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**CASE REPORT**

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# Punched With A Fist: The Etiology of a Fatal Depressed Cranial Fracture*

**ABSTRACT:** We report a case in which a 33-year-old man was discovered unconscious following a fistfight with another man. Emergency neurosurgical efforts to repair a depressed temporoparietal skull fracture and associated brain injuries were unsuccessful. The forensic anthropologist and pathologist worked in tandem to sort out a complex combination of cranial evidence, including healed antemortem trauma, perimortem blunt force trauma, remote and recent neurosurgical intervention, and the craniotomy cut performed at autopsy. The victim had suffered head injuries and a right temporoparietal craniotomy ten years prior to death. The perimortem cranial fractures were centrally located within a surgically repaired roundel of bone involving portions of the right temporal and parietal bones. Reportedly, the victim was punched on the right side of his head as he was lying on the ground with the left side of his head against an asphalt surface. A primary question in the case was whether a blow with a fist could have produced the observed cranial injuries. To adequately answer that question, known data on the minimum amount of force required to fracture the temporoparietal region were compared to data on the amount of force generated by a blow with a fist. A biomechanics expert demonstrated that a single blow with a fist to the rigidly supported head of the victim could generate the required force to produce the observed fractures. The previous medical condition possibly predisposed the victim to the cranial fractures and contributed to the depressed nature of the fractures. Although depressed cranial fractures do not typically result from a blow with a fist, it was determined in this case that the fracture pattern was consistent with a punch to the head.

**KEYWORDS:** forensic science, forensic anthropology, forensic pathology, blunt force trauma, cranial fractures, biomechanics

Severe blows to the head with blunt instruments are known to cause fatal depressed skull fractures with associated fracture lacerations of the brain, cerebral contusions beneath the location of the blow, and, occasionally, intracerebral hemorrhage. Typically, blows resulting in such injuries are delivered with an object other than a fist. We present the unusual case of a man who died from craniocerebral injuries following a fistfight with another man. At autopsy, the right temporoparietal region of the cranium exhibited fractures and brain injuries consistent with blunt force trauma. The extent of these injuries, however, was difficult to discern due to the presence of healed antemortem trauma, remote neurosurgical intervention, recent neurosurgical intervention, and the autopsy craniotomy all in the same area. This complex cranial evidence warranted the involvement of the forensic anthropologist at autopsy. It is widely recognized that the anthropologist can provide valuable assistance to the pathologist in the reconstruction of an individual's death history, especially in cases where the remains are skeletonized, decomposing, mummified, or burned (1). Increasingly, the pathologist is involving the anthropologist during the autopsy in deaths with short postmortem intervals, especially when there is trauma to bone (2). In this case, the forensic pathologist and forensic anthropologist worked in tandem on a death that occurred in a hospital to establish the complex combination of cranial evidence to determine the circumstances of death.

A key element in this case was the etiology of the blunt force trauma. It is often difficult to unequivocally assign a specific etiology for blunt cranial trauma because bone can only respond in a limited number of ways to an almost infinite number of implements. Yet, if asked to offer a professional opinion, it is sometimes possible for the expert to state that the observed blunt force trauma is "consistent with" a specific implement. In this case, an eyewitness to the assault reported that the victim had been punched with a fist. Therefore, a primary question during the trial of the assailant was whether the cranial fractures were "consistent with" a punch. In order to adequately answer that question, known data on the minimum amount of force required to fracture the temporoparietal region were compared to data on the amount of force generated by a boxer's punch. Contributions of the biomechanics expert in this case were critical in assessing whether the observed cranial trauma was "consistent with" a punch from a fist.

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## Case Report

A 33-year-old man, intoxicated with alcohol, was involved in a fistfight with another man outside of a tavern. Witnesses reported that during the altercation, the subject fell to the ground with the left side of his face against the asphalt surface of a parking lot. The assailant, who was also intoxicated, reportedly punched the subject two or three times on the exposed right side of the head. The fight ended shortly after these blows were struck, and the subject stood and walked a short distance to his apartment. Roommates who saw the injured man upon his return home reported that he acted confused and spoke very little, but that he maintained he was okay. The subject went to bed within an hour of the altercation. A roommate found him unresponsive several hours later. Medical records from the hospital where he was treated indicated he presented with a Glasgow coma scale of three and fixed dilated pupils. The CT scan showed a depressed cranial fracture in the right temporoparietal region and a right-sided intacerebral hematoma. Emergency neurosurgical intervention included realignment of the depressed fracture and repair of a torn dura mater. The neurosurgeon's report documented four cranial fragments within a remote craniotomy site. One of the fragments had penetrated the dura mater and was embedded in the brain. To remove all four fragments, the surgeon cut sutures placed ten years before during a craniotomy performed to treat injuries incurred in a motor vehicle collision. Exact details of the injuries sustained in the collision were not available. No neurological sequelae followed the incident. The past medical history was otherwise negative.

## Autopsy

Examination at autopsy showed a well-healed C-shaped scar on the right tempoparietal region. Overlapping this scar and extending into the frontal region of the scalp was a recent 230-mm C-shaped incision that was secured with staples. Extending from two stab incisions in the right parietal region were an intracranial pressure monitor and a Jackson-Pratt drain. Hemorrhage extended through the scalp and the underlying soft tissues of the right temporoparietal region. The right temporal and parietal bones exhibited recent fractures that had been stabilized with titanium Synthes plates and screws. Beneath the fractured bone fragments, the dura mater contained a 32-mm oval defect secured with sutures. A thin layer of subdural hemorrhage loosely adhered to the dura mater over the right temporal and parietal regions. A thin layer of subarachnoid hemorrhage covered the right side of the cerebrum. The brain exhibited fracture lacerations beneath the recently fractured bone fragments. Fracture contusions measuring up to 20 mm in greatest diameter were observed on the right temporoparietal regions of the cerebrum beneath the fractures. A cavitary defect with features of a "burst lobe" in the right temporal and parietal lobes of the cerebrum contained about 150 mL of blood and communicated with a 30-mm defect over the temporal portion of the brain and the right lateral ventricle. The markedly swollen and softened brain displayed a cingulate gyrus herniation with a right to left shift. The unci were notched. All other injuries were cutaneous and included a 20-mm circular abrasion on the left ear, a 38-mm circular contusion on the right lateral deltoid region, a 25-mm circular contusion on the right anterior biceps, a 12-mm circular contusion over the right olecranon region, two circular contusions (25 and 20 mm) over the left anterior axillary fold region, a 130 by 50 mm contusion over the left biceps, a 12-mm circular contusion over the left patellar region, and five abrasions measuring about 5 mm in diameter over the left distal pre-tibial region. The autopsy was otherwise negative. Evidence of remote brain injury was absent. The victim lived for about 24 h after presentation to the hospital and toxicology testing upon admission was not done. The medical examiner was unable to obtain blood taken around the time of admission to either the outlying hospital where the patient was initially evaluated or the tertiary care hospital where the patient was definitively treated and subsequently died. The cause of death was certified as being due to craniocerebral injuries.

## Anthropology

Due to the gravity of the questions raised in the case, a decision was made by the pathologist to remove the skull at completion of the autopsy, following proper authorization, to facilitate further examination by the forensic anthropologist. In order to expose all osseous surfaces for analysis, the anthropologist macerated and cleaned the remains utilizing a non-bleaching cooking method. Upon examination, the skull exhibited evidence of healed antemortem trauma, blunt force trauma with no osseous remodeling, recent neurosurgical intervention, and the craniotomy performed at autopsy (Fig. 1). Associating skeletal trauma with the time of death is one of the most important considerations in the anthropological analysis (3). In this case, the ability to sort out a complex combination of cranial evidence was critical in reconstructing the individual's death history.

Healed antemortem trauma was observed in the right temporoparietal region in the form of a surgically repaired, roughly circular plaque of bone, or roundel (4). This roundel, the result of neurosurgery approximately a decade earlier, involved portions of the right temporal and parietal bones and measured approximately 55 by 53 mm (Fig. 1). The circumference of the roundel exhibited healed margins, although there was no evidence of significant osseous connection or bridging between the roundel and the surrounding bone. Eight sets of drilled holes with healed margins indicated that the roundel had been surgically attached to the surrounding bone by sutures. It is believed that over time the roundel was further stabilized by the development of scar tissue around the circumference. The thickness of the right temporal and parietal bones within the roundel were approximately one half the thickness of the non-injured left side.

Blunt force trauma was observed within the roundel in the form of comminuted and diastatic cranial fractures (1,5,6). At least one blunt force impact site resulted in three complete and simple cranial fractures (1,7). The margins of these fractures displayed no evidence of osseous remodeling or healing, suggesting that they were

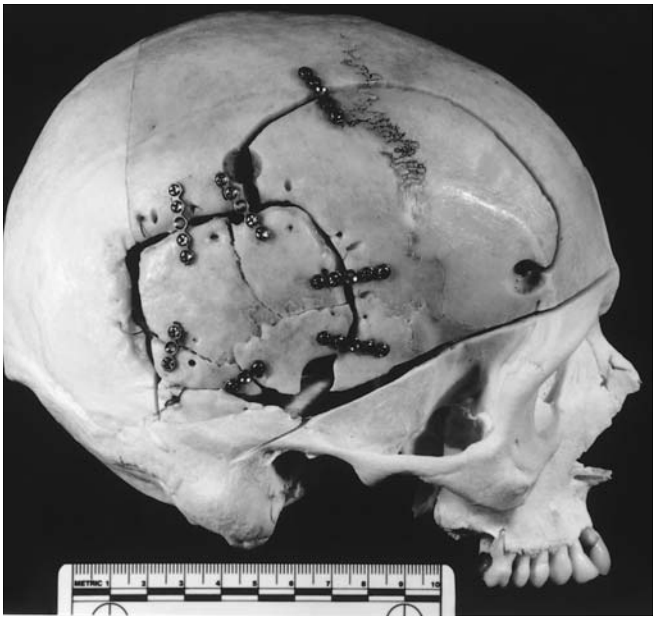

FIG. 1—*Right supero-lateral photograph of cranium showing the presence of healed antemortem trauma in the form of a roundel, perimortem blunt force trauma within the roundel, recent emergency neurosurgery, and the craniotomy performed at autopsy.*

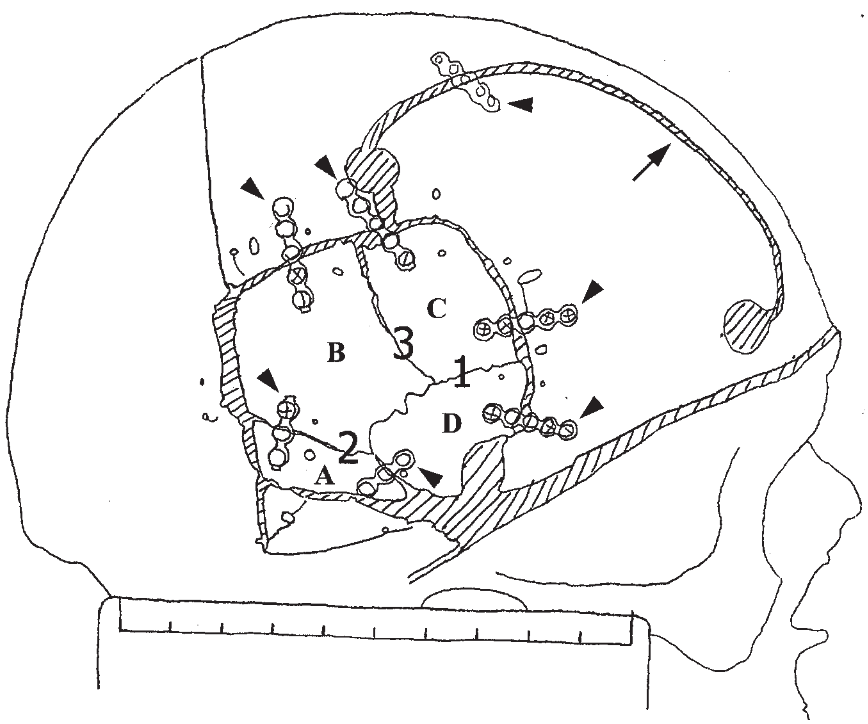


FIG. 2—*Right supero-lateral view of the cranium showing the roundel from remote neurosurgery, perimortem fractures within the roundel (1–3), the resulting fragments of bone (A-D), the superiorly arching craniotomy cut (tailed arrow), and titanium plates (tail-less arrows) from the emergency neurosurgery.*

perimortem in nature (3). Fracture 1 was a diastatic fracture that ran along the squamosal suture and measured 35 mm. Fracture 2 ran posteriorly from the squamosal suture to the margin of the roundel and measured 25 mm. Fracture 3, 30 mm in length, ran superiorly from the squamosal suture to the margin of the roundel. The three fractures produced four main bone fragments within the roundel, identified as A, B, C, and D in Fig. 2. It was the inferior margin of fragment "D" that had been depressed through the dura mater and into the brain.

The right side of the cranium also exhibited evidence of recent neurosurgical intervention including: four titanium Synthes plates and screws that attached the fragmented roundel to the surrounding bone; new drill holes adjacent to the margins of the roundel to accommodate surgical sutures in order to tack down the dura; two more Synthes plates that stabilized Fracture 2; two burr holes measuring approximately 12 mm in diameter, one 8-mm superior to the roundel, and the other 46-mm antero-superior to the roundel; an arching, semi-circular craniotomy cut connecting these burr holes, which were 96 mm apart; and one Synthes plate and screws bridged this craniotomy cut (Fig. 2).

### Minimum Force to Fracture

The potential for blunt force injury to the cranial vault depends on the amount of energy transmitted by the blow and the size of the impact area. It is generally reported that the minimum amount of pressure required to produce a linear fracture of the cranial vault ranges from 2.7 to 4.1 MPa (400 to 600 psi) (1). It has been experimentally shown, using a large number of cadaver heads with the scalp and intracranial contents intact, that for a linear skull fracture to occur a pressure of 3.1 to 5.2 MPa (450 to 750 psi) must be generated in a striking blow to the head (7–9). There is considerable variation in the fracture tolerance of different cranial bones in the same individual, as well as between individuals. For example, the temporal squamous requires less pressure to fracture than other bones of the vault. To produce a linear fracture in the temporal squamous, a pressure of 2.6 to 2.9 MPa (374 to 418 psi) must be generated in a striking blow to the head (1,10).

In studies for the automotive industry (11–13), data have been generated on the force to fracture tolerance of various cranial bones employing embalmed and unembalmed human cadaver specimens. In one study (12), a stiff impact interface of a 6.45-cm-squared circular disk was dropped onto the supported human skull. The disk was connected to a load cell that recorded the impact force-time data. A range of impact velocities was obtained by varying the drop height. Fracture forces ranged from 2.11 to 5.20 kN (mean = 3.63 kN) for injury to the temporoparietal region. These data converted to pressure are: 3.25 to 8.0 MPa. Impact durations for these experiments were in the range of 3 to 10 ms. The pulse duration and rate of onset were found not to be critical factors in the determination of tolerance criteria.

### Biomechanical Analysis

A primary question in this case was whether the cranial fractures could have been produced by a punch from the assailant's fist. To address this question, biomechanical data were gathered from a number of sources, and various assumptions were made concerning the potential blows to the victim's right temporoparietal region. Data on medical injuries in the martial arts indicated that cranial vault fractures do occur as the result of the directed and concentrated force of a punch to the head (14). Unfortunately, data on the amount of force generated by a punch was unavailable in this study.

To determine the potential for fracture of the temporoparietal region from a single blow, experimental data were gathered on the range of punch velocities that could be generated by amateur boxers (15). An experimental study on the kinematics of various punches (jab, cross, hook) indicated that, for subjects impacting a simulated head, the corresponding average peak velocities were 4.1, 6.4, and 10.3 m/s, respectively. On average, the mass of the upper extremity (arm and hand) is approximately 3.8 kg (with a range of 2.6 to 6.0 kg) based on Air Force data (16).

To estimate the range of forces that may have been produced in a punch to the head, rigid-body mechanics were employed as a first approximation (17). During the impact event, the momentum (mass times velocity) of the upper extremity changes from a maximum at the peak velocity (near contact with the head) to zero as energy is transferred to the head. Using the concept of impulse-momentum and the assumption that for a typical contact event, such as in this case, the force-time pulse was approximately a 100-Hz haversine (12) and yielded a peak contact force of approximately 3.16 kN for a "jab," and approximately 4.93 kN for a "cross." These predicted forces fall within the range of force needed to fracture the temporoparietal region of a normal skull. This indicates that a single punch to the rigidly supported head of the victim could theoretically have generated the required force to produce the observed fractures.

The skull of the victim in this case, however, was not normal. As a result of the injury sustained ten years earlier to the right side of the head, the thickness of the roundel in the right temporoparietal region was half that of the non-injured left side. Biomechanical data (18) suggest that a thinner than normal skull would increase the potential for fracture, as the square of the thickness parameter reduces the force to cause fracture by approximately four-fold (19). Therefore, the theoretical analysis based on limited experimental data suggests that the decedent's medical history may have predisposed him to sustaining the fatal, depressed fracture.

## Discussion

While our biomechanical data show that a punch could have produced the fractures in the temporoparietal region of a "normal" head, another challenge presented by this case was explaining the etiology of the depressed cranial fracture. It is known that depressed skull fractures can occur when the head is impacted by a relatively slow-moving object of high kinetic energy, such as a club or a thrown projectile (20–22). In this unusual case, it is believed that the focused impact of a punch with a fist was able to do so, especially in light of the victim's past medical history. Specifically, the roundel of bone in the temporoparietal region played a key role in the depressed nature of the cranial fracture. The presence of this roundel, which was held in place by scar tissue, significantly altered how the bone reacted to the blunt force and made any linear fracture in that region more susceptible to becoming a depressed skull fracture. As the fist impacted the cranium, fractures radiated away from the impact site and several wedge-shaped plates of bone were formed. If this had been a normal head, as the fist continued into the skull the wedge-shaped plates would have been forced inward and perpendicular concentric fractures would have formed and circumscribed the impact site (23). But because the impact site was centrally located within the roundel in this case, the concentric fractures that would normally circumscribe the impact site were essentially absorbed by the scar tissue. Therefore, as the fist continued into the skull, one inwardly forced wedge-shaped plate of bone was driven through the dura and into the brain.

Although it is theoretically believed that a single punch could have generated the observed damage, it is possible that a first punch could have produced the vault fractures and a subsequent blow could have depressed one of the fragments through the dura and into the brain. While injury to the impacting fist may have been suspected, the authors have not found relevant data to determine this possibility. On the other hand, the circumstances of a previous injury could have helped mitigate the potential for injury to the fist of the assailant.

## Conclusion

Biomechanical data demonstrate that the cranial vault can be fractured by a punch with a fist. Although a depressed cranial fracture is not typically "diagnostic of" a blow to the head with a fist, this case illustrates that such an injury can be "consistent with" a punch with a fist. Finally, it is believed that the observed cranial vault thinning resulting from a previous craniotomy predisposed the victim to the depressed cranial fracture and associated lethal brain injuries.

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