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Intracranial stab injuries: case report and case study

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Abstract

Non-missile penetrating brain injuries are rare events in western countries. We report a case with lethal stab injury of the brain and identification of the weapon used in the assault by digital superimposition on CT scans taken at admission of the victim to a hospital. Furthermore, all cases with knife stab wounds of the skull between 1971 and 2000 were analyzed and compared with literature reports. Results of this study show that there is no region preference despite of differences in bone thickness, that stab wounds of the brain are almost invariably associated with multiple stab wounds to the trunk and that the wound tract may correspond to the dimensions of the blade allowing the identification of the weapon by digital image analysis.

Keywords: Stab wound; Brain; Superimposition; Computed tomography; Slot fracture

1. Introduction

Stab wounds of the brain are relatively uncommon in western countries because the adult calvarium usually provides an effective barrier [1]. However, there are areas of thin bone such as the orbitae or the temporal region where knives may penetrate easily and even full-thickness skull will not stop a forcefully thrust sharp object. Since brain injury usually is restricted to the wound tract victims frequently do not die on the scene but are admitted to a hospital with good prognosis of recovery unless the brain stem is damaged. Forensic investigation of brain stab wounds thus involves clinical examination of surviving victims as well as postmortem examinations.

The following case report highlights an unusual stab injury to the head and demonstrates the use of CT scans obtained at hospital admission for establishing the forensic diagnosis and for identification of the assault weapon. To obtain data about frequency, localization, mechanisms and pathological findings, all autopsies with cranial stab wounds performed in Wuerzburg between 1971 and 2000 were analyzed and compared with literature reports.

2. Case report

A 60-year-old man was involved in an altercation which resulted in the patient sustaining multiple wounds to the chest and head. At arrival to the trauma center the patient was comatose and responsive only to deep pain. Immediate CT scan of the head demonstrated left temporal intracranial hemorrhage with skull fracture. Surgical evaluation of the chest and abdomen revealed three stab wounds with severance of ribs but without injury of organs. After closing the wounds neurosurgical consultation was obtained but no surgical intervention was recommended. The assailant, a 45-year-old man, who had called police and emergency services himself, claimed that he was attacked by the victim with a knife after drinking vodka together with him and that he could not remember details. Physical examination of the injuries of the victim before surgical intervention and of the injuries of the assailant was performed by the forensic pathologist on duty who also investigated the scene, a stairwell in an apartment building. It became clear that the injuries of the suspect were self-inflicted whereas the chest injuries of the victim were not. The brain injury was attributed to a fall onto the edge of the bottom step of the staircase. With this diagnosis the initial charge after the death of the patient 2 days later due to increased brain pressure and loss of brain stem function was involuntary manslaughter.

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Autopsy which was performed 3 days after death revealed a stab wound to the head as cause of the intracranial hemorrhage with slot fracture of the temporal bone and hemorrhagic wound tract through the temporal lobe and the cerebellum (Figs. 1 and 2). With this diagnosis the case had to be considered as homicide. The apartment of the assailant and the surroundings of the scene were searched for the weapon and numerous knives were brought in. Re-evaluation of the CT scans showed a well circumscribed wound tract obviously corresponding to the form of a knife blade.

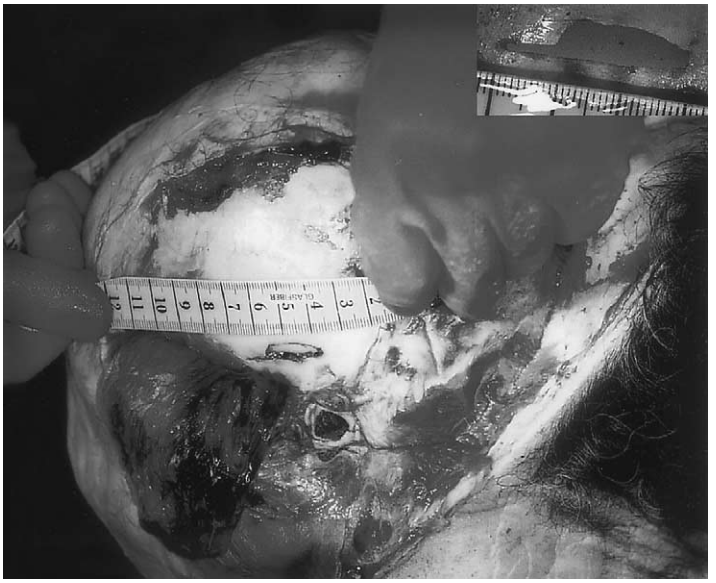

Fig. 1. Lateral view of the skull with slot fracture in the temporal bone.

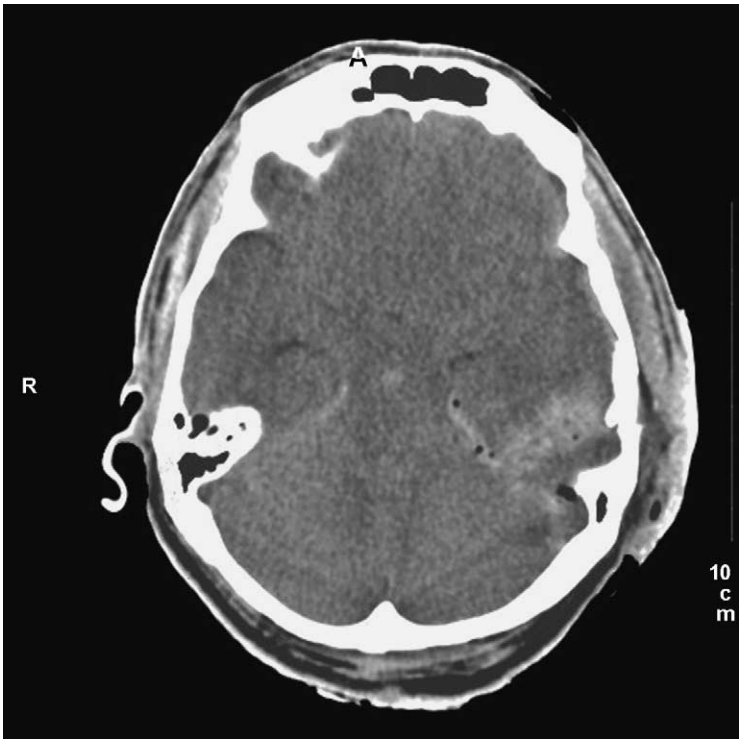

Fig. 2. Non-contrasted CT scan showing hemorrhagic wound tract in the left temporal lobe with air inclusions and diffuse brain swelling.

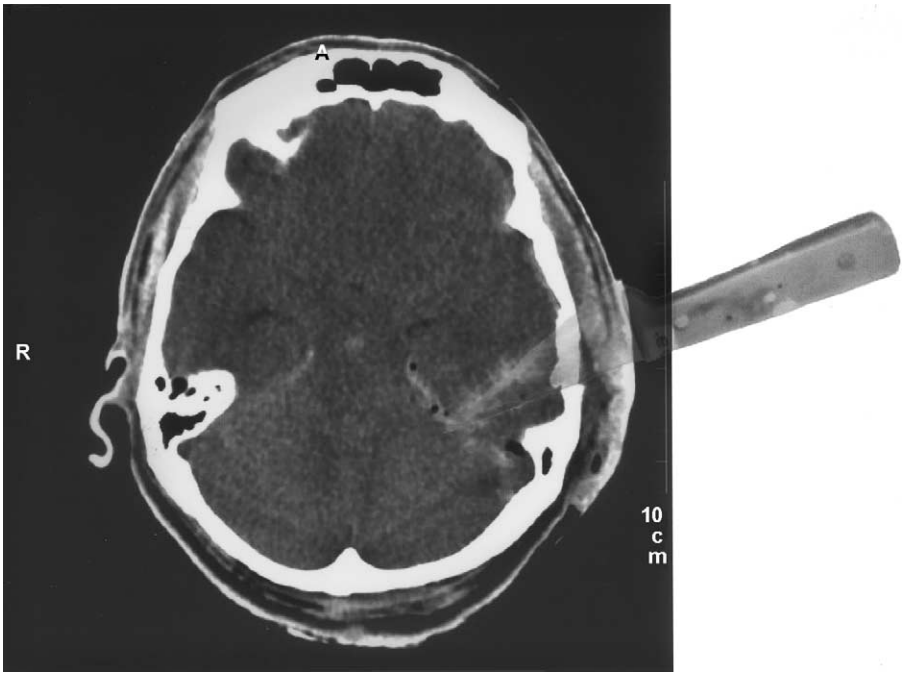

Fig. 3. Same CT scan as in Fig. 2. A digital image of the weapon used in the assault was superimposed to show correspondence of the wound tract with the dimensions of the blade.

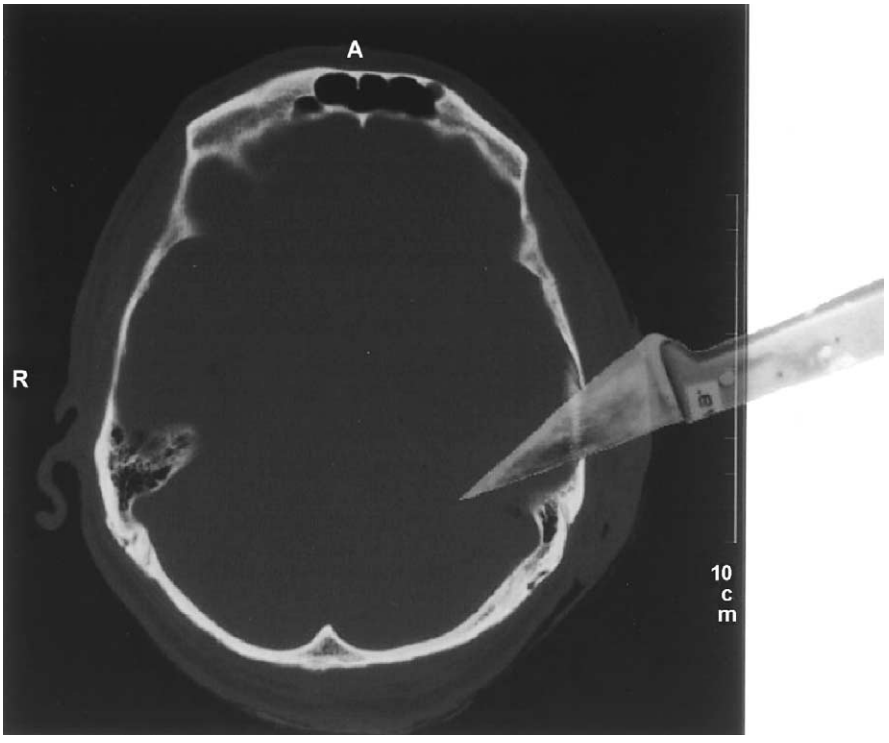

Fig. 4. Bone window of the CT scan shown in Fig. 3 with superimposed weapon. The depth of insertion corresponds to the width of the slot fracture.

Digital images were taken of the knives and superimposed on the CT scans after adjusting the angle of the blade to that of the CT images as calculated from the scout image (Figs. 3 and 4).

After identifying a suitable knife DNA from the victim was detected on the blade near the guard although this knife had been thoroughly cleaned in a dishwasher.

3. Case study

Autopsies performed in the Institute of Legal Medicine, University of Wuerzburg, during the period 1971–2000 ($n = 9487$) were reviewed retrospectively. In 503 consecutive homicides and 175 cases with lethal stabbing injuries, 13 intracranial stab wounds (7.4% of all stab injuries, 0.14% of all autopsies) were found (Table 1). From these 13 cases, 6 cases showed non-lethal and 4 cases lethal brain injuries, 3 cases involved only penetration of the skull without injury to the brain parenchyma. Twelve cases were associated with multiple stab wounds to the chest, neck and/or abdomen or other injuries. The causes of death in the nine cases without lethal brain injury were hypovolemic shock due to heart or vessel penetration ($n = 8$) or blunt injury to the head ($n = 1$). The regions involved were temporal ($n = 4$), frontal ($n = 4$), transorbital ($n = 3$), occipital ($n = 4$) and parietal ($n = 2$). The victims were males in seven cases, females in six cases, the assailants exclusively males. The motive of the assaults was rape (four cases), domestic quarrels (two cases) or private altercations between friends or colleagues. In these cases alcohol intoxication and/or a psychiatric disorder played a major role for the motivation of the assailant.

4. Discussion

Penetrating craniocerebral knife injuries are rare in western countries and occur almost exclusively in homicides. In our data only 13 cases were documented in 30 years. Even less frequent are lethal stab injuries of the brain with only four cases in this time period. In Brooklyn, New York, 3 such cases occurred in 1508 homicides from 1963 to 1968 [2], in Essen, Germany, 8 homicides with stab wounds to the skull among 3545 autopsies and 118 cases with stab injuries were observed between 1973 and 1984 [3]. Among 151 patients with external wounds of the head after a stabbing assault treated in a Level I trauma center in Washington, DC, over a 10-year-period only six had intracranial injuries [4]. Studies

Table 1
Listing of cases with intracranial stab wounds examined in Wuerzburg between 1971 and 2000

Case	Age/sex	Site of skull penetration	Additional injuries	Assault motive	Assailant	Brain injury: present/cause of death
1	31/m	Frontal	Multiple stab wounds to the chest/neck	Private	Psychiatric disorder	Yes/no
2	29/m	Temporal	Blunt injury to the head, multiple stab wounds to the chest/abdomen	Private	Alcohol influence, 1.5 g/kg	Yes/no
3	63/m	Transorbital	Multiple stab wounds to the chest/neck	Private	Psychiatric disorder	Yes/no
4	51/f	Frontal	Multiple stab wounds to the chest/neck	Rape	Alcohol influence, 2.1 g/kg	No
5	22/f	Occipital	Multiple stab wounds to the chest/neck	Rape	Psychiatric disorder	No
6	41/f	Occipital	Multiple stab wounds to the chest/neck	Rape	Not known	No
7	14/f	Temporo-parieto-occipital	Multiple stab wounds to the chest/neck	Rape	Not known	Yes/yes
8	40/m	Transorbital	Multiple stab wounds to the chest	Private	Alcohol influence	Yes/no
9	66/f	Parieto-occipital	Strangulation	Domestic	Killed himself with hand grenade, alcohol influence	Yes/yes
10	53/m	Transorbital	Multiple stab wounds to the chest	Private	Alcohol influence	Yes/yes
11	49/m	Fronto-temporal	None	Not known	Not known	Yes/yes
12	58/f	Frontal	Multiple stab wounds to the chest	Domestic	Alcohol influence, 2.4 g/dl	Yes/no
13	60/m	Temporal	Multiple stab wounds to the chest/abdomen	Private	Alcohol influence, 1.8 g/dl	Yes/yes

with incredible case numbers (up to 597 patients in 12 years) are reported from South Africa [5,6] where transcranial stab injuries remain a frequent cause of emergent neurosurgical intervention. Whereas in these studies only 10% of the patients had stab wounds to regions other than the head [7], in our series all cases except one were associated with multiple stab wounds to the trunk. This probably reflects differences in violent behavior: the patients in South Africa are predominantly young males involved in fights [8,9], in our data comparable fight situations did not occur. Assault motives were rape, domestic quarrels or private altercations between friends or colleagues. In the latter cases, the assailants almost invariably were under significant alcoholic influence or suffered from a psychiatric disorder.

In suicides perforation of the skull is rare and self-inflicted stab injuries of the brain were not yet reported [10]. Interestingly, although 14% of all assailants using a knife were females, none of them stabbed the head. This seems to be a male-specific kind of violence potentially related with the force assumed to be necessary for penetrating the skull. Indeed this force is believed to be about 5× higher in the temporal region (255 N) and 11× higher in the parietal region (540 N) [11] than the force needed to perforate the skin (49 N) [12], but well within the range of up to 1000–2000 N postulated to be seen during impact on targets in experimental knife attacks [13,14]. Therefore, intracranial knife penetration can be expected to occur if the blade is sharp and rigid, the force created by the assailant high and the head of the victim fixed. We believe that the low number of skull penetrations by sharp force is not directly related to the alleged barrier function of the skull or to the enhanced resistance of bone but rather to the fact that stab attacks in western countries are only rarely directed to the head but more frequently to more vulnerable regions such as the neck, heart or abdomen. Another reason might be that penetration of the skull is more readily achieved when the head of the victim is fixed and when the physical activity of the victim is reduced or totally lost. In all but one cases presented here there were extracranial injuries that could explain rapid incapacitation. The force necessary for skull penetration which has to be created by muscular work of the assailant because the mass of the weapon (knife) is negligibly small, requires to be thrust onto a very small surface area. Any movement of the skull relative to the stab direction would probably prevent skull penetration and cause the knife to be deflected. However, fixation of the head is not a conditio sine qua non if the impact force is high enough. There are case reports with witnessed attacks to the non-fixed head with severe intracranial penetration [15].

According to the literature most stab wounds of the brain occur through the orbita or the temporal region [16]. This hypothesis sounds plausible because of the thinness of the bone in these areas but it is not supported by the available data. The sites of scalp and skull penetration appear to be evenly distributed with a majority of wounds in the parietal (40%) and frontal (21%) region in the South African data [7] and no significant region preference in our cases (Table 1). This supports the assumption that the difference in bone thickness is not the most important parameter for effective intracranial penetration in knife attacks and that under suitable conditions as discussed above a knife attack to the head will penetrate the skull regardless of the site of injury.

Postmortem diagnosis of intracranial stab injury is easy to establish if a characteristic slot fracture is present. The blood-filled wound slit created by a stab wound is largely restricted to the wound tract and corresponds to the dimensions of the penetrating object. This may be identified from CT scans using digital image superimposition because the insertion of the knife will be stopped by the cranium which cannot be indented such as the abdominal and chest wall and which prevents twisting or rotating of the knife. This is especially true in stab wounds to the temporal fossa in which the blade after penetrating the skull usually slides through the temporal lobe parallel to the floor of the middle fossa because a steep entrance angle would cause the blade to be driven into the petrous ridge or adjacent bone structures [8,17]. The hemorrhagic wound tract therefore is directly projected onto the axial CT sections and the dimensions of the penetrating object can under optimal conditions be measured directly from the CT image considering the angulation of the blade and of the CT. In our case, the murder weapon initially was missing but a great number of knives was seized in the apartment of the assailant and around the scene so that each one could be measured and compared with the wound tract. The weapon with the best match eventually was confirmed to have caused the brain injury by DNA analysis although, it had been thoroughly cleaned in a dishwasher.

5. Conclusion

This case demonstrates that stab injuries of the brain provide the opportunity of exactly correlating the wound tract with the weapon used in killing in contrast to stab wounds of the trunk where due to the elastic properties of skin and organ tissues and to the variable relative position of the organs only limited information about the characteristics of the knife used is available. Since secondary bleedings and autopsy artifacts might interfere with exact identification of the wound tract, postmortem CT scans in cases with immediate death on the scene should be obtained when possible. In surviving victims the use of CT scans taken immediately after admission is recommended. If no CT images are available, the brain slices should correspond to the plane of the wound tract which, however will be difficult to achieve in most cases.

The case study and the literature review presented here show that although, the force needed to penetrate the skull is considerably higher than the force necessary for penetrating the skin a forcefully performed attack with a sharp and rigid

knife will perforate the cranium regardless of the anatomical site. In contrast to South Africa where the head frequently is the only target for knife attacks in fights between young males, in western countries knife assaults are predominantly directed to the trunk with stab injuries of the head occurring in situations with exacerbating violence frequently due to alcohol intoxication or psychiatric disorder.

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