Fracture of Temporal Bone With Exsanguination: Pathology and Mechanism

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ABSTRACT: Eight cases of basal skull fracture with transverse fracture of the petrous temporal bone with medial extension to the internal carotid artery and lateral extension of the structures of the middle ear are described. Injuries in all cases were due to major blunt impact to the head usually occurring in a motor vehicle accident. General autopsy revealed major blood loss without any obvious external or internal site of hemorrhage suggesting that exsanguination was a complication of the head injury. The internal carotid arteries at the most medial extension of the fractures were lacerated or transected in all cases. In selected cases, the cervical internal carotid arteries were perfused and perfusate escaped rapidly from the ear(s) with the majority of fluid bypassing the cerebral venous system. Magnetic resonance image reconstruction of sequential sections of the fractured base of the skull confirmed the laceration of the internal carotid arteries and disruption of the middle ear. Based on this evidence, we propose that some displaced fractures of the base of the skull produce carotid-middle ear continuities which act as arterial shunts, resulting in rapid fatal exsanguination through the ear.

RÉSUMÉ: Fracture de l'os temporal avec exsanguination — anatomo-pathologie et mécanisme. Nous décrivons huit cas de fracture de la base du crâne avec fracture transverse du rocher, extension médiane à la carotide interne et extension latérale aux structures de l'oreille moyenne. Les blessures étaient dues à une contusion majeure à la tête dans tous les cas, habituellement à la suite d'un accident de la route. L'autopsie a révélé une perte de sang majeure sans site externe ou interne évident d'hémorragie, suggérant que l'exsanguination était une complication du traumatisme crânien. La carotide interne était lacérée ou sectionnée au niveau le plus médian de l'extension de la fracture dans tous les cas. Dans un certain nombre de cas, les carotides internes ont été perfusées au niveau cervical et le perfusat s'écoulait rapidement de(s) oreille(s), sans que la plus grande partie du liquide ne passe par le système veineux cérébral. La reconstruction de sections séquentielles de la base du crâne fracturée, au moyen de l'imagerie par résonance magnétique, a confirmé la laceration de la carotide interne et l'atteinte de l'oreille moyenne. En nous basant sur ces données, nous proposons que certaines fractures avec déplacement de la base du crâne provoquent une communication entre la carotide et l'oreille moyenne qui agit comme un shunt artériel, donnant lieu à une exsanguination rapide et fatale par l'oreille.

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Major blunt craniocerebral trauma often results in fractures of the base of the skull with fatal consequences. In two studies of fatal closed head injuries, 70 and 79% of cases had skull fractures with many of them involving the petrous temporal bone.[1,2] However, temporal bone fractures account for only 4% of non-fatal blunt cranial injuries suggesting a correlation of temporal fracture and fatal outcome.[3] Despite this, the mechanism of death in cases of skull fracture involving the temporal bone is largely uninvestigated. Several clinical complications have been described in nonfatal cases of temporal bone fracture.[4-8] Complications include displacement of the auditory canal,[4] otorhagia,[5-8] facial nerve palsy,[6-8] hearing loss[7] and less commonly, venous sinus thrombosis.[7]

Over the course of several years, we have examined many cases of a fatal complication of temporal bone fracture. All cases had apparently exsanguinated following major head trauma and had extensive transverse fractures of the temporal bone with involvement of the middle ear structures and laceration or transection of the patrosal segment of the internal carotid artery. Our search of the English literature has failed to disclose any documentation of such a mechanism of sudden death. We propose that, in such cases, the fracture line acted as a direct path between the lacerated carotid artery and the auditory canal via the middle ear. In Figure 1, an unfractured temporal bone has been sectioned along the plane of a typical transverse fracture of the temporal bone. The petrosal segment of the carotid artery, middle ear and auditory canal can all be seen in the same plane (Figure 1) indicating that a fracture along the plane of section would produce a communicating path between these structures. Under the conditions of systolic perfusion, we propose that

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blood from the torn carotid artery may shunt along the displaced fracture line, bypassing the cerebral venous system and exit through the ear, resulting in rapid fatal exsanguination. In this communication, we present (1) neuropathological findings in eight cases of temporal bone fractures with exsanguination and (2) preliminary experimental findings to support the proposed mechanism of exsanguination.

Materials and Methods

Neuropathological Studies

Over a ten year period, eight cases of temporal bone fractures with exsanguination came to the attention of one of us (JHND). Of these patients, there were five men and three women. Death was due to accidental motor vehicle collisions in seven cases and fall from a great height in the remaining case. Six of the eight patients were either dead at the scene of the accident or on arrival to hospital, the two remaining patients died shortly after being brought to hospital. Complete postmortem examinations to ascertain cause of death and to obtain toxicologic samples were performed under Coroner's warrant.

Perfusing Studies

In two cases (Patients 6 and 8), the internal carotid arteries in the neck were exposed and the internal carotid artery cannulated. The cannula was attached to a peristaltic perfusion pump or a 60 mL syringe and perfused under constant pressure and flow rate. The ears were then examined for escaping perfusate. After perfusion, the head was opened in the routine manner and following removal of the brain the basal skull including both temporal bones, pituitary fossa, a portion of the middle fossa and clivus was removed *en bloc*. The excised bony specimens were subjected to careful gross examination and magnetic resonance imaging (MRI) analysis with computerized reconstruction of sequential coronal images.

Results

The autopsy findings of the eight cases are summarized in the table. The pattern of basal skull fracture could be subdivided into three groups, all of which had in common a widely displaced transverse fracture of one or both temporal bones (Figure 2). Three patients (cases 1-3) had simple fractures of one (case 1) or both temporal bones (case 2,3) with laceration or transection of the carotid arteries at a point just proximal to the posterior clinoid process. In each case the fracture extended laterally to

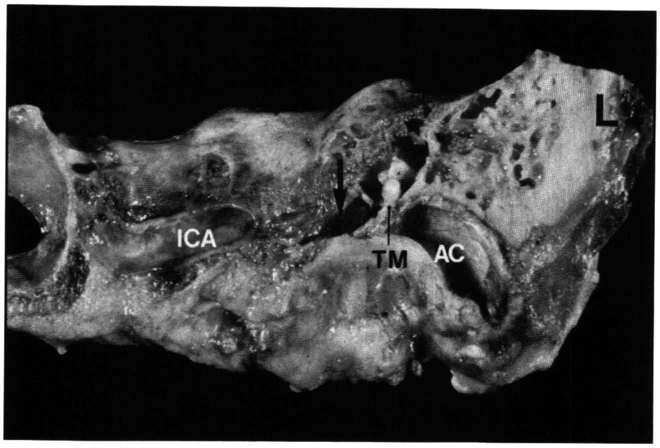

Figure 1 — Section through an unfractured temporal bone in the plane of fracture occurring in cases of temporal bone fracture with exsanguination. The obliquely sectioned sigmoidal segment of the internal carotid artery (ICA), the auditory canal (AC) and tympanic membrane (TM), are all in proximity in the plane of fracture. The arrow indicates the middle ear which is the point of communication between the auditory canal and the carotid artery in the fractured temporal bone. The most lateral portion of the temporal bone is indicated (L)

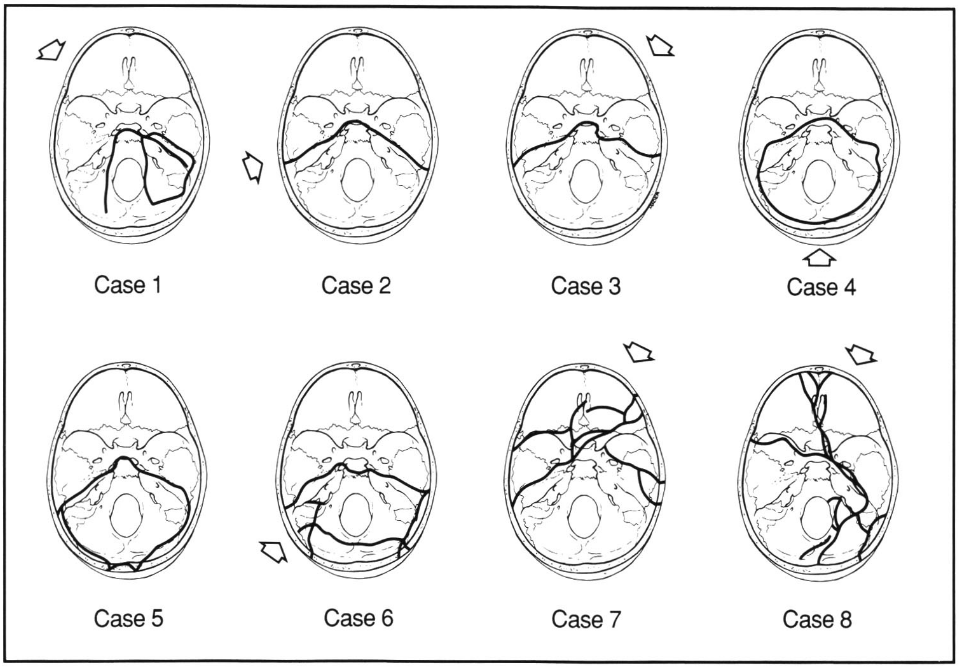

Figure 2 — Pattern of basal skull fracture in eight cases of temporal bone fracture with exsanguination.

the external auditory meatus. Three patients (cases 4-6) had bilateral fractures of the petrous temporal bone as described that were continuous with a circumferential fracture of the posterior fossa. The remainder of the patients (case 7,8) showed complex fractures of the skull with involvement of the temporal bone. The site and direction of impact was inferred from external injuries to the head, usually in the form of an abraded laceration. The deduced direction of injury correlated well with the anatomical course of the fracture lines in all but patient 5, which likely represents an avulsive type injury of the base of skull rather than direct impact. In most cases, examination of the basal fracture site did not require stripping of the dura mater from the floor of the middle cranial fossa, the dura being already torn along the fracture line. The extent of cerebral injury varied greatly from case to case. Minimal cerebral injuries consisting of superfical temporal lobe contusions and low-volume subdural hematomas were found in 50% of the patients (cases 2, 4, 6 and 8). Pontomedullary avulsion was found in two patients (cases 1 and 5) and major contracoup contusions were found in two patients (cases 3 and 5).

At general autopsy, all cases had scant amounts of blood remaining in great blood vessels and all parenchymal organs were pale. In no case could internal hematomas, hemorrhage into body cavities, or hemorrhage through cutaneous injuries account for blood loss.

Examination of the excised basal skull showed that fractures of the temporal bone extended medially to involve the petrosal portion of the carotid canal and transected the sigmoidal segment of the subclinoid carotid artery (Figures 3,4). The ear, auditory canal and middle ear contained blood and the middle ear was disrupted. The fracture line effectively created a transverse roughly linear path between the lacerated carotid artery and the auditory canal (compare Figure 4 and Figure 1). MRI reconstruction showed complete transection of the carotid arteries and verified the path of the fracture (Figure 5).

In two patients (cases 6 and 8), when the internal carotid artery in the neck was perfused, a minimal volume of perfusate flowed from the transected cervical segment of the jugular veins as most of the perfusate escaped through the ear(s), presumably via the temporal bone fracture.

Discussion

To the best of our knowledge, this mechanism of sudden death has never been described in the literature. The mechanism of injury to the carotid artery is analogous to that which causes traumatic carotid cavernous fistula. Many cases of basal skull fracture involve the petrous temporal bone and otorhagia is a well recognized clinical sign of basal skull fracture; however relatively few result in the fatal outcome of the cases we are here reporting. It should therefore be emphasized that exsanguinating hemorrhage is the result of petrous temporal bone fracture with sufficient displacement along the fracture line to shear or stretch the carotid artery and to cause its rupture. In our

Table 1: Summary of Anatomic Findings in Eight Cases of Temporal Bone Fracture with Exsanguination

Case No.	Age/Sex	Type of Accident	Craniocerebral Injuries	Other Traumatic Findings
1	29/F	MVA	Abrasions of forehead and face, left Pontomedullary avulsion	Trunk and limb abrasions, long bone fractures, laceration of liver
2	21/M	MVA	Laceration of temple, left Minimal SDH, contusion of inferior temporal lobe, right	Trunk and limb abrasions
3	19/F	MVA	Abrasions of scalp, forehead and face, right Shear injury of brainstem, Contusions of temporal lobes and cerebellum	Trunk and limb abrasions, long bone fractures, fat embolism
4	59/M	MVA	Stellate laceration of occiput minimal SDH and basal SAH, contusions of temporal lobes	Intimal tears of aortic arch
5	20/M	MVA	Abrasion of chin Pontomedullary avulsion	Trunk and limb abrasions
6	28/F	MVA	(1) Laceration of forehead and frontal convexity, left (2) Laceration of occiput, left Minimal SDH	Abrasions of legs
7	57/M	MVA	Laceration of supraorbital ridge, right laceration of frontal and temporal lobes, SDH in posterior fossa	Contusions of chest, rib fractures, lacerated liver and spleen
8	21/M	Fall onto head	(1) Abrasions of supraorbital ridge and nose, bilateral, (2) Hematoma of scalp, frontal, right Minimal SDH	Trunk and limb abrasions, mediastinal hemorrhage and pulmonary contusions

M: Male, F: Female, MVA: Motor Vehicle Accident, SDH: Subdural Hemorrhage, SAH: Subarachnoid Hemorrhage cases, evidence of significant displacement was present in the form of tearing of the dura mater along the fracture line. Only one report in the literature details potentially fatal arterial hemorrhage from the base of the skull derived from the carotid artery.[9] The circumstances, however, are at variance with present cases since the hemorrhage was due to direct bullet injury to the carotid artery in one case, and a surgical complication associated with erosive carcinoma of the temporal bone in the other case.

An additional observation at the accident scene in several of our cases was the presence of a large volume of exsanguinated blood beside the victim. The volume of blood remaining in the body at autopsy is difficult to determine with accuracy; however, difficulty experienced in obtaining sufficient blood for toxicological examination and pallor of organs was comparable with that seen in other types of exsanguinating injury. The basal skull fractures which occurred in these cases were sufficiently severe that a fatal outcome might well be expected as a result of the head injury even if exsanguination had not occurred as described. It is also unlikely that any medical or surgical intervention would be effective in salvaging such accident victims. In 50% of the patients only minor cerebral injuries were found while the remaining cases had extensive disruption of the frontal and temporal lobes and/or the brainstem. Since the force required to fracture the basicranium is great, it is likely that shearing forces were present at the time of impact(s). On this basis, although some cases did not have gross cerebral injuries, it is possible that there was significant diffuse shear injury of the cerebral white matter and brainstem which would have been detectable with the appropriate survival interval (>24 hours).

In summary, the morphologic findings in these eight cases of temporal bone fracture showed an anatomic communication between a lacerated carotid artery and the disrupted structures of the middle ear. With the additional observation of profuse hemorrhage at the scene, the finding of little blood remaining in the body at the time of autopsy, and the absence of significant hemorrhage into body tissues or cavities, it was concluded that exsanguination occurred as a result of the escape of blood along the temporal bone fracture line from the lacerated carotid artery to the auditory canal. To determine if the temporal bone fracture could function effectively as a fluid shunt between a torn carotid artery and the middle ear, the cerebral arterial supply was perfused through a carotid cannula. Under postmortem condition, the perfusate issued freely from the ear indicating a fluid mechanically functional carotid-middle ear shunt which accounts for death by exsanguination.

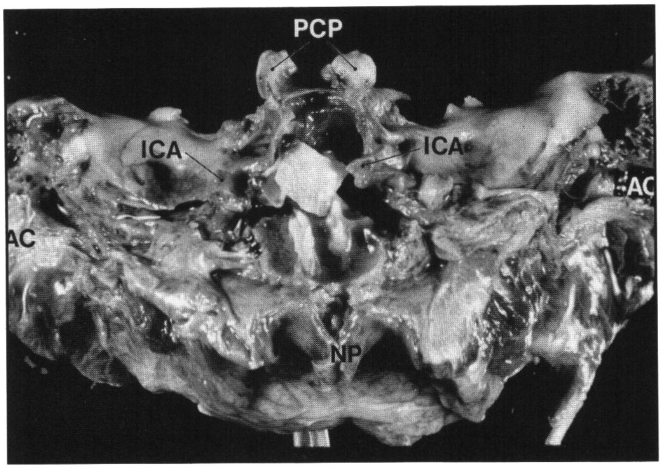

Figure 3 — Irregular surface of the fracture face of an excised base of skull with bilateral temporal bone fractures, viewed from the inferior surface. The fracture is roughly in the plane of section in Figure 1, and the same structures are visible, internal carotid artery (ICA), and the auditory canal (AC). For orientation, the posterior clinoid processes (PCP) and nasopharynx (NP) are labelled.

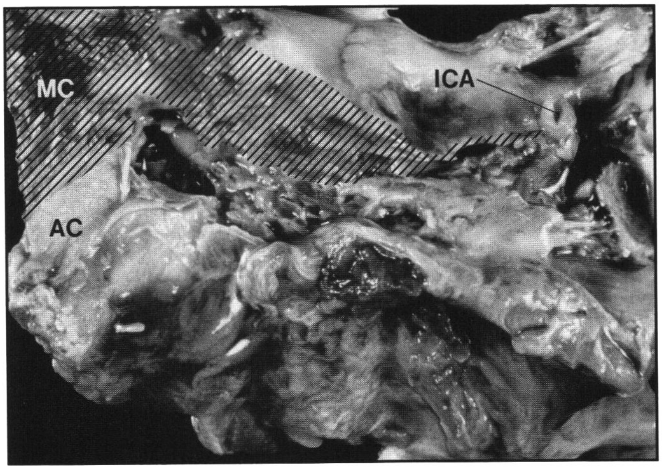

Figure 4 — Close up of the irregular fracture face of one of the petrous temporal bones in Figure 3. Shaded region shows the fracture face of the petrous temporal bone. The torn segment of the internal carotid artery (ICA) is visible, as is the middle ear, and the auditory canal (AC). The proposed hypothesis is that the continuity produced by the fracture is the path for arterial blood flow and exsanguination via the ear. For orientation, a mastoid air cell (MC) is labelled.

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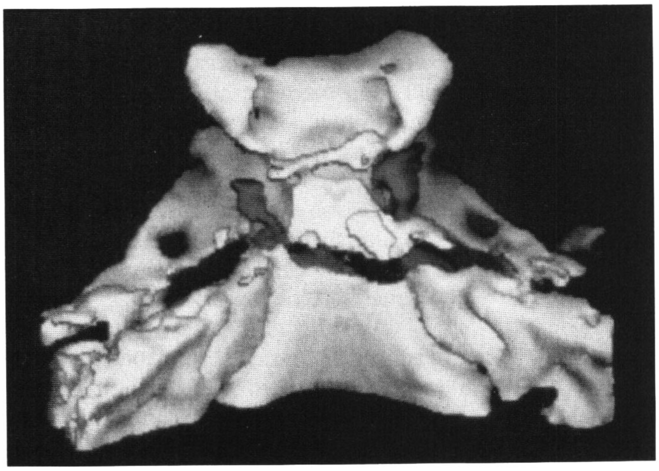

Figure 5 — MRI reconstructed image of the excised basal skull specimen of bilateral petrous temporal bone fracture in Figure 3. The fracture line clearly transects the carotid arteries (enhanced). Figures 3 and 4 are made from the fracture face of the lower bony fragment visible in this MRI image.

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