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"Typical" Basal Skull Fracture of Both Petrous Bones: An Unreliable Indicator of Head Impact Site

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ABSTRACT: A basilar skull fracture that extends along both petrous bones is generally considered to be a response to impacts to the lateral aspects of the head. This generalization is not warranted as such a fracture often results from impacts to any point around the base of the skull or to the chin. These facts were appreciated as long ago as 1905 but present-day literature does not adequately reflect them. Eight carefully selected autopsy cases of fatal blunt head injury with well-documented single head impact sites and bilateral petrous bone fractures are presented. They illustrate the variety of impact sites that may produce bilateral petrous bone skull fractures.

KEY WORDS: pathology and biology, musculoskeletal system, postmortem examinations

Skull fractures are reported to occur in 50% [*1*] of fatal road accidents and in 70 to 72% [*1,2*] of fatal cases of blunt head trauma owing to multiple causes. Most (80 to 92%) [*3,4*] skull fractures seen in this context involve the base of the skull. The condition and direction of most skull fractures correlate well with the site of impact [*4-12*] and are thus of medicolegal significance in cases in which the impact site is to some extent in question.

An important exception to the rule that a good correlation exists between impact site and fracture direction is the common type of transverse basilar skull fracture extending along both petrous bones. This type of skull fracture was termed the "typical" basal skull fracture (Fig. 1) by Rawling [*5*], who was aware of its exceptional nature. It has also been referred to as incomplete marginal ring fracture [*13*], lateral composite fracture [*4*], and dorsal transverse incomplete marginal ring fracture [*11*]. This fracture may result from impact to any point on the head, including the chin, and does not indicate a lateral head impact site as often as is suggested by current reviews [*7,8*].

Materials and Methods

The material for this study was selected from routine medicolegal autopsies performed at the Office of Medical Investigator, Albuquerque, N. Mex. Only cases were included in which the brain was fixed for neuropathologic examination, the type of trauma was ascertained, skull fractures were diagrammed, and a definite single main site of head

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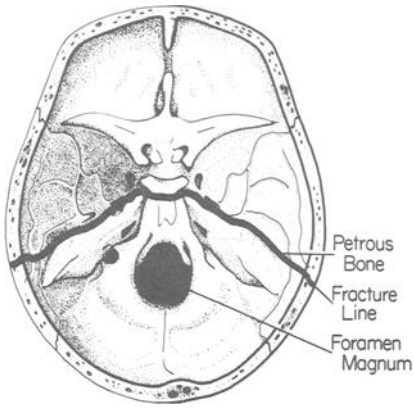

FIG. 1—*Typical basilar skull fracture* [5].

impact was identified. This last criterion is emphasized. Dr. Allen Jones (second author) personally verified that in each case there was only a single head impact site (in Case 1 there was head compression). At the indicated impact site was found the only scalp abrasion or laceration. Eight such cases with well-documented impact sites had typical basal skull fractures (Fig. 1) extending along both petrous bones and usually traversing the clivus and posterior clinoid processes. In three cases this was the sole fracture (Fig. 2), termed solitary basal fracture [*11*], while in the remainder there were associated fractures of the base and vault (Fig. 3). The last group is included since the vault fractures may have been extensions of the basilar fracture [*5*], or the converse.

Results

Cases 1 to 3 (Fig. 2) sustained fractures similar to that shown in Fig. 1.

Case 1 was an 11-year-old male who died when a voting machine fell over, striking the posterior aspect of his head and compressing it in the posteroanterior direction. He sustained fracture contusions and mild intraventricular hemorrhage secondary to a torn fornix. According to the available literature the fracture sustained is atypical for either

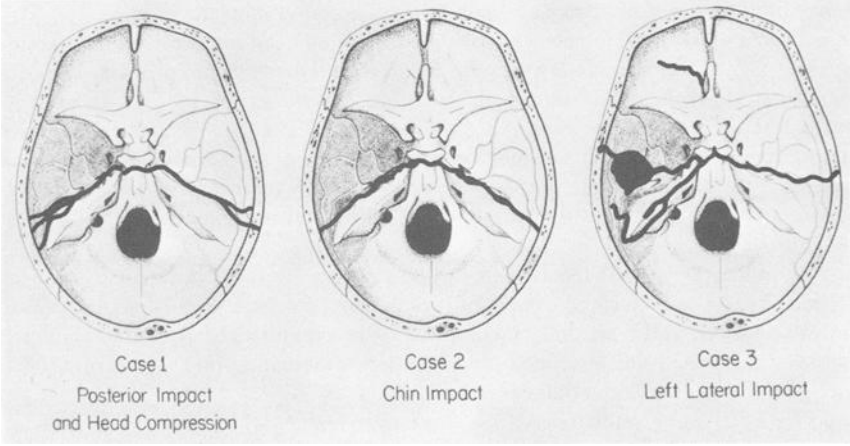

FIG. 2—*Typical fractures.*

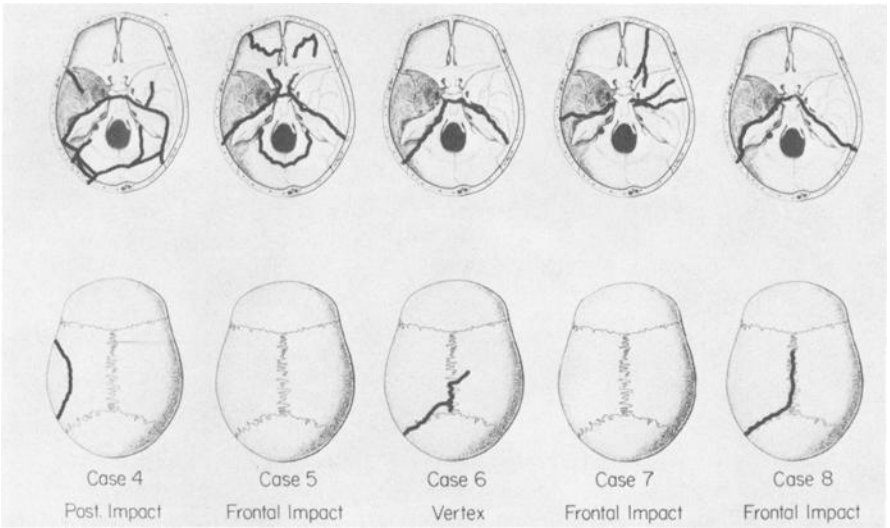

FIG. 3—*Typical fractures combined with other fractures.*

a posterior impact (to the movable head) or a fracture resulting from compression (of the fixed head) in the sagittal plane [*8,14*].

Case 2 was an 18-year-old male who died after falling out of a moving truck. His chin, the only point of head impact, struck the pavement. He sustained a brain stem contusion and a vertex pattern of cerebral contusions.

Case 3 was a 6-year-old male who died in an auto accident and sustained an impact to the left side of the head. There were right lateral cerebral contusions but no brain stem contusion.

Cases 4 to 8 (Fig. 3) also sustained bilateral petrous fractures similar to that shown in Fig. 1, but in most it is not clear whether the vault fracture was an extension of the basilar fracture, as often occurs [*5*], or the converse.

Case 4 was a 10-year-old female who, while riding a bicycle, was struck by an auto. The head impact was posterior. A ponto-medullary brain stem tear and fracture contusions were present. The petrous fractures appeared to extend from the occipital fractures, but they may have been a simultaneous response to the occipital impact.

Case 5 was a 48-year-old female who sustained a frontal head impact in an auto accident. Extensive fracture lacerations were present. Brain stem injury was not present. The petrous fractures may have been extensions of the orbital fractures (as in Fig. 4) or the two separate fractures may have occurred simultaneously. The partial small ring fracture extending posteriorly to the foramen magnum between the hypoglossal foramina is interesting since small ring fractures are often [*6,7*], but by no means invariably [*11,13,15, 16*], associated with impact to the base of the skull by the spinal column such as by a fall on the buttocks.

Case 6 was an 8-year-old female who, while riding a bicycle, was struck by an auto. The head impact was vertex. Coup and contrecoup cerebral contusions, a cerebellar fracture-laceration, and a medullary contusion were present. The fracture originated in the vertex as expected and extended down the left lambdoid suture and across the base as a long approximately coronal linear fracture.

Case 7 was a young adult (exact age unknown) female who was thrown from a car during an accident. The head impact was frontal. A brain stem contusion and several small temporal contusions were present. The orbital fracture is typical of those resulting from

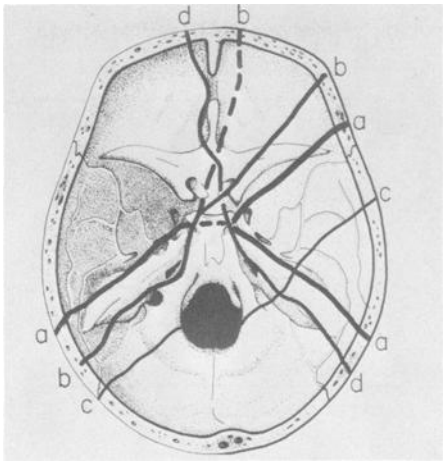

FIG. 4—*Correlation of fracture extensions and impact sites (after Ref* 5).

frontal impacts [*5, 9*]. Since the petrous fractures were not continuous with the orbital fractures they were probably not extensions of the latter. The petrous fractures were probably due to the impact itself.

Case 8 was an 18-year-old female who was the victim of a hit-and-run accident and sustained impact to the right forehead. There were fracture contusions adjacent to the petrous fracture and contusions of the right superior frontal gyrus, right uncus, and right amygdaloid nucleus. There was a ponto-medullary brain stem tear and a more rostral brain stem contusion. We believe that in this case the vault fracture was an extension of the basilar fracture. Note the similarity to Case 6 (Fig. 3) in which the converse obtained.

Discussion

Fractures of the cranial vault resulting from impacts on the vault initiate near the point of impact [*7, 10, 17*]. Those of the base also tend to do the same and to extend along the suture lines [*5*] and other paths of least resistance [*5, 9*] in the same direction as that of the impact. We believe typical basal fractures do not follow this generalization as often as the literature might indicate [*7, 8*]. The literature on skull fractures is rather sparse in view of their frequency and significance; generalizations abound. Our Cases 1, 2, and 8 serve as exceptions to the generalization (see also Case 2 from Ref *13*). However, they do conform to a statement in Ref *5* that the typical basal skull fracture is a result of impacts at any point around the skull at a level with the base of the skull. Rawling [*5*] is the classic reference, although subsequent authors usually limit their citations to his diagrams rather than the text. Thus his diagram that associates the typical fracture only with laterally directed impacts to the skull has been faithfully referred to [*8*] while his text has been largely ignored.

Another consideration of the relationship of basilar skull fractures to impacts at various sites concerns those fractures that involve the entire length or breadth of the skull base. Diagrams based on Rawling's Figs. 31 to 36 [*5*] are usually associated with a single impact site. But if these diagrams are combined (Fig. 4) as a composite it is quite obvious that any fracture extending from virtually any point on the circumference of the base to any other may have originated at either end. Although this observation is somewhat self-apparent, it has not previously been published to our knowledge.

Voigt and Skold [*13*] encountered 4 of 77 basilar skull fractures that appear to correspond to the typical fracture. They term these fractures marginal incomplete ring fractures and found all of them to have been caused by chin impact. Voigt and Skold [*13*] and Vondra [*9*] implicate forces generated at the temporomandibular joint as being the

TABLE 1—*Brain stem lesions associated with typical basal skull fractures.*

Case Number	Contusion	Tear[a]
1	−	−
2	+	−
3	−	−
4	−	+
5	−	−
6	+	−
7	+	−
8	+	+

[a] At the ponto-medullary junction.

mechanism. Rawling [5] points out that the skull is joined front to back at the petrous bones and that severe impacts at any site around the skull base are capable of breaking the skull apart in this transverse plane ("... the fracture traversing the base and splitting it much in the same way as a chisel splits a board of wood"). Gurdjian [*17*] was able to produce transverse fracture of the base through the foramen magnum in 5% of skulls receiving occipital blows.

The typical fracture is often associated with stretching of the anterior brain stem with contusion or ponto-medullary tear, dural laceration [*13*], and, rarely, basilar artery rupture [*18*]. It often causes fracture contusions or lacerations of the inferior temporal lobes. If the impact is in the lateral head area the contusion pattern may resemble the contrecoup type with the contusions in fact being fracture contusions (pseudo-contrecoup).

Typical basilar skull fractures are usually associated with brain stem contusions and tears, both in our experience (Table 1) and in that of others [*13*]. We agree with some others [*19,20*], but disagree with Sevitt [*1*], that this is a manifestation of the severity of the impact and not the location of the fracture line (there need not be a fracture at all), that is, that these are not fracture contusions or lacerations of the brain stem. This is quite evident when fracture diagrams are compared with the brain stem lesions in our eight cases; brain stem contusions and tears are often found with no adjacent skull fracture (Table 2). This high incidence of brain stem injury is responsible in large part for the high mortality attending typical basal skull fractures.

Conclusions

Fractures extending across the base of the skull through both petrous bones are a response to severe impacts applied to a variety of sites on the head, including the chin and occiput, lateral surfaces, and, in association with local fractures, to the frontal, vertex, and occipital regions. Therefore, the bilateral petrous fracture is not a reliable indicator of the site of impact. These fractures are often associated with brain stem contusions and tears, in large part explaining their high mortality rate.

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The manuscript was read and criticized by James T. Weston, M.D., chief medical investigator and professor of pathology, School of Medicine, The University of New Mexico, Albuquerque.

TABLE 2—*Correlation of impact site with typical petrous fractures in eight cases.*

Case Number	Type of Trauma	Head Impact Site	Skull Fracture(s)	Neuropathology
1	struck by falling voting machine	posterior (with compression)	typical	fracture (Fx) contusions, torn fornix
2	fell from moving truck	chin	typical	vertex contusion pattern, brain stem contusion
3	auto accident	left side	typical	contrecoup contusions
4	struck by auto while riding bicycle	posterior	typical, large ring fracture (Fx), and right parietal Fx	Fx contusions, brain stem tear
5	auto accident	frontal	typical, partial ring Fx, and orbital Fx's	Fx lacerations
6	struck by auto while riding bicycle	vertex	typical, from vertex Fx	coup and contrecoup contusions, Fx laceration cerebellum, brain stem contusion
7	ejected during auto accident	frontal	typical and orbital Fx	brain stem contusion, temporal lobe contusions
8	auto—pedestrian	right forehead	typical, to vertex Fx	petrous Fx contusions, vertex pattern contusions, brain stem tear and contusion

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