Brain Tissue Electrolytes and Water Content in Experimental Concussion in the Monkey

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Although a great deal has been written about the physical and physiological changes in experimental head injury, very little of this effort has been directed to the electrolytes of the brain and cerebrospinal fluid. We have found only one report concerning the electrolyte content of the brain following experimental cerebral concussion; Eichelberger, et al.,7 in 1949 performed the analyses on canine cerebral and cerebellar homogenates with no separation of gray and white matter.

Various studies of brain water, blood content, and brain volume after experimental head injury have yielded conflicting evidence as to the presence or absence of cerebral edema.2,23,36 Some of the conflicting data are undoubtedly related to the difficulty in comparing such physiopathological effects when the physical factors of the impact are not defined clearly or are even quite variable. For this reason, initial efforts in an over-all Head Injury Project have been to develop statistically significant correlations between the physical data associated with experimental head injury and the production of experimental cerebral concussion in the Rhesus monkey.

The study reported in this paper was performed to delineate what changes occur in the sodium, potassium, chloride, and water content of the brain after experimental brain concussion and also to examine these data as evidence for or against the existence of cerebral edema. This degree of head injury in the monkey was conceived as the experimental analog of a closed human head injury severe enough to produce loss of consciousness but not associated with skull fracture or significant cerebral contusions and hemorrhage.

Materials and Methods

The analyses of 20 monkey brains (Macaca mulatta) are included in this report. Three animals were sacrificed as normal controls; 15 monkeys in five groups of three were sacrificed at 0.3 hours, 1.5 hours, 6 hours, 24 hours, and 48 hours after experimental concussion; and two were sacrificed at 1 week after concussion. Cerebral concussion was produced with the animal lying on its side with the head free to move. The impact was delivered to the occiput by a modified, rubber-tipped Remington Humane stunner, the tip of the piston starting at 1 inch from the monkey's head. A strain gauge was built into the impacting end of the piston in order to measure the force of impact (Fig. 1). The captive piston was powered by Type IPL 4/2 grain Industrial blank .22 caliber cartridges. The detonation force from these cartridges was shown to be capable of producing cerebral concussion in practically 100% of the animals; it produced impacts with an impulse greater than 0.9 lb/sec in accordance with our previously established criteria.18,20

Severe concussion was consistently produced without skull fracture. The immediate heart rate, a good index of the severity of head injury after impact, was usually about 50/minute compared to about 200/minute in the normal monkey.9 The head injury thus produced did not result in macroscopic brain damage in the majority of animals. In an occasional monkey, a minor subdural or subarachnoid hemorrhage was found. The results from these animals were not excluded from the series because the values for water content and electrolytes were not significantly different from the concussed animals without such minimal hemorrhages. After the impact, the animals were allowed to recover; they were then maintained until time for sacrifice. No animal showed any evidence of neurological defect before sacrifice.

The technique of fluid and tissue sampling was as follows. The animal was anesthetized with sodium pentobarbital, 3 to 5 cc of blood were drawn from the femoral vein, and 1 cc of cerebrospinal fluid was taken by a cisternal
puncture. The animal was then placed in a Horsley-Clarke stereotaxic apparatus, the calvarium and dura opened widely, and the cerebral hemispheres rapidly removed at the level of the midbrain while the animal was still alive. The hemispheres were then quickly separated; one was used intact to determine specific gravity and water content, the other to take samples of gray and white matter for electrolyte analysis and water content. Two samples each of gray and white matter, weighing between 200 and 500 mg apiece, were taken from the anterior half of the hemisphere and two each from the posterior half. Thus, each animal provided two gray and two white matter samples for electrolyte analysis. An effort was made to get pure gray and white matter as far as possible. The wet samples were weighed immediately to the nearest 0.2 mg on a torsion balance. The entire procedure from the taking of the blood to separation of the samples took no longer than 20 minutes and the weighing of the samples an additional 5 minutes. The time of midbrain transection was considered the time of sacrifice.

The specific gravity of a hemisphere was calculated by dividing its weight by its volume. The weight was determined to the nearest 0.01 gm on a pharmaceutical, two-pan, platform balance; the volume was determined by volume displacement in a 250 ml graduated cylinder filled with Elliott's solution, reading the meniscus to the nearest 1.0 ml with a cathetometer.

The water content of the hemispheres was determined by drying to a constant weight at 100° C for 48 to 72 hours. The individual samples were weighed in individually made aluminum foil pans and dried at 110° for 16 to 24 hours.

Electrolyte analysis of the serum and cerebrospinal fluid was performed after centrifugation to remove any red cells. The wet brain tissue was homogenized in 4 ml distilled water with ultrasound using a Bronson Instrument S-110 Sonifier. It was noted that white matter samples were more difficult to homogenize thoroughly than gray matter samples; if homogenization was not adequate, falsely low potassium values resulted. The electrolyte