection at the end of the experiment produced an equal rise in pressure among recording balloons.

Three monkeys were used to compare communication of pressure from the supratentorial space to the brain stem and to the posterior fossa basal cisterns. A recording balloon and a catheter were placed in opposite cerebellopontine cisterns. The balloon pressure was considered a measurement of brain-stem tissue pressure. A subdural catheter and a subdural balloon in the supratentorial space recorded cerebrospinal fluid and brain tissue pressures respectively. All pressures were measured with Sanborn transducers and recorded on an 8-channel Sanborn polygraph.

Fifty-one cats were used to assess patterns of displacement, distortion, and ischemia of the brain during rapid expansion of an extracerebral subdural balloon. Evans Blue dye (3%, 5 ml/kg) was injected into the femoral vein immediately following completion of the balloon injection. The distribution of dye permitted estimation of regional ischemia in the brain. Intracranial pressure was measured from a subdural balloon over the cerebral hemisphere contralateral to the injection balloon. The position of the recording balloon was the same in all animals, and the injection and recording balloons were accurately placed in the anteroposterior stereotaxic plane. The cats' heads were frozen in liquid nitrogen at 15 seconds, 2½ minutes, or 5 minutes after dye injection. The heads were then sectioned in coronal and mid-sagittal planes with a bandsaw and photographed with Kodacolor-X color negative film. The black and white prints used for illustration were made with yellow and magenta filters.

In 10 animals 3 mm samples of frozen tissue were fixed in very cold, 10% formaldehyde

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solution for 10 to 14 days. The tissue was then sectioned on a microtome in 200 μ sections and stained by the benzidine procedure for hemoglobin.

Results

Communication of Pressure Within the Brain. Expansion of an intracerebral balloon sufficient to raise the pressure adjacent to the balloon to approximately 100 mm Hg in 20 seconds results in a significant difference in pressure across the brain. Figure 1 is a diagram of intracerebral balloon pressures at various distances from the injection balloon in six animals at the end of injection. The maximum difference recorded was 35 mm Hg. Figure 2 illustrates an equal rise in intracerebral balloon pressures in response to injection of saline into the cisterna magna, and the difference in pressure across the brain that accompanies expansion of a supratentorial balloon.

In Fig. 3, pressures were recorded from a balloon and a catheter in the posterior fossa, and from a supratentorial subdural catheter and balloon. Intracranial pressure was increased by gradual expansion of a second supratentorial subdural balloon. Pressure was readily transmitted from the cerebral hemispheres to the posterior fossa balloon adjacent to the brain stem at a time when obstruction of the subarachnoid pathways at the tentorial incisura prevented free communication of fluid pressure to the basal cisterns surrounding the brain stem.

Displacement, Distortion, and Vascular Compression. Rapid expansion of an extracerebral subdural balloon caused cessation of blood flow in cerebral tissue subjacent to the balloon and also in remote regions of the