FUNCTIONAL AND STRUCTURAL CHANGES IN THE
MONKEY'S BRAIN DURING AND AFTER
CONCUSSION*

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THE PRESENT study was undertaken to check in a primate the functional
alterations of simple concussion found in the cat and the histologic
alterations demonstrated in the guinea pig. Little previous use has
been made of monkeys to study functional aspects of concussion and it
would seem that the present histologic results are the first obtained after
simple concussion. It is unlikely that autopsy material will ever be available
after simple concussion in man but the findings probably would not differ
significantly from those in the monkey.

Denny-Brown and Russell employed monkeys, but most of their experi-
ments were performed on cats. So far as their observations went, concussion
and subconcussion were the same in the two species. Their protocols of four
monkeys show that subconcussive respiratory and blood pressure alterations
(with or without section of vagus nerves) were irregular. The concussive
phenomena that they observed (with vagus nerves cut) were transitory
loss of the corneal reflex, cessation of respiration and steep rise of blood pres-
sure with a gradual decline within about 5 minutes. Concussion was char-
acterized as a condition in which brain-stem centers are inert to reflex
activation although they themselves may be in a state of stimulation.
Denny-Brown and Russell had the opportunity to observe an intact unan-
esthetized monkey which was rendered unconscious in the course of an ex-
periment with a model bomb shelter. Percussion injury sufficient to stun the
animal abolished the corneal reflex although a lesser injury did not.

Experimentation on cats formed the chief basis for the conclusions of
Walker, Kollros and Case, but some monkeys were used and presumably
with similar results. They believe that the physiologic basis of concussion
consists of depolarization of many nerve cell bodies within the central nerv-
ous system caused by the shaking up or vibration of the brain as a result of
trauma, and that widespread central and peripheral excitation ensues as
axons are fired by this electrical breakdown of the cell membranes. The
authors enumerated tetanic phenomena, respiratory, blood pressure, heart
rate and spinal reflex alterations and electrical disturbances as evidence for
the validity of their theory.

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ments.
Sheiden, Pudenz and Restarski have studied and demonstrated, by high-speed motion picture photography, brain movements during subconcussive and concussive blows to various parts of the monkey’s head. They observed the brain through very large apertures covered by a lucite calvarium. Publication of their most interesting studies on concussion is awaited.

Jakob attempted to investigate histologic changes following concussion in three monkeys. Rabbits formed the bulk of his material. Concussions of doubtful nature were produced in the monkeys by multiple blows. Infection and malnutrition in the animals restrained the author from reporting any observations except some Marchi degeneration.

METHODS AND MATERIAL

Physiologic studies were conducted in acute experiments on 7 rhesus monkeys lightly anesthetized with chloralosane. Only mild concussion could occasionally be produced by means of the pendulum or the hydraulic apparatus previously used on cats. Force applied by either method sufficient to kill a cat would not affect a monkey. Rather than add weight to the pendulum and incur the risk of fracturing the skull, the piston of the hydraulic apparatus was increased in diameter and the falling weight was made heavier. In this way, a force of sufficient magnitude to produce concussion in a monkey could be transmitted to its brain. During the concussion experiment, the state of respiration, corneal reflex, spontaneous motor activity and threshold of stimulus required to elicit appropriate responses of the motor cortex, hypothalamus or facial nucleus were followed and recorded. Adequate recovery intervals were allowed between blows in the same animal. Placement and fixation of electrodes in the brain, stimulation and other details were like those described in concussion experiments in the cat.

Three monkeys that had suffered concussion and one control supplied material for the histologic study. One monkey, No. 6, was from the functional alteration series. It was perfused with 10 per cent formalin (after washing out blood with 1 per cent NaCl solution) at the termination of the experiment. A second, No. 9, was given a light concussion with the hydraulic apparatus and sacrificed 6 days later. In the third, No. 11, severe concussion was produced by striking with a hammer a Wood’s metal life-cast attached to the intact head; this specimen was sacrificed after 8 days. Monkeys 9, 11, and the control, No. 10, were given anesthetic doses of nembutal and perfused with 10 per cent formalin (after washing out the blood with 1 per cent NaCl solution).

The brains and spinal cords were carefully removed and the brain stems cut away from the forward parts at the level of the superior colliculus. Each brain stem was placed in 10 per cent formalin for 36 hours; the cerebrum, divided in the midsagittal plane, was placed in formalin for 5 to 7 days. The several pieces of the brain were then embedded in low viscosity nitrocellulose and sectioned at 20\(\mu\) and 40\(\mu\). The stem was cut serially in the transverse plane. Groups of frontal sections were taken at five levels through the hemispheres. The first three segments of the spinal cord were sectioned serially in the frontal plane and horizontal serial sections of the upper part of C4 were prepared. Staining was by the buffered thionin technique (pH 4.3 and 4.9), as in previous studies of concussion changes in the guinea pig.

PHYSIOLOGIC RESULTS

Monkey 1. One bipolar electrode was placed in the face area of the motor cortex (response: contraction of labial musculature) and another in the facial nucleus (response: contraction of labial musculature and eyelid closure). The pendulum apparatus was used. The first three blows were struck on the temporo-parietal region of the skull, corresponding to the area struck.