Significance of Relative Movements of Scalp, Skull, and Intracranial Contents During Impact Injury of the Head*

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At the time of impact, the scalp, the skull, and the brain move both as a unit and relative to each other. Relative movements occur as a result of differential deformation and accelerations of the structures and the development of pressure gradients. Functional and organic derangement of head and contents occurs as a result of the operation of these forces in impact injuries.

Observations

High speed cinephotography provides an ideal method for the study of rapid movements occurring at the time of impact. We have used this technique to analyze blows to the head by linear and rotating impactors in the dog, Rhesus monkey, in human cadavers, and skull models. Movements of the skull in its soft tissue environment may be seen at the time of impact in spite of restraints. This is seen in exaggerated form in Fig. 1 when the head is free to move; after impact the stiffer skull tends to move more rapidly than the scalp, which appears to lag behind. Such movements may result in tear of connecting blood vessels between scalp and skull. Subaponeurotic hematoma may develop by this mechanism with no apparent bruise or laceration of the scalp.

Relative movements of the intracranial contents have been deduced on clinical grounds; for instance, anosmia due to torn olfactory nerve filaments may result from a deceleration impact of the occipital area. Movements of the brain within the dural sac due to angular acceleration may produce subdural hematoma due to tears of venous channels joining the sagittal sinus. Movements of the brain against the rough floor of the anterior fossa and the knife-like lesser wing of the sphenoid may result in contusions. A study of the locations of contusions in 152 consecutively autopsied cases showed a preponderance of brain contusions in the region of the base of the frontal lobe and the temporal tip. Earlier investigators suggested that the irregular and rough bony environment of the anterior fossa and the lesser wing of the sphenoid is conducive to contusions. Surface contusions of the brain are much less frequent in the more posterior portions of the head where bone and dura are smoother. Of course there are other mechanisms of cerebral contusion. Sufficient deformation of the skull at the time of impact may directly bruise the underlying brain and contusions may also result from negative pressure at the opposite end from the point of impact.

Deformation of the brain itself is more difficult to demonstrate. Many authors have theorized about movement of brain tissues at the time of impact. Gurdjian and Lissner demonstrated the presence of shear stresses at the craniospinal junction. These movements represent the product of pressure gradients throughout the brain.

Utilizing the flash x-ray technique, we have photographed lead pellets introduced into the brain to demonstrate movements at the time of impact. We have found that the movements of the lead pellets (indicating movements of the brain) are proportional to the time duration of the pulse (Fig. 2) as well as proportional to the pressure applied (Fig. 3). The pellets tend to move with the impact and then return to their previous position (Fig. 4). Therefore, it can be concluded that the deformation and displace-
Differential Tissue Movement in Head Injury

FIG. 1. Mid-occipital impact in the stumptail monkey under anesthesia. Observe relative movements of skull and scalp. The latter lags behind the stiffer skull. (From a high speed cinephotograph 1,500 fps.)

ment of the brain during impact is elastic in character rather than plastic. The position of the pellets may be seen in Fig. 5. Gross and microscopic study indicates that the pellets have moved with the brain rather than simply moving through the brain substance.

Conclusions

At the time of impact the scalp, the skull, and the enclosed brain deform and accelerate differentially, due to differences in the mechanical properties of the tissues and in their transmission of the involved forces. As a result, these tissues move in relation to each other, producing damage at the interface and to structures crossing the interface. This relative movement produces a subgaleal hematoma when the vessels between the scalp and skull are torn. Cerebral contusion results from movements of the brain across and against the irregular bony surface of the anterior and middle fossae. Movements of the brain inside of its dural envelope may disrupt connecting vessels producing subdural hematoma.

Deformation of the skull at impact produces stresses due to movements of one portion of the skull in relation to other portions. Such stresses may produce a fracture. The amount of bony deformation is related to the relative weight of the head and striker, the velocities involved, and the time duration of

FIG. 2. Overlay of 0.010 and 0.020 sec position flash x-rays upon the 0 reference x-ray show the movement of the lead tags in the foramen magnum region during a pressure pulse. The lead tags are introduced into the brain stem through a 17-gauge needle puncturing the atlantooccipital ligament.

FIG. 3. Displacement of the brain and the brain stem by air pressure imparted to the dura through a ½ inch hole in the skull. Lead tags are moved from an uppermost 0 reference position to successively greater displacement with 10, 20, and 30 psi.