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# *Frontal Injuries of the Skull*

*Paul H. Crandall, M.D.**

**SUMMARY: Results of injuries to the frontal parts of the skull are often serious but treatable by prompt surgery. Various types of fractures are common. Most dangerous is the possibility of infection in the interior cavities of the skull. X-ray study of such injuries is practically mandatory. Failure to give prompt and proper treatment often results in serious complications later.**

**Any injury to the frontal parts of the skull should be viewed by attorneys as serious, with strong probability of future complications except perhaps when prompt medical attention of highly modern character has forestalled some of the possible complications.**

IN RECENT YEARS, many excellent studies of the mechanics of head injury, together with clinical surveys of the incidence and type, have led to a greater understanding of this complex and important subject. Knowledge of the site and kind of injury may often provide facts as to the pathological conditions present and the complications which might result from such injury. This article concentrates upon the considerations in injuries to the anterior fossa. This is not to infer that this area is injured in isolation, but is to show that injuries in this region have unique characteristics, are sometimes difficult to detect, and may have unfortunate complications which sometimes may be avoided. For legal purposes, correct evaluation of such injuries involves determination of possible future effects as well as other considerations. Among all types of anterior cranial injuries, the author has studied in detail and treated a group of twenty-two patients with compound fractures and contamination by organisms of the intracranial space. The considerations in regard to the type of injury are amplified.

## Anatomy

Certain anatomical features must be called to attention in order to understand the form of damage which may take place. The skull is composed of a vault of "flat bones" each of which is composed of inner and outer plates separated by narrow strips of soft bone called the diploic spaces. These frontal, parietal,

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temporal and occipital bones join at suture lines. Because these are fairly uniform in physical character, injuries to the vault in these areas are much alike. The base of the skull, however, is made up of thick buttresses of bone separated by thin panels of brittle compact bone. (Fig. 1.) Furthermore, the base of the skull is irregular in shape and is perforated by numerous foramina for blood vessels, nerves and the spinal cord. The sphenoid ridge separates the anterior and middle fossae and the petrous ridges separate the middle and posterior fossae.

Figure 1. Transillumination through the orbits of dried skull, displaying the buttresses and ridges of bone with relation to the anterior fossa.

The entire head cavity is enclosed in a tough, inelastic, heavy membrane called the dura mater, which has a midline, vertical large septum incompletely separating the two hemispheres of the brain, known as the falx cerebri, and a tent-like prolongation (the tentorium) suspended from the petrous ridges laterally, the occipital bones posteriorly and the falx cerebri in the midline. The brain substance is soft, nearly amorphous, and is enclosed by a thin external membrane known as the pia mater which connects by numerous filaments to a membrane (the arachnoid) directly apposed but not continuous with the dura mater.

Between the pia mater and the arachnoid mater circulates the subarachnoid cerebrospinal fluid, which is the principal suspending mechanism of the brain. Although the average brain weighs 1500 grams in air, when suspended *in situ* it probably weighs about 50 grams. Enlargements of the subarachnoid space, known as cisterns, lie next to bony and dural prominences and near the exits or entrances of blood vessels and nerves. They presumably allow accommodation for the brain should movement of the brain occur within the intracranial cavity. The filamentous arachnoid and the cranial nerves and blood vessels are the only other suspending elements. It is noteworthy also that the arterial blood supply to the brain is centrally placed in the base, while the venous drainage is mainly located peripherally, flowing into large venous sinuses enclosed in the dura mater.

## Mechanisms of Injury

In any head injury three effects are transmitted from the applied force: (1) Deformation of the skull at and around the site of impact and with or without fracture; (2) movement of the entire brain in the skull within the limits offered by the subarachnoid fluid spaces; and (3) compressional or rarefactional strains in the brain substance along the direction of the applied force, or shear strains in torsion states.

Deformation of the skull vault depends on the velocity of the impact, the size and shape of the striking object, and the type and tensile strength of the bone in the area. The tensile strength of the bone varies with the age, sex, and race of the patient as well as with the site of injury. Studies by Gurdjian, Webster, and Lissner[1] have shown that around the site and at the instant of impact there is an area of inbending of the bone and, at a distance, an area of outbending much like a crater formation. A high velocity blunt object causes locally circumscribed fracture and depression because the tensile strength of the bone is quickly overcome, and hence the bone will fracture close to the impact site.

Low velocity blunt impact results in the same but more widely distributed changes, and concentric fractures form in deformed walls of the bent bone; linear fractures form in the outbent portion and propagate both toward the point of the blow and in the opposite direction. Figure 2 demonstrates this type of injury in the vault. At the risk of some oversimplification, one can state that most fractures in the vault are larger or smaller examples of this basic mechanism.

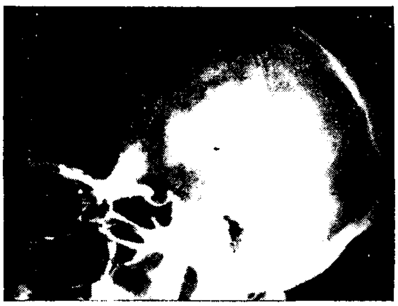

Figure 2. Depressed vault fracture due to blunt impact in temporaparietal area.

Rotation effects are greatest in producing laceration or tearing of veins, and occur wherever contour of the skull permits gliding of the brain, i.e. in the parietal and occipital regions.[2]

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1 Gurdjian, E. S., Webster, E. S., and Lissner, H. R.: Biomechanics: Fractures, Skull. 2 Medical Physics, 99-105 (Chicago Year Book Publishers, Inc., 1950).

2 Pudenz, R. H. and Sheldon, C. H.: The lucite calvarium—A method of direct observation, 3 J. Neurosurg. 487-505 (1946).

In cases of force applied to the frontal regions, because the frontal lobes are narrower and more pyramidal and because the contour of the anterior fossa floor, the sphenoid ridge and the midline falx cerebri limit this rotation, interior shear strains are most often produced.

In the opinion of Holbourn[3] the compressional or linear rarefactional strains directly along the line of force are not especially injurious. Therefore, in frontal injuries it is the fracturing of the skull and the shear strains within the lobes which are relatively more important than in other cranial locations. It will be shown that, because the anterior fossa basilar fractures so commonly involve the paranasal sinuses with great risk of infection, they become more important than fractures in any other location of the skull. This condition is termed a craniosinus fistula—a direct communication from the nose to the intracranial cavity.

From a large group of all types of head injury, there seem to be four situations in which a craniosinus fistula is likely to be present:

*Direct Frontal Injuries.*

Nine patients suffered from compound depressed frontal fractures with open scalp wounds, bone fragments depressed into the brain, and numerous fractures radiating from the vault into the anterior fossa floor and the underlying paranasal sinuses. Two injuries were from blows by tire rims when truck tires exploded while being inflated. Most of the group had large bony and meningeal defects with frequent herniation of brain tissue through them.

*Temporal Fractures.*

The presence of midline cranial and meningeal defects may not be recognized in the instance of temporal fractures. The fracture may run in an arc-like fashion across the flow of the anterior fossa, resulting in comminuted fractures in the roof of the paranasal sinuses. In the anterior basal regions are the heavy buttresses of the midline vertical metopic suture and the transverse sphenoid ridges. The supraorbital ridges of bone form a horizontal arch. It is a rule that radiating linear frac-

[3] Holbourn, A. H. S.: Mechanics of head injury, 2 Lancet 438-441 (1943).

tures will be deflected to run parallel to heavy ridges unless they are nearly at right angles to the ridge. Therefore, these heavy ridges tend to deflect radiating fractures into the thin bone of the orbital roof and toward the midline ethmoidal sphenoidal air cells. Figures 3 and 4 illustrate these relations. It has also been found that the small thin eminences of the ethmoidal cells are especially prone to split into small fragments and at times be absorbed or disappear, leaving an oval aperture. The dura mater in these areas is very thin and closely adherent to the bone. Its healing properties are very poor.

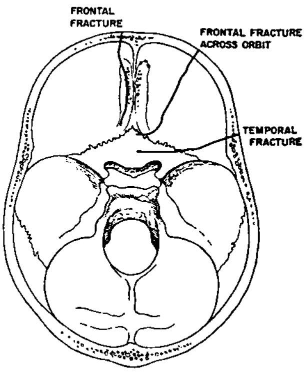


**Figure 3.** Principles of radiation of fractures from the vault of the skull into the anterior fossa. The locus in common between these different types is unfortunately the paranasal sinus area.

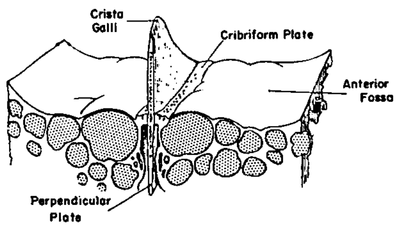


**Figure 4.** Schematic drawing of midline anterior fossa structures illustrating the proximity of the paranasal sinuses to the intracranial space in the anterior ethmoidal region. The falx cerebri attaches to the crista galli and thus to the perpendicular plate.

*Case 1:* (Fig. 5.) A 31-year-old white soldier sustained a left, compound, frontotemporal skull injury in September, 1950. At the time the depressed temporal fracture was treated surgically, but the midline defects were apparently not recognized. In November, 1950, the patient had meningitis and recovered. In 1953 a tantalum cranioplasty for the temporal skull defect was done. In 1954 he died before coming under medical attention. At autopsy a large frontal abscess was found which was due to an

**Figure 5. Case 1.** Above: A large cranial defect is present in the roofs of the anterior ethmoidal cells. Note also the tantalum plate in the left temporal region.
Below: The brain shows a right frontal abscess which extends across the midline and involves the left frontal pole as well.

extension of infection from the paranasal sinus into the brain because of the bony and meningeal defects illustrated.

Figure 6. Case 2. Above: Film shows a large, bifrontal fissure fracture and cranial defect in the left temporal region. Note the marked tilting of the crista galli to the right.
Below: Note bilateral ethmoid cell defects associated with the arc-like fracture of the anterior fossa floor.

*Case 2:* (Fig. 6.) A 23-year-old negro received a transverse, through-and-through frontal missile injury. This was debrided shortly after injury. The patient survived 15 days and expired from renal disease. Besides numerous other conditions elsewhere in the body, the autopsy disclosed an irregular coronal fracture in the anterior fossa floor spreading between the puncture defects of the entrance and exit wounds caused by the missile. Large defects in the cribriform plate and the sphenoidal sinus had allowed a herniation of brain substance into the nasal sinuses. Another factor in the production of fractures in this region is shown in the roentgenograms (Fig. 6.) The tough, inelastic falx attaches to the crista galli and stretch injuries of the falx may wrench this and the ethmoid bone of which it is a part (Fig. 4).

*Facial Injuries.*

Head-on blows to the face may result in a block-like separation of the entire maxilla from the anterior fossa floor. Inferior blows may transmit force via the inferior frontal processes of the maxilla to the basilar skull anteriorly and via the condylar process of the mandible to the middle fossa floor. There were six examples of the former in our group. The exact status of fractures within the facial bones is often difficult to determine in the x-ray films.

*Isolated Discrete Fractures of the Anterior Fossa.*

In this series one patient was found with only a single discrete fracture into an ethmoidal cell after a head injury in 1951. He had suffered from five attacks of meningitis and one prolonged period of cerebrospinal rhinorrhea late after injury. Two surgical procedures were required to heal the communication.

Adson[4] reported a case of a man who sustained a depressed skull fracture at the vertex from the fall of a 50-pound weight, and who also had a discrete fracture of the anterior fossa floor not connecting with the direct injury.

*Clinical Manifestation.*

The principal manifestation of craniosinus communication is cerebrospinal fluid rhinorrhea (watery discharge of C. S. F. through the nose). Of the twenty-two cases in this series, it was present in fourteen. Immediately after injury the rhinorrhea produces a thin, bloody fluid which becomes pink in one day and later is colorless and watery. The sugar content of the fluid was usually helpful in identifying it as cerebrospinal fluid and not nasal secretions. To avoid overlooking rhinorrhea, all unconscious or irrational patients should be placed for a few minutes in the prone position with their faces dependent over the side of the bed.

Hemorrhagic swelling about the orbit and protrusions of the eyeballs are also significant findings. These signs were noted in thirteen patients. Rigidity of the neck (not attributable to meningitis, subarachnoid blood, or injury to the neck) was often present and may be a clue to diagnosis.

Defects in vision due to fracture of the optic foramen were found in seven cases. Imbalance of the muscles moving the eyeballs was present in eight cases. A grating of bones at the base of the nose when it was moved slightly indicates fracture of the nasal bones and perhaps the floor of the anterior fossa. In three cases, when the upper teeth were grasped, the whole block of the maxilla could be moved.

As other authors[5, 6] have pointed out, signs which are definitely indicative of a dural communication with the sinuses include aeroceles (intracerebral air collection) and pneumocephalus (collection of air in the subarachnoid spaces inside or over the surface of the brain). Two such instances occurred in this series.

Radiologic demonstration of the bony defect is of great im-

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[4] Adson, A. W.: Cerebrospinal Rhinorrhea. Surgical repair of craniosinus fistula, 114 Ann. Surg. 697 (1941).

[5] Rizzoli, H. V., Hayes, G. J., and Steelman, H. F.: Rhinorrhea and pneumocephalus, 11 J. Neurosurg. 277 (1954).

[6] Rand, C. W.: Traumatic Pneumocephalus—report of eight cases. 20 Arch. Surg. 935 (1930).

portance. Stereoscopic views are helpful in tracing fissures. Roentgenograms of the orbits have been emphasized by Johnson and Dutt.[7]

*Craniosinus fistulas revealed only by meningitis.*

There were six cases in our group in which head injury was sustained, meningitis appeared at various times after injury, and only special examinations disclosed that a craniosinus communication existed. In treating an instance of meningitis, it is well to consider seriously any past instance of severe head injury, and by radiologic investigation search for a fracture of the anterior fossa. In one of our cases the use of antibiotic drugs evidently prevented episodes of acute meningitis, but a chronic meningitis due to a fungus eventually caused death. Autopsy disclosed an unsuspected osseous defect in an ethmoid sinus and an infected herniation of brain tissue which had blocked cerebrospinal rhinorrhea but not the infection.

*Treatment.*

The indications that surgery is necessary are: (1) compound depressed frontal fractures; (2) extensively comminuted fractures of the anterior fossa floor; (3) persisting or increasing pneumocephalus; (4) widely fissured fractures in the anterior fossa accompanied with rhinorrhea; and (5) recurrent or prolonged cerebrospinal rhinorrhea or recurrent bouts of meningitis.

Much discussion has taken place as to how long after injury rhinorrhea should be allowed to persist before operative intervention is decided as necessary. Recently, Lewin[8] concluded that: "Dural repair should be considered in all cases of paranasal sinus fracture with rhinorrhea, whether it is of early or late onset, of brief or long duration." This conclusion is based on a follow-up study varying from three to nine years. Late complications of operatively repaired patients were almost nil, while cases in which there was no surgery had a high incidence of late infections, recurrent rhinorrhea, and mortality.

Operative observations on our patients late after injury led us to the conclusion that the natural processes of repair in this region are particularly poor. Herniations of cerebral tissue, pre-

[7] Johnson, R. T. and Dutt, P.: On dural laceration over paranasal and petrous air sinuses. 1 Brit. J. Surg. (War Surg. Supp.) 141 (1947).

[8] Lewin, W.: Cerebrospinal rhinorrhea in closed head injuries. 42 Brit. J. Surg. 1 (1954).

venting repair, were common. Previous meningitis did not seem to have increased the thickness of the usual web-like membranes bridging the dural defects. It seemed that the only instance in which successful natural repair can be expected is that in which the dural edges are in contact without the interposition or interference of other tissue (i.e., bony spicules, mucous membrane, brain, and so forth). On the other hand, it was possible to perform the operative repairs without added mortality or neurologic defect, and in most cases, with improvement in the neurologic state. In our acute cases we have usually done the operation on the day of injury or have delayed it 10 to 18 days after injury because of the intervening period of brain edema.

The details of surgical technique are most important since failure was common when the older methods were used. The principles we believe are important have been previously outlined.[9] These were developed on the basis of experiences in twelve operations and also on the recommendations of Cairns and Lewin.[10] Three patients required two operations each before successful closure was obtained; all three had originally been treated by older techniques. On the whole, our results were very gratifying. In calling attention to these injuries, it is hoped that many more cases will be recognized at an earlier date and proper treatment carried out in order to prevent the frequent and unfortunate complications which can occur at any later date. It should also be stated that the smaller osseous and dural defects discussed may escape the most careful and expert diagnostic methods.

## Summary

The results of injury to the anterior fossa of the skull are discussed, with particular reference to the type of fracture encountered. A series of twenty-two cases of cranionasal fistulas, in which nine patients were operated upon, is presented. Of those patients operated upon for repair of fistulas, there were no deaths or increase of neurologic deficit.

The mechanisms of injury and the clinical manifestations are reviewed. The conditions which call for surgical repair of

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[9] Crandall, P. H.: Post-traumatic cranial defects in the anterior fossa, 93 Amer. J. Surg. 517 (1957).

[10] Cairns, H. and Lewin, W.: Fractures of the sphenoidal sinus with cerebrospinal rhinorrhea, 1 Brit. M. J. 1 (1951).

fistulas are: (1) compound depressed frontal fractures; (2) extensively comminuted fractures of the anterior fossa; (3) increasing or persistent pneumocephalus; (4) widely fissured fractures of the anterior fossa accompanied with rhinorrhea; (5) recurrent cerebrospinal fluid rhinorrhea; and (6) episodes of acute or chronic meningitis associated with demonstrable paranasal sinus bony defect. Characteristic injury should call for proper roentgenographic examination.