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CRANIO-CEREBRAL INJURY

LEO M. DAVIDOFF*

IN TIMES past, human ecology was largely concerned with epidemics of infectious diseases such as smallpox, diphtheria, tuberculosis, malaria, poliomyelitis, yellow fever, plague, typhoid and typhus fever, meningitis, and syphilis. Gradually, as these diseases were being successfully held at bay by appropriate vaccinations and destruction of vectors, and curable in individual cases by definitive medication including the sulfa drugs and antibiotics, public health shifted its aim to degenerative and neoplastic diseases such as heart disease, cancer, and stroke. The epidemiological approach to these disease entities must naturally be different from those in which the cause is known, and it is just a matter of eliminating the etiological factors.

Illnesses arising from trauma belong to the former classification, those diseases the cause of which is known, and it is again a matter of eliminating known causes or at least diminishing them to insignificance. This must include legal action against built-in lethal factors in automobile construction. Stricter statutes must be enacted, aimed at reducing the incompetence of automobile drivers by such measures as the elevation of minimal age limits for driving and the fixing of an upper age limit for the withdrawal of licenses, and controlling the incidence of drunken driving. The prohibition of professional boxing, and to some extent of football, both amateur and professional, must be seriously considered. Inadequate gun control laws must be redrafted to include

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gun registration and licensing of gun owners. While traumatic injury has thus become a public health problem necessitating legal action to a considerable degree, the physician has to meet the exigencies of the individual patient's case. It is this latter problem which is the subject of this article.

The human brain is, beyond doubt, the most complex mechanism in the world, perhaps even in the universe, and it may be desirable at this point to call attention to a few of its landmarks. Nature has provided it with appropriate protection by a series of increasingly tough envelopes, from the gossamer-like pia-arachnoid which immediately enfolds the brain, to the thick, tough, dura mater which lines the bone of the cranial cavity, to the inner aspect of the cranium itself. A special feature of the dura mater is the formation of partitions incompletely dividing the cranial cavity into compartments. These partitions with open doors are called *falx cerebri* between the two cerebral hemispheres, and the *tentorium* between the two larger anterior chambers and the posterior one, the posterior fossa.

The pia-arachnoid is a delicate membrane in two layers—the pia against the brain, and the arachnoid, removed from the pia by an average distance of one centimeter. The space between these layers is filled with a clear, colorless fluid, the *cerebrospinal fluid*, providing a liquid buffer in which the brain literally floats like a ship's compass suspended in a jacket of oil.

The space between the *outer* surface of the arachnoid and the dura is normally only a potential space, known as the *subdural space*. However, in abnormal situations it may fill up with cerebrospinal fluid, blood, or pus, giving rise to a variety of symptoms.

The outer surface of dura is in intimate contact with the inner surface of the cranial cavity; actually, especially in elderly people, it may be adherent in spots to the bone itself.

The bony box, containing the brain, the membranes, and the fluid, may be divided roughly into the *calvarium*, or vault, which is the relatively uncomplicated top of the skull, and the base, which is an irregular, complicated area through which pass the spinal cord and the other nerves—the twelve pairs of cranial nerves. These nerves serve as pathways of communication between the outer world via the senses of smell, sight, sound, taste, and touch, and the outgoing messages to the muscles and glands in response to the information received

from the special senses. The outside of the skull, of course, is covered by the scalp and hair.

All the structures named may be lightly or severely injured in an accident, separately or in combination. The physician of first contact must be alert to all these possibilities, and many others as well. It would be easier to discuss them didactically, from the simplest to the most complex cranio-cerebral injuries, but this is not the way it happens. I would propose to take my reader by the hand, make ourselves invisible, and together haunt the emergency room of a large municipal hospital some evening between seven and eleven. The chances are that one or two such visits will supply us with enough material to use as examples of many of the singly occurring or multiple lesions of the brain and its coverings. The wait will not be long. Each year in the United States about 10,000,000 people are injured. About one and one-half million of these are as a result of motor car accidents. In 1960 alone, nearly 40,000 of these injuries were fatal; 120,000 ended with permanent physical or mental impairment, and 1,280,000 were temporarily disabled. In economic terms, the total bill for that year was \$8,100,000,000, and more than half of this was spent in connection with motor car injuries. Seventy-five percent of the persons involved in motor car accidents suffer head injuries, and brain injuries represent one of the most common causes of death in accidents of this kind.¹

But wait, here is our first case, an unconscious man on a stretcher, brought in by ambulance from the scene of the accident. The ambulance driver reports that the victim was an elderly pedestrian, struck down at a crossing by a passing automobile. The police report states that both the driver of the car and the victim had alcohol on their breaths. The driver had only minor injuries, for which he was treated at a nearby hospital. While the information in this case, as in many others, is disturbingly brief, obtaining a detailed and reliable history whenever possible is of the utmost importance.

The patient on the stretcher is completely immobile. His skin is pale. His lips and nailbeds are blue. His pulse is thready and barely perceptible. His blood pressure cannot be obtained. His respirations are slow, irregular and feeble. Auscultation by stethoscope reveals some râles in his chest, indicating the gathering of fluid in his lungs. Tem-

¹ THE WORLD ALMANAC AND BOOK OF FACTS FOR 1962 303 (Hansen ed. 1961).

perature is 97°. There is urinary incontinence. General examination fails to reveal any injury to his limbs, abdominal or chest organs. He is bleeding from both ears and nose. Neurologically he is entirely flaccid; motor reflexes are all suppressed. His pupils are very large and fail to respond to light. Bruises are present on his legs and chest. There are a few abrasions on one side of his face, but no lacerations. He is seen by a neurosurgeon, whose diagnosis is, "severe brain injury, probably involving the brain stem, and shock." The prognosis is very serious. Major procedures are instituted to revive him. Nothing helps. The patient is officially pronounced dead before he has been in the hospital one hour. There has been no time for taking skull X-rays. A post-mortem examination reveals a wide-spread contusion of both of the cerebral hemispheres, with multiple small hemorrhages and several larger hemorrhages in the mid-brain portion of the brain stem and the pons; the base of the skull is the site of multiple irregularly shaped fracture lines.

Nobody is quite sure of the site in the brain where consciousness resides. This may be because there is no single limited area which, if injured, will alone produce unconsciousness. The nearest to such a site is the brain stem in its "midbrain" portion. Although a person may be made unconscious by a mild shaking up of the brain as a whole, under such circumstances the loss of consciousness would be from only a few minutes up to an hour. As between the latter, which will be discussed later under the term "concussion," and the case discussed above which exemplified a fatal brain injury, there are all stages proportional to the degree of injury. In all cases, except for some gunshot wounds and other sharply localized injuries, the history, degree and duration of coma are extremely important in evaluating the seriousness of the brain injury.

Our next case is an injured man who was also unconscious immediately after the injury, but by the time he reaches the hospital his coma has lightened somewhat. He is still deeply obtunded, very restless, moves all his limbs in seemingly purposeless activity, breathes stertorously, and may try to brush away painful stimuli such as pinprick. His pulse is rapid but strong; his blood pressure is normal or somewhat elevated; and his temperature may be somewhat or even severely elevated. In the course of another hour or two he may try to answer simple questions, or obey simple commands. Gradually, he may become aware of his surroundings and begin to complain of some

headache. He may also vomit several times. When he is fully aware, one may discover amnesia, both retrograde and post-traumatic. The retrograde loss of memory may cover only the period of the accident and a few minutes before it happened, or it may involve hours, days, weeks, or months before the accident. The same may also be true of the post-traumatic period of forgetfulness counting from the time of recovery of consciousness. Often it happens that when the one period of amnesia is of long duration, the other is also. Both are ascribed to the generalized brain injury, recovery from which also shrinks the period of amnesia.

Instead of becoming fully conscious, this patient might have had a temporary lightening of consciousness, followed by a deepening of coma, indicating a progression and even an irreversibility of severe brain damage. If this happens, the physician must make sure that hemorrhage producing a space-occupying blood clot has not occurred outside of the dura mater, subdurally, or into the brain substance as well. All these would call for surgical interference. But if they are ruled out, the supportive measures should be continued with the hope that recovery may still occur, even though more delayed. Such delays may last several days or weeks, or, although rarely, even longer. Eventually such a patient may recover, as nearly as we can tell, completely. But much more commonly certain permanent sequelae remain. The patient's whole personality may change. He may become short-tempered, unreasonable, subject to fits of rage. He may show defects of memory, poor judgment, and a short attention span.

If his work prior to the accident was that of an unskilled laborer, he may be able to resume work in three to six months. In this he may be successful, or after a time he may be discharged because he may not relate well enough to fellow workers. The patient himself may become aware of his behavior and thus become anxious and depressed, complain of headaches, dizziness, and fatigability. If the accident has occurred to a professional, a technician, a blue-collar worker, a man who must deal with the public, he may never reach the point of readiness to attempt resumption of his pre-trauma work, and may remain dependent for the rest of his life. Children who suffer from a severe brain injury and survive, also may recover completely, but often develop personality changes, behavior disorders, delinquency, truancy, and inability to learn.

Rarely, although often enough to mention, people who have had

an injury with severe brain damage may develop epileptic seizures months or years later, indicating that in addition to the generalized trauma to the brain, there was also a more severe disturbance at some site locally, with brain scar formation serving as a focus of irritability where the seizures originate.

Our second hypothetical case showed the response to a severe but reversible brain trauma. These patients usually have bleeding into the cerebrospinal fluid in the subarachnoid spaces. The gossamer arachnoidal membrane may be ruptured by the traumatic episode which permits the bloody cerebrospinal fluid, or unmixed blood to enter the potential subdural space. Depending upon the quantity of material accumulating there, compression of the brain with corresponding progressive stupor, contralateral disturbance of motor power, sensation, or disturbances in the field of vision ensue. Indeed, in most cases the bruised brain reacts by swelling some hours after the event, and, if large areas of the brain are involved, coma may supervene in the same way as when there has been a hemorrhage. It is important to distinguish these two possibilities, since surgical relief can be anticipated only in the case of localized hemorrhage. Widespread brain edema is a serious complication which nevertheless is not necessarily fatal, for it may respond to measures producing reduction of the swelling, along with supportive measures of a more technical nature like tracheostomy for relief of respiratory embarrassment.

Even with the best of attention patients with severe brain injury like our second case have only about eighty percent chance of survival. For those patients belonging in this group who survive twenty-four hours after the injury, the prognosis for life is improved by another ten to fifteen percent.

Among the more numerous head injuries seen in the emergency clinic are those with a minor degree of brain injury. These cases are usually classified as "concussion" cases. The term "brain concussion" literally means a jarring or shaking of the brain. Its subjective manifestations are usually a "dazedness" or brief period, from a few minutes to an hour, of loss of consciousness. The patient appears confused, moody, lacking coordination, complaining of headache, and often vomiting. However, these symptoms begin to diminish in a matter of minutes. The headaches lessen, the vomiting stops, the patient becomes aware of his surroundings, may recognize that he is in a hospital, and may ask how he got there. On examination, aside from some bruises

and scratches, he is physically, mentally, and neurologically normal, and from there on he may continue to improve so that twenty-four hours later, the whole experience may seem to him to have been a bad dream. If fluid were removed by lumbar puncture during the first few days it might be normal, or would either be discolored by fresh blood, or appear yellow instead of the clear, colorless, watery appearance which is its normal condition, indicating reabsorption of blood.

In such a case, plain skull X-rays often, although not always, reveal a linear fracture in the dome of the skull. Almost anyone can recognize a fracture on the X-ray film when the edges of the crack are widely separated (0.5 cm. or more), but it takes an expert to distinguish between a thin line of fracture and the normal grooves in the bone caused by blood vessels or suture lines. The treatment of these thin fractures of the skull is no treatment at all. The presence of such a fracture, moreover, is usually no criterion of the severity of the injury to the brain. Indeed, we have often seen multiple wide-open fractures of the skull in patients with practically no symptoms or signs of brain injury, and conversely, cases of fatal brain injury without any skull fracture demonstrable, radiologically at least.

One may then ask, why bother taking X-rays at all? The answer is that depressed fractures, and in-driven fragments of bone must be removed surgically, and X-rays are required for their diagnosis. In addition, laymen, and even our legally trained colleagues, feel that the demonstration of a fracture line on an X-ray film somehow adds authenticity to the claim that an injury has occurred. This is particularly so in minor head injuries which cause no loss of consciousness, or one so fleeting that no one, including the injured person, is at all sure that it happened: The patient may have seemed dazed for a minute, complained of headache, and even vomited, but by the time he was seen by a doctor, while he may still be pale and somewhat subdued in mood, and perhaps a little dazed, there is no neurological sign of the accident. Such patients may be kept for an hour or two in the receiving ward connected with the emergency room. After this, if he feels substantially recovered, he may be allowed to go home. On the other hand, if he becomes drowsy, or difficult to arouse from sleep, or his headache has increased in intensity, or he has vomited again, he should be checked once more by a neurologist who will probably decide to have him stay in the hospital all night with his vital signs checked at frequent intervals. The morning may bring complete recovery, or

complications indicative of hemorrhage with accumulating blood clot. This would call for confirmatory diagnostic tests, followed by surgical treatment.

The uncomplicated cases are, fortunately, much more frequent than those cases with more serious head injury. They are classified as examples of concussion, and very rarely result in death. Occasionally, when a patient who has suffered a brain concussion also has serious injuries to other organs which are fatal, the neuropathologist is afforded the rare opportunity to examine the concussed brain. These examinations are very unrevealing, and the assumption is that the displacement of the brain during the accident caused some reversible changes in the brain cells which have disappeared by the time the examination is made.

In marked contrast is the appearance of the brain in the more severe injury cases. Here the whole organ is swollen. There are discolorations of the brain from multiple, small, often confluent hemorrhages; accumulating blood clots at some one or more points, most often in the mid-brain; and herniations of the brain from one into another chamber of the subdivisions of the intracranial cavity.

The brain injuries we have been discussing so far have been the "closed" head injuries. These are caused by the impact of the moving head with a solid surface like the road pavement when a pedestrian is struck by an automobile; or when a person falls, or jumps, or is pushed out of an upstairs window; or when he is projected out of a rapidly moving automobile which suddenly has struck an obstacle and no restraint such as a safety-belt had been used. The force of the impact of the head is proportional to the speed of the moving victim, and the consequent severity is dependent upon the speed. Since a roadway is smooth and flat, the area of contact of the head is relatively large, so that the injury to the brain is over a fairly large surface, but the damage is distributed and less severe at any one place. When the moving head is suddenly stopped by the impact, the brain, suspended in its jacket of fluid, is still free to move in the direction of the blow for a centimeter or two before it, too, is stopped, and an impact occurs between the brain surface and the inner surface of the cranial cavity. As soon as this has happened, the brain is forced to move in a diametrically opposite direction. But the distance the brain may travel is again limited to the size of the intracranial cavity, where it hits the opposite inner surface of the skull against which the brain

is damaged over a corresponding surface area. This is said to have been the result of a *contra coup*.

Quite another type of brain injury occurs when the distance the head travels is negligible, and the stationary head, by accident or design, is struck by a hammer, lead pipe, or similar object. Recently, a teenager walked into our emergency room with a broken-off switchblade sticking out of his forehead. The X-rays before operation disclose an additional three-inch length of blade penetrating the brain. Here the head as a whole may have moved hardly at all, but at the site of the blow the scalp is lacerated, the skull is fractured, and a part of the fractured bone is driven into the brain, which locally is completely destroyed over a limited area. In these cases, usually because the brain as a whole has not been shaken up, the patient does not lose consciousness at all. However, this does not mean that his case is any the less serious. Driven into the brain along with the portion of the skull, which incidentally may be shattered into many fragments, are often parts of scalp, hair, cloth, gravel, and, above all, germs which will most likely result in an infected wound, even a brain abscess, unless appropriate measures are taken. Even without hemorrhage or infection, if the area of brain where the blow fell happens to be one in which speech, vision, motor power, or sensibility reside, permanent impairment in function may result.

Still another form of brain injury which nowadays, alas, is distressingly common, is one caused by gunshot. Here again, because the victim's head is not moving fast, there may not be any concussion or loss of consciousness. Of course, the brain tissue in the pathway of the bullet is completely destroyed by the heat and velocity of the bullet. There are cases in which the bullet has entered one side, come through the head and out the other side, and yet the patient never lost consciousness. The part of the brain that is hit, therefore, becomes of paramount importance. Notorious examples of this are the recently witnessed political assassinations of the Kennedy brothers and Martin Luther King, where the immediate loss of consciousness, continuing to persist, indicated the destruction of vital centers and foretold the fatal outcome in each case.

While complete recovery is possible from moderate, indeed even, in rare instances, from severe head injury, it is equally true that patients with minor brain injury (concussion cases) may be left with disagreeable symptoms that interfere with total rehabilitation.

The severe injury cases, after recovering consciousness, may show persistent memory defects, hemiplegia, hemisensory defects, defects in the visual fields, speech disturbances, and perhaps other subjective, as well as objective, manifestations of disturbed cerebral functioning.

The post-concussion cases more commonly show chiefly subjective changes. These consist usually of headaches, dizziness, and "nervousness"—all three in some cases, only one of them in others, or any two in combination. Their occurrence and severity do not necessarily reflect the seriousness of the initial injury. Thus, these symptoms may be severe and most distressing in cases in which practically no loss of consciousness had occurred, and may appear only several days to weeks after the traumatic episode.

The patients demonstrate emotional instability, impatience, short temper, inability to concentrate, poor judgment, anxiety, depression, and tearfulness, especially when bouts of headaches and giddiness make them unhappy. It is often stated that these symptoms are more severe and more persistent in those patients who are involved in litigation in relation to the accident. While it is true that usually no organic abnormalities can be demonstrated by our present diagnostic tools such as electroencephalography, memory tests, reaction time, power to calculate and the like, many patients who are not seeking compensation often present the same symptoms, and the same slow recovery. In light of this phenomenon, many experienced clinicians believe that some underlying organic disturbance, albeit little understood, is present in these cases. Correlations have been found with pre-traumatic emotional instability, the duration of unconsciousness resulting from the accident, and the duration of the period of amnesia both before and after trauma.

In the treatment of head injury cases, there is no single prescribed regimen, but certain basic rules must be obeyed if serious sequelae are to be avoided. Thus, with the unconscious patient, it is important to see that he is protected from falling out of bed by padded bed rails. Posture must be so maintained that the patient does not obstruct his airway by letting his own tongue fall back into his pharynx. The supply of oxygen to the brain is most important, and tracheostomy should be done more freely even if in doubt. Next to oxygen, sugar is most important for brain metabolism, and should be supplied in appropriate form intravenously to the unconscious patient. Reduction of intracranial pressure can be achieved at the same time by using hyper-

tonic glucose for the intravenous injection. The patient arousing from coma is often very restless and may complain of headaches. For this, various tranquilizing drugs are available as well as aspirin and the barbiturates. The important point to remember is that morphine is contraindicated in patients with increased, or increasing intracranial pressure.

Diminishing states of consciousness often indicate hemorrhage or increasing edema, and intelligent, watchful nursing is essential if such a contingency is to be recognized as early as possible. Indeed, at night, a seemingly sleeping patient should be aroused at frequent intervals to see that he is sleeping and not unconscious. If headache does not yield to these simpler measures, one may have to remove some fluid from the subarachnoid space by lumbar puncture. The patient with a minor brain injury will be largely recovered within a few hours. The more seriously injured, but not surgical case, may require many days, weeks, or sometimes even months of such alert supportive care. In forty-eight hours, if the state of coma is still quite deep, feeding should be switched from the intravenous route to feeding of a well balanced liquid mixture of food by way of a tube inserted through the nose into the stomach. Massage, as well as passive motion of the extremities, should be instituted. The patient should be turned every few hours, and the bed linen should be kept meticulously clean in order to avoid bed sores.

After recovering consciousness the patient should be allowed to see people, read, listen to radio, and watch television. If physical deficits exist, such as speech disturbances, hemiplegia, sensory or visual defects, rehabilitation of appropriate types should be instituted. Visits from a physician skilled in the treatment of psychosomatic disease, along with some form of occupational therapy, will hasten recovery.

If the original accident has led to litigation, this should be settled as expeditiously as possible, and the patient himself relieved, as much as possible, from personal appearances before judges, courts, and lawyers. Salvation lies in the successful resumption of the pre-traumatic occupation. Concentration on achieving this state will do more to help nature than does a larger settlement.