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CASE REPORT

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Fatal impalement injury of the head due to a curtain rail

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Abstract During a dispute, a boy was injured by a curtain rail which penetrated the skull in the left frontal region and led to severe brain injury. Despite intensive medical care, death occurred 10 days later due to malignant cerebral edema. With regard to the question whether the trauma resulted from throwing or pushing, some biomechanical aspects are discussed including individual morphologic findings as well as the kinetic energy required for penetrating the skull. According to the calculated data, we conclude that the velocity necessary for penetrating could be reached by throwing the curtain rail.

Keywords Penetrating injury · Impalement · Skull

Introduction

Accidental impalement injuries of the skull due to traffic accidents [3, 7, 11, 16, 24] or at work [2, 4, 17, 18] are not unusual. Such accidental injuries in sports, particularly in javelin, have also been reported [22]. Fatal impalement trauma of the head in homicides, however, is rather rare and predominantly caused by penetrating injuries of the orbita [1, 21]. In this paper, a case of homicidal impalement of skull and brain by a curtain rail is presented. As other reports of rare manners of death [5, 15, 19, 25], this unusual homicide needs to be promulgated with regard to forensic purposes.

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Case report

In a children's home, a 16-year-old boy speared the head of another boy aged 15 years with a metallic curtain rail. The rail had the form of a pipe with a length of 2 m, a caliber of 20 mm, and a weight of 750 g (Fig. 1a,b). The boy immediately lost consciousness, and brain tissue extruded through the penetration defect of the skull. The lesion was surgically treated, and a trepanation of the skull was performed. However, brain death was diagnosed 10 days later due to malignant cerebral edema.

Because there were no reliable reports of witnesses, the central question was whether the injury could have been caused by throwing the curtain rail—as declared by the perpetrator—or whether it must have been pushed into the skull from a short distance.

Autopsy findings

At autopsy, a surgically sutured scalp lesion high on the left forehead was found. Underneath, an approximately round depressed fracture (2.6×2.4 cm) of the left frontal bone (thickness of calvarium 3 mm) was present with apparent metallically glittering material clinging to the lamina externa and to blasted fragments of the lamina interna (Fig. 2a–c). Impressed fragments of bone were detected in the cranial cavity and in cerebral tissue. In addition to the trepanation defect of the left frontal bone, a longitudinal fracture line of the left calvarium located 1.1 cm behind the described depressed fracture and crossing the left base of the skull was found. The meninges showed congruent defects beneath the depressed fracture. Cerebral tissue was diffusely swollen, softened, and discolored dark red and brown.

After fixation and preparation, the cerebrum showed a nearly 8-cm long wound channel entering the left frontal lobe, transcending the center line and reaching the white matter of the right frontal lobe (Fig. 3a,b).

Further pathologic findings in particular in other internal organs were absent.

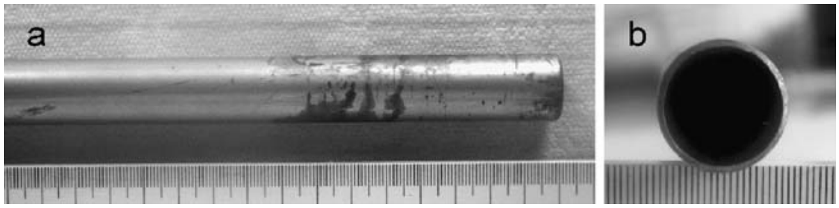

Fig. 1 Curtain rail (length 2 m) showing blood stains at the impaling end (**a**). Ring-like impinging area with a diameter of 20 mm (**b**)

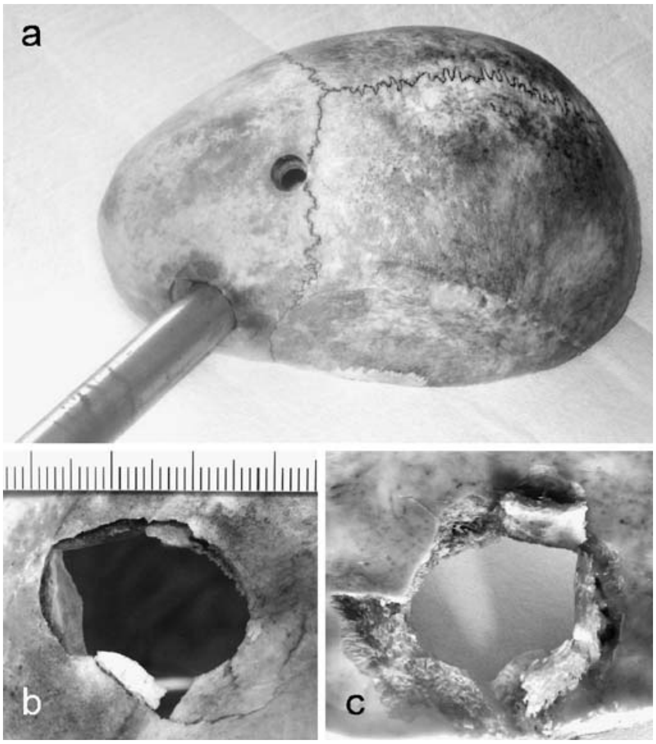

Fig. 2 Calvarium showing the penetrating curtain rail in the left frontal bone of the skull (and the trepanation defect above) (**a**), round-shape impression fracture (2.6×2.4 cm) in the outer (**b**) and inner surfaces (**c**) of the skull

Discussion

Homicidal fatal impalement injuries of the skull are particularly unusual, and the cerebral lesion is mainly caused by a penetration of the orbita due to their rather thin osseous structures [1, 8]. The calvarium, however, is much more resistant to impalement trauma, but many case reports dealing in particular with accidents (traffic, work, or sports) exist (for example [11, 18]).

Abundant investigations have already been carried out to establish the mechanical properties of cranial bone concerning with traction, pressure, inflection, and torsion [10, 12–14, 26]. However, these studies do not consider the protective effect of the scalp, which can absorb a considerable portion of the impinging energy, and are therefore of limited value for forensic practical use [6, 13]. In contrast, Sellier [23] described the tensile strength of cranial bone sheltered by scalp. He established biomechanical data of the tensile strength related to the area of impact. However, he also pointed out the great variation of the experimental data, depending on individual characteristics such as thickness of calvarium, covering soft tissue and hair, as well as the weight of the head.

In the present case, a 15-year-old boy was killed during a dispute due to impalement trauma of the head caused by a curtain rail. For discussion on whether the trauma resulted from throwing or pushing the spear-like curtain rail, it is essential to know the minimum kinetic energy required for penetrating the scalp and skull as well as the necessary velocity of the curtain rail after throwing. Sellier [23] described a minimum energy of 0.40–0.75 mkp/cm^2

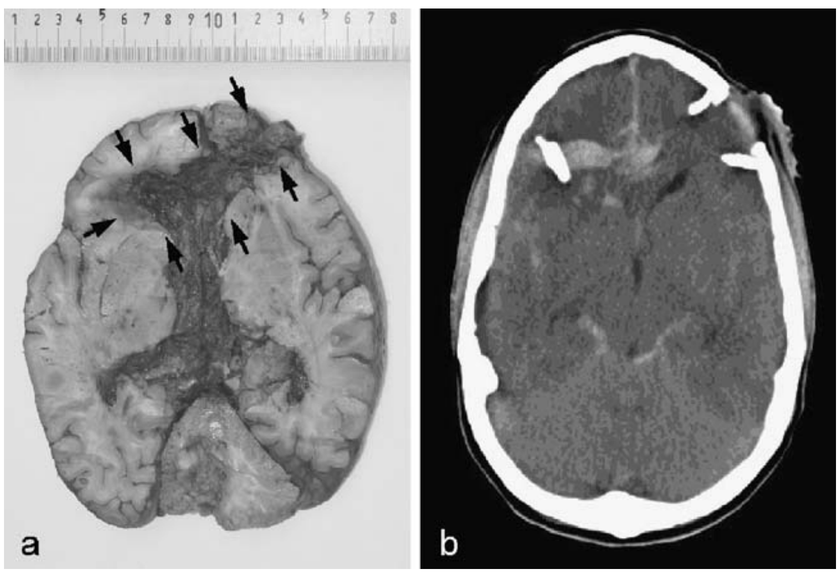

Fig. 3 Section of the brain showing an approximately 8-cm wound channel in the parenchyma of the forebrain (**a**). Computed tomography of the head showing depressed fracture (**b**)

(equivalent to 4.0–7.5 J/cm^2) for objects with a penetrating area of about 3 cm^2 to cause depressed fractures of the skull and scalp. Thus, it could be concluded that the curtain rail with a diameter of 20 mm which transfers energy to an area of 3.15 cm^2 (cross-sectional area) requires an energy ranging from 12.57 up to 23.56 J to induce a fracture. According to the formula E=1/2*m*v^2 (E=energy, m = mass, and v = velocity), the minimum velocity of the curtain rail (750 g) hitting the victim's head must be at least about 5.8 m/s (20.8 km/h) up to 7.9 m/s (28.5 km/h).

The findings of Sellier, however, do not consider relevant individual factors. In this content, the varying gauges (in particular) of the calvarium depending on age, sex, site at the skull, individual morphologic characteristics, etc. are of importance. In the presented case, the thickness of the frontal bone reaching exclusively 3 mm was significantly reduced compared to the common average values [13]. Because there is a close correlation between the thickness of the skull and the resistance to impact [13], the necessary minimum energy or velocity of the curtain rail, respectively, to cause fracture could therefore even be much lower than the above-mentioned values. In addition, the curtain rail, which transfers energy to a whole area of 3.15 cm^2, had the form of a pipe leading to a ring-like pressure area. This means that for the first part of the injury process, the energy is concentrated on a much smaller area of about 0.6 cm^2, which could explain an effect of stamping out and an additive reduction of the minimum energy to provoke fracture. However, there is no data to perform a more precise estimation of this threshold energy, as biomechanic investigations concerning objects with such small impinging areas only exist for solid bullets [23]. Even though the ability of deformation of the calvarium depends on the age, as tensile strength is higher in juveniles than at advanced individual age [23], the velocity necessary for causing the lethal impalement injury in the present case could in our opinion be reached easily by throwing in particular considering the rather athletic constitution of the 16-year-old contrahent. In athletics, javelin throwers are able to accelerate spears of similar form and weight as the curtain rail up to a speed of approximately 27 m/s (97 km/h) [9, 20].

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